DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, DIRECTOR

BULLETIN 398

GEOLOGY AND OIL RESOURCES

OF THE

COALINGA DISTRICT

CALIFORNIA

BY

RALPH ARNOLD AND ROBERT ANDERSON

WITH A REPORT ON THE

CHEMICAL AND PHYSICAL PROPERTIES OF THE OILS

BY

IRVING C. ALLEN

WASHINGTON

GOVERNMENT PRINTING OFFICE

1910

CONTENTS.

ILLUSTRATIONS.

GEOLOGY AND OIL RESOURCES OF THE COALINGA DISTRICT, CALIFORNIA.

By Ralph Arnold and Robert Anderson.

INTRODUCTION.

GENERAL.

The Coalinga oil district occupies a strip of land about 50 miles in length by 15 miles in width along the northeastern base of the Diablo Range, on the southwest side of the San Joaquin Valley, in western Fresno and Kings counties in central California. The region is accessible by rail from the main lines of both the Southern Pacific and the Atchison, Topeka and Santa Fe railroads by a branch line of the Southern Pacific running westerly from Goshen to Coalinga. The proved productive oil territory is comprised in a band 13 miles long by 3 miles wide in the foothills in the northern end of the district, within the Coalinga field proper, together with a narrow strip along the district's southwestern boundary in the Kreyenhagen field.

The rocks of this region are chiefly marine sedimentary strata of Cretaceous and Tertiary age. These have been subjected to much disturbance, but are in large part only slightly consolidated. There are two types of oil, a paraffin oil which appears to have originated in foraminiferal shales in the Upper Cretaceous, and an asphalt oil which is believed to have its original source in diatomaceous and foraminiferal shales of upper Eocene age. The former is accumulated in sandy zones interbedded with the shales that are supposed to have given rise to it; the latter, which is the chief product of the district, is accumulated to some extent in the Tejon formation, but chiefly in sands of the Vaqueros (lower Miocene), Santa Margarita(?) (upper middle Miocene), and Jacalitos (upper Miocene) formations. The Vaqueros is the principal producer of the district. The oil wells vary in depth from 600 to over 4,000 feet and penetrate from 20 to over 200 feet of productive sands. The product varies from a black oil of 14° or 15° Baumé to a greenish oil of 35° Baumé or better. The yield ranges from 3 or 4 barrels per day for individual wells in the Oil City field to as much as 3,000 barrels per day for the deeper holes in the Eastside field. The total production for the district in 1907 was 8,871,723 barrels, in 1908, 10,386,168 barrels, and it has probably reached over 15,200,000 barrels in 1909. It ranks first among the districts of the State in production.

The location of the Coalinga district and of the other oil districts of southern California is shown in figure 1.

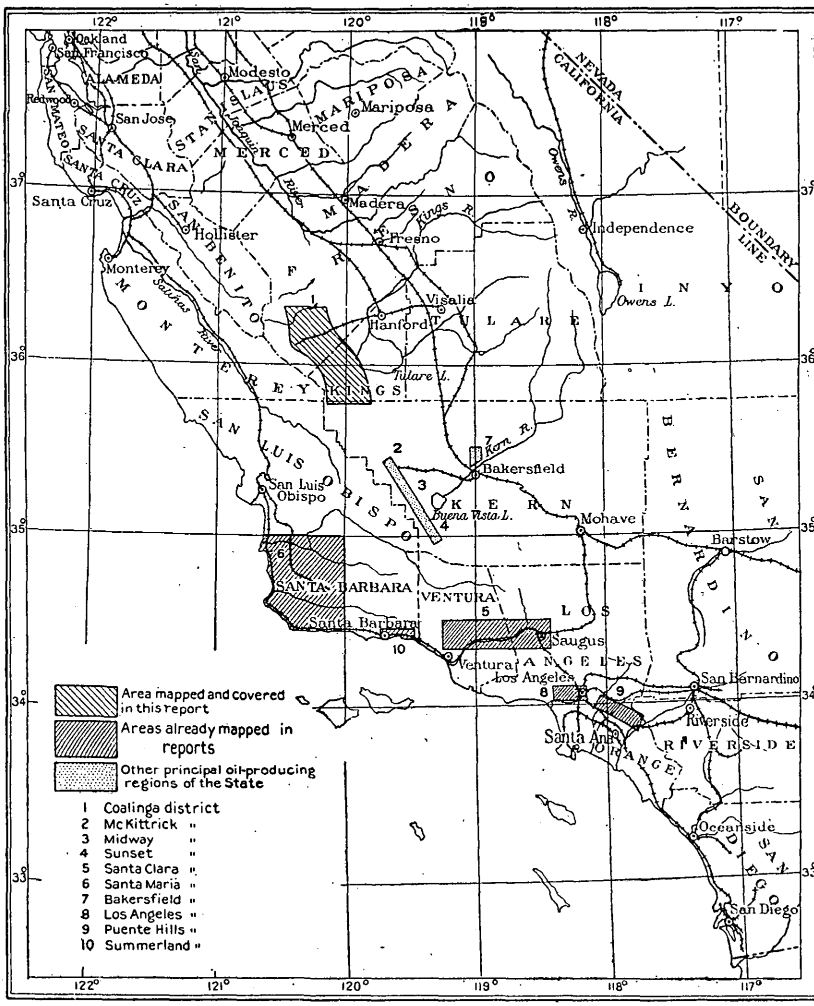


FIGURE 1.—Index map showing position of the Coalinga district in central California.

PLAN OF THE PRESENT WORK.

The purpose of this report is to treat of the general topography, geology, paleontology, and occurrence of petroleum in the Coalinga district, special importance being given in the discussion of the geology to those features bearing a direct relation to the problems of present and future development of the oil resources of the region.

The work is a continuation of the investigation of the California oil fields that is being carried on by the United States Geological Survey. During the last half of 1901 and the first half of 1902 George H. Eldridge began this investigation and made more or less detailed examinations of the various California oil districts, with the expectation of preparing a monograph on them. Upon his return from field work he wrote a brief résumé of the results obtained, and this was published in "Contributions to economic geology for 1902."[a] Later he began the preparation of detailed reports on each field, but unfortunately his death in June, 1905, cut short this work. In the fall of 1905 the senior author of the present report was assigned to the completion of the work begun by Mr. Eldridge, and by the middle of 1907 detailed reports on all of the oil districts in the counties bordering the coast had been made ready for the press.[b]

The summer and fall of 1907 were spent by the writers in making a detailed geologic investigation of the Coalinga field proper and of the territory south of it as far as the line between Kings County and Kern County, near Dudley, and a reconnaissance of the surrounding regions. In order to make the economic results of this investigation available as soon as possible a preliminary report containing a portion of the matter here presented was published in the autumn of 1908.[c]

The present report includes a more complete discussion of the topography, geology, and paleontology, and gains in value by the addition of maps, sections, and other illustrations, and in particular by the addition of the paper on the physical properties of the oils prepared by Irving C. Allen. The preliminary report may be considered as superseded by the present one.

In explanation of the plan of this and the other geologic reports bearing upon the California oil fields, it must be stated that these publications are intended to be as thoroughly scientific discussions as possible within the limitations of time available for their preparation, and they assume upon the part of the reader a general knowledge of the fundamental facts and conceptions upon which any searching study of the composition, mineral deposits, and history of

---

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

[b] The editions of these reports that were issued for free distribution are entirely exhausted. They are as follows:

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, xi+266 pp., 17 figs., 41 pls.

Arnold, Ralph, and Anderson, Robert, Preliminary report on the Santa Maria oil district, Santa Barbara County, California: Bull. U. S. Geol. Survey No. 317, 1907, 69 pp., 1 fig., 2 pls.

Arnold, Ralph, Geology and oil resources of the Summerland district, Santa Barbara County, California: Bull. U. S. Geol. Survey No. 321, 1907, 93 pp., 3 figs., 17 pls.

Arnold, Ralph, and Anderson, Robert, Geology and oil resources of the Santa Maria district, Santa Barbara County, California: Bull. U. S. Geol. Survey No. 322, 1908, 161 pp., 26 pls.

[c] Bull. U. S. Geol. Survey No. 357, 1908, 142 pp., 1 fig., 2 pls.

the earth must be based. The reports may be criticised as being too technical and as not easily comprehensible by the ordinary reader; but the form of discussion adopted is the only possible method of presentation because the treatment involves a certain amount of technical knowledge and the use of exact terms. For explanations of the principles of geology or the meaning of terms the reader is referred to any one of the numerous text-books of geology.[a]

ACKNOWLEDGMENTS.

The writers wish to acknowledge their indebtedness to the late George H. Eldridge for the use of the notes collected by him during his examination of the field. Acknowledgment is also due to other previous workers in the field, among whom are W. L. Watts, Frank M. Anderson, John H. Means, and H. R. Johnson. This paper benefits by the inclusion of chemical analyses of rocks furnished by W. F. Hillebrand and R. C. Wells, of the United States Geological Survey, and of a discussion of the petrographic character of the syenite from White Creek, by E. S. Larsen, jr., also of the Survey. S. G. Mason aided in the preparation of the fossil tables.

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

From the drilling of wells in the Coalinga field during the last ten years a large body of useful data concerning the underground conditions has been accumulated, and whatever of accuracy and value there is in the underground map and statements concerning the geology of the wells in this report is due almost entirely to the generosity of the operators in this field in supplying the information. The writers therefore wish to acknowledge their indebtedness to the officers, managers, and other operators of the different oil companies for their hearty cooperation and support. Thanks are due more particularly to Messrs. James H. Pierce, W. W. Orcutt, S. A. Guiberson, jr., R. W. Dallas, W. R. Hamilton, A. and H. Kreyenhagen, R. S. Peeler, A. M. Anderson, H. G. Anderson, J. M. Atwell, Charles Babtie, Gordon M. Baker, R. C. Baker, Orlando Barton, H. J. Bender, Scott Blair, S. R. Bowen, F. S. Brack, H. H. Brix, C. A. Canfield,

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

Frank Cleary, H. R. Crozier, F. P. Dagany, P. B. Daubenspeck, D. M. De Long, J. F. Ecbert, Andrew Ferguson, A. D. Ferguson, W. S. Fisher, A. D. Fram, Charles Fredeman, W. A. Gray, W. A. Greer, L. P. Guiberson, H. D. Guthrey, S. H. Hain, H. H. Hart, Thomas Hayes, R. S. Hazeltine, H. Henshaw, W. A. Hersey, Paul Huntsch, W. A. Irwin, W. N. Kerr, W. P. Kerr, J. E. Kibele, Besley Lafever, J. L. Lennon, Walter Lewin, M. E. Lombardi, E. W. Mason, W. G. McCutcheon, R. P. McLaughlin, W. O. Miles, J. H. Miller, S. E. Mills, R. B. Moran, T. A. O'Donnell, P. F. Page, Z. L. Phelps, J. H. Raney, Charles V. Reynolds, George D. Roberts, J. M. Robertson, C. N. Root, Guy H. Salisbury, George Schwinn, H. N. Seavers, Max Shaffrath, R. E. Shore, R. H. Smith, H. F. Stranahan, R. E. Thompson, T. H. Turner, P. S. Turnbull, J. Waley, J. L. D. Walp, Alex Wark, J. H. Webb, M. L. Woy, J. B. Wrenn, John M. Wright, and many others who have contributed in one way or another to the value of the report.

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

ADVANTAGE OF COOPERATION AMONG OPERATORS.

The Coalinga oil field will continue to be the greatest in California if every operator will conserve to the utmost the supply of oil stored within the boundaries of the district, and by wise management aid in keeping it available. An approximation of the amount of available oil in the territory covered by the underground-contour map (Pl. XV) is 2,737,000,000 barrels. (See under the heading "Production," p. 247.) Some persons have the idea that underground resources of any kind are inexhaustible, but the notion is erroneous. When the oil in any field is once exhausted it will not be replaced within the limits of many centuries, if ever. It is not impossible that the processes of oil formation and migration are taking place constantly in some places, but such processes are so exceedingly slow when measured in years that they may be considered for practical purposes as nonexistent.

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

PREVIOUS KNOWLEDGE OF THE GEOLOGY.

The mountains and plain along the western border of the interior valley of California have not received much attention from scientific investigators, owing to their isolation, the sparseness of the population, and the difficulties of travel. In recent years, however, the exploitation of its mineral resources has called attention to the region, and a small body of literature containing information of various kinds regarding it is gradually growing up. The early surveys of portions of California that were made in connection with the explorations for a railroad route to the Pacific Ocean by a number of engineers and scientists under the direction of the United States War Department, and in connection with the State Geological Survey under J. D. Whitney, did not include the region of the Coalinga district, so that until recent years little was known directly concerning its geology or physical features.

The State Geological Survey party carried its geologic reconnaissance no farther south in the Diablo Range than the region of the New Idria quicksilver mine, which is about 25 miles northwest of Coalinga, but some general references to the topographic aspect of the more southerly mountains were made in the report published by Whitney and are quoted below in the discussion of place names. In 1888 the United States Geological Survey published a report by G. F. Becker [a] on the quicksilver deposits of the Pacific slope, which contains a chapter on the geology of the New Idria region. The features of that region are in many respects similar to those along the Diablo Range farther south.

The occurrence of coal, quicksilver, oil seepages, and gypsum in the region of the Coalinga district and the hope of finding other mineral deposits led a number of persons to prospect there in the early years, and the amount of investigation of this kind that has been conducted has increased more recently, with the result that an extremely productive oil region has been discovered and developed. But the first systematic geologic investigations that are known

[a] Mon. U. S. Geol. Survey, vol. 13, 1888.

to have been carried on were those of W. L. Watts, who examined the oil fields along the border of the central valley of California for the California State Mining Bureau, and published a report on them in 1894.[a] The report contains valuable information concerning the geology of particular areas and gives a general outline of the succession of the geologic formations, the ages of which were determined roughly with the aid of paleontologic identifications by J. G. Cooper. The material of this report is reviewed in a later publication by the same writer.[b]

In 1894 J. G. Cooper published a paper in which he describes the fresh-water fossils collected by Watts in the region of the Kettleman Hills, west of Tulare Lake.[c]

In the course of his investigations of the geology of the California oil fields George H. Eldridge, of the United States Geological Survey, spent much labor in studying out the intricacies of the geologic formations along the eastern flank of the Diablo Range, but unfortunately his death left the work uncompleted. A brief review of his knowledge of the petroleum fields of the State, in which he outlined some of the main facts in the geology of the Coalinga field and adjoining regions, appeared in 1903.[d]

Up to 1905 the notes published on the physical features of the Coalinga district had been scattering, but in that year Frank M. Anderson, who had been led by his interest in the oil fields and in California geology in general to take up a study of this region, published a paper[e] in which a comprehensive review of the geology and paleontology of the Coalinga district and neighboring regions is given. The paper has been of considerable service to the present writers and frequent reference to it will be noted in the text.

Shortly before the appearance of the authors' preliminary report (Bull. 357) Frank M. Anderson issued a paper[f] supplementing the one just mentioned and offering a revision of some of his first conclusions regarding the age of what he called the "Coalinga beds" and "Monterey shale." A brief summary of the principal paragraphs in his first paper is also given, this being made advisable by the destruction of the California Academy's stock of that paper during the fire of April, 1906.

[a] The gas and petroleum yielding formations of the central valley of California: California State Min. Bureau, Bull. 3; 1894.

[b] Oil and gas yielding formations of California: California State Min. Bureau, Bull. 19, 1900.

[c] On some Pliocene fresh-water fossils of California: Proc. California Acad. Sci., 2d ser., vol. 4, pt. 1, 1894, p. 166.

[d] Contributions to economic geology for 1902: Bull. U. S. Geol. Survey No. 213, 1903, pp. 306-321.

[e] A stratigraphic study in the Mount Diablo Range, California: Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, pp. 156-206, with plates.

[f] A further stratigraphic study in the Mount Diablo Range of California: Proc. California Acad. Sci., 4th ser., vol. 3, 1908, pp. 1-40.

Owing to the rapid development of the oil resources of the Coalinga district and the demand for information regarding the region, a preliminary report, containing the major portion of the data of direct importance to the problems of oil occurrence that have been collected by the present writers, was published in November, 1908, as Bulletin 357 of the United States Geological Survey. A brief paper dealing with a portion of the district describes the occurrence of recently formed conglomerate on White Creek.[a]

Paleontology has played a prominent part in the working out of the various problems, both scientific and economic, connected with the Coalinga district, and in order to present this branch of geology more fully a bulletin entitled "Paleontology of the Coalinga district, Fresno and Kings counties, California," was prepared by the senior author and has just been issued as Bulletin 396 of the United States Geological Survey.

GEOGRAPHY AND TOPOGRAPHY.

DEFINITION OF PLACE NAMES.

For the sake of accuracy and convenience of reference a proper understanding must be reached regarding the names of the various places and features in the Coalinga district before a proper topographic and geologic description can be given. 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. In the following pages are definitions of names that have been newly applied and names whose application has been made more definite. Almost all these names, including all the more important ones, 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 accompanying this report.

Coalinga district.—The application of this name to the whole region included in the map accompanying this report is discussed on page 25.

Coalinga field.—The term "field" has been adopted as representing a subdivision of a "district," and the name "Coalinga field" is used in this report in its accepted sense as meaning the region of the developed oil field in the northern portion of the territory mapped, round about Pleasant Valley, in which Coalinga is situated. This region is in turn subdivided into the Eastside, the Westside, and the Oil City fields, terms which are in common usage and will be defined in the discussion of the developed territory.

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

---

[a] Conglomerate formed by a mineral-laden stream in California, by Ralph Arnold and Robert Anderson: Bull. Geol. Soc. America, vol. 19, 1908, pp. 147-154.

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

Diablo Range.—The Diablo Range is the easternmost member of the California Coast Ranges south of San Francisco Bay. It extends southeastward from Carquinez Straits along the western border of the San Joaquin Valley. The name is taken from Mount Diablo, a prominent peak 15 miles southeast of Martinez on the Carquinez Straits, and heretofore has been variously used for the small group of mountains centering around this peak, or for a part or all of the group of mountains extending southeastward from there and limiting the central valley of California on the west. The United States Geographic Board has fixed the southern limit of the range at Antelope Valley in the northwest part of Kern County just south of the region mapped as the Coalinga district, and has determined that the correct name is "Diablo Range," instead of "Mount Diablo," "Monte Diablo," or "Sierra del Monte Diablo." The range is considered as terminating at this valley because it there sinks into low spurs, and the continuation of the mountain belt beyond the valley is a markedly individual range that is en échelon with the southernmost spur of the mountains to the north. This spur bringing the Diablo Range to an end is the one dividing Antelope and McLure valleys, later referred to as Avenal Ridge. San Benito River separates the Diablo and Gabilan ranges farther north, but in the latitude of the Coalinga district the two ranges, owing to a complication of structures, coalesce into a high mountainous tract in which various component members run at angles oblique to the main trend of the Coast Ranges. In the portion south of the headwaters of San Benito River and Los Gatos Creek, the range may be considered as extending clear across to the drainage basin of Salinas River. In his chapter on the "Monte Diablo Range" [a] J. D. Whitney devotes the opening paragraph to a definition of the range. He says:

> In its northern extension the Monte Diablo Range is easily defined; but to the south it widens and inosculates with other ranges, or spurs, falling into it from the northwest, until finally, uniting with the extreme western members of the great group of the Coast Ranges, it forms the broad region of high rolling hills, intersected by a labyrinth of narrow valleys, which lies between the parallels of 35° and 35° 30′ and where distinctness of nomenclature for the different groups of elevations is almost entirely lost. For convenience, and as representing as nearly as possible a natural division of the Coast Ranges, the Monte Diablo Range may be considered as terminating to the south in the low ridges running out into the San Joaquin Plain at the head of Los Gatos Creek, in latitude 36° 20′.

Elsewhere,[b] however, Whitney does not adhere to this limitation of the range, and describes as its most southerly division the mountains lying to the south between the "Estrella Pass," by which

[a] Geol. Survey California, Geology, vol. 1, 1865, p. 8.
[b] Idem, pp. 9-10.

he means the divide at the head of Los Gatos Creek, and the "Roble Pass," by which he means some divide across the range opposite the town of Paso Robles, most probably the pass now known as the Polonio Pass, which is at the head of Antelope Valley and which is here adopted as the southern termination of the Diablo Range. Whitney divided the range into several divisions, of which the above-mentioned division is the southernmost. He named it the "Estrella division," the group of mountains next to the north of it, between the head of Los Gatos Creek and the Panoche Pass, being named by him the "San Carlos division."

The explorations of the Geological Survey of California in the Diablo Range did not extend farther south than the region of the New Idria quicksilver mines, and therefore the knowledge obtained by them of the mountains to the south was not extensive. This is indicated by Whitney's impression, stated in the paragraph above quoted, that the southern continuation of the Diablo Range united with the westernmost members of the Coast Ranges between latitudes 35° and 35° 30′. As a matter of fact, the easternmost division of the Coast Ranges is isolated along most of this portion of its course, and may more properly be said to unite with the westernmost mountains south of latitude 35°. Other points in his description of the mountains are correct, however, and point to the appropriateness of including the "Estrella division" as a part of the Diablo Range. He characterizes the divide between the head of Los Gatos Creek and the San Benito River as "not a low one," and states that the "Estrella division" to the south of this is of considerably less elevation than the "San Carlos division," and that it "sinks very low as we approach Paso Roble." The divide at the head of Los Gatos Creek is, in fact, high and does not form a pronounced break in the range, whereas the mountains do sink low in the McLure, Antelope, and Cholame valleys, at the south end of the group named by Whitney the "Estrella division." It is therefore in harmony with Whitney's description of the Diablo Range, as well as with the features of the relief, to consider the range as terminating in the region of Antelope Valley.

Temblor Range.—Southeast of Antelope Valley a range of distinct topographic and structural individuality forms the divide between the San Joaquin Valley on the northeast and the basin of San Juan Creek and the Carrizo Plain, on the southwest. It extends from Cholame Creek on the north to about latitude 35°, where it merges with the high mountain mass around Mount Pinos called the "Tejon Mountains." To this range the name "Temblor" is here applied.

The topographic and structural separation of this range from the Diablo Range is definitely marked on the north by Antelope Valley, but its northeastern termination must be more arbitrarily assigned. It may be considered as ending at Cholame, or as continuing to the northwest across the canyon of Cholame Creek and following the western side of Cholame Valley to some point northwest of Parkfield. It seems more appropriate to consider it as so continuing and finally terminating gradually in the inclined plateau that slopes to Salinas River. The name Temblor is particularly suited to the range for two reasons: First, because the great California fault line, along which earthquakes have repeatedly originated, follows the range from one end to the other, being in the very heart of it throughout its northern part. A pronounced scarp and trough resulting from recent movements can be traced all along this line. Second, because the well-known old Temblor ranch, west of McKittrick, is situated on its flanks.

Joaquin Ridge.—A very prominent structural ridge runs southeast from the high mountains south of Idria to the San Joaquin Valley north of Coalinga, forming the divide between Los Gatos Creek on the south and the tributaries of Salt Creek and Cantua Creek that run northeastward to the San Joaquin Valley. The ridge forks in its upper part, one branch heading in a mountain nearly 5,000 feet high situated in the northwest corner of the area mapped, and the other to the north, in the high region of San Benito Mountain. The summit of the ridge is serrated with picturesque rocks, one striking group of which is locally known as the "Joaquin Rocks." The name Joaquin Ridge is here applied to the ridge.

Anticline Ridge.—The oil field north of Coalinga is on the nose of Joaquin Ridge, and immediately southeast of the main portion of the field is a depression in the ridge. Southeast of this point, which is in the southern part of sec. 34, T. 19 S., R. 15 E., a low, broad line of hills extends about 6 miles to the railroad line in the gap formed by Los Gatos Creek. (See Pl. XV.) This ridge is formed by a perfect anticlinal nose, and is therefore referred to as "Anticline Ridge."

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

Castle Mountain.—The name Castle Mountain has heretofore been indefinitely applied to a part or all of a high, sharp ridge at the headwaters of Zapato, Canoas, and Big Tar creeks, which is visible from the valley on the east as the summit of the Diablo Range. The ridge is a very definite natural feature, presenting an abrupt escarpment to the northeast, and forms the western boundary of the southern corner of Fresno County. It extends from about the head of Zapato Creek to a point south of the head of Avenal Creek. The name may well be used for the whole ridge. This name has not been passed upon by the United States Geographic Board.

Avenal Ridge.—The name Avenal Ridge is here applied to the mountains separating Avenal Creek and McLure Valley from the Cholame and Antelope valleys. It is the southernmost of the spurs of the Diablo Range. The name, which means a "field of oats," is appropriate, because the hills forming the ridge are rounded and grass-grown, and afford a flourishing annual growth of volunteer oats. (See Pls. IX, *A*, and XI, *A*.)

Reef Ridge.—A prominent ridge faces the low hills that border Kettleman Plain, running southeast, between Castle Mountain and the foothills, from the south fork of Jacalitos Creek (Jasper Canyon) as far as Little Tar Canyon north of Dudley. A steep escarpment follows the northeast flank of this ridge, being formed by the prominent lower Miocene fossiliferous strata termed the "reef beds," which dip at a high angle and owing to their resistance rise high above the softer sand hills on the northeast. The name Reef Ridge, which is indicative of the most prominent one of its topographic features and of an important element of its geologic structure, is here applied to this ridge. (See Pl. VIII.)

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

Jacalitos Hills.—The foothills between Waltham and Jacalitos creeks are here given the name Jacalitos Hills. Xacalli is an Aztec word adopted by the Mexicans, meaning "Indian hut" or "wigwam," and Jacalitos means "the little wigwams." The origin of this name is not known, but an observer can not fail to see in the symmetrical conical knolls a resemblance to tents or wigwams from which the name might have sprung. This descriptive suggestion makes the name particularly applicable to these hills. (See Pl. II, *B*.)

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

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

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

Guijarral Hills.—Immediately southeast of Anticline Ridge, on the opposite side of the railroad, is a small low group of gravelly hills referred to in the text under the designation Guijarral. This is a Spanish word meaning "a heap of pebbles" or "a place abounding in pebbles."

Dagany Gap.—The name Dagany Gap is used for the gap at the lower end of McLure Valley, south of Dudley, through which Avenal Creek takes its outlet. It is named from an old settler of that region.

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

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

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

Waltham Valley and Creek, and Alcalde Canyon.—The creek at the mouth of which Alcalde is situated is variously known as "Wartham," "Warthan," "Waltham," and "Alcalde." The United States Geographic Board has decided that Waltham is the correct name. This stream heads in a broad structural valley having no relationship in geologic character with the lower portion of the stream course. (See Pl. V, *A*.) The name Waltham Valley already in use for this upper valley should be definitely restricted to that part and not applied to the valley of the lower portion of the stream. It seems advisable to distinguish the canyon formed by Waltham Creek along its lower course under the name Alcalde Canyon, thus preserving a name which is already understood as referring only to the lower part.

This name is therefore applied to the canyon extending from the edge of Waltham Valley, where the stream cuts between Juniper Ridge and Curry Mountain, to Pleasant Valley.

McLure Valley.—The valley in which Dudley is situated has long been known as McLure Valley, after an early settler, now dead. According to old inhabitants, that is the original and proper name. It is, however, widely known as "Sunflower Valley" by reason of the abundant growth of wild sunflowers. The United States Geographic Board has decided that the former is the correct usage. (See Pl. XI, *A*.)

Kettleman Hills and Plain.—The United States Geographic Board has decided that these names are properly written with an "e" and should not be spelled "Kittleman."

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

For convenience of reference the present authors have applied names to the various marked canyons in the district. The canyon that runs north and south 7 to 10 miles due north of Coalinga, which is followed by the road to Oil City, is named Oil Canyon. (See Pl. III.) The canyon in the Alcalde Hills which runs southeasterly across secs. 2, 11, 12, and 13, T. 21 S., R. 14 E., and which throughout its course across secs. 2, 11, and 12 is practically coincident with an anticline, is called Anticline Canyon. The application of the name Alcalde Canyon has been made above. The south fork of Jacalitos Creek may be appropriately named Jasper Creek, from the picturesque and brilliantly colored buttes of jasper that surround its upper portion. The name Jasper Canyon is therefore applied to the gorge that this stream forms across the northwest end of Reef Ridge. The sharp canyon cut through Reef Ridge by Zapato Creek is called Zapato Canyon, and the similar one, formed through Reef Ridge by the south fork of Zapato Creek, 2 miles farther east, may be named Sulphur Spring Canyon from the abundance of sulphur water that issues in it. The similar canyon at the head of Canoas Creek is called Canoas Canyon. The names Big Tar Canyon and Little Tar Canyon are in common usage for the features to which these names are applied on the map.

Laval grade.—The Laval grade is a name locally known for the road leading northeastward up a branch of Oil Canyon, starting in that canyon on the east side of the NW. ¼ sec. 29 and crossing the ridge at the head of this branch canyon in the center of the NW. ¼ sec. 21, T. 19 S., R. 15 E. This name will be frequently used for reference.

Dudley-Lemoore road.—The good road crossing the Kettleman Hills about 4 miles north of Avenal Gap will be referred to as the Dudley-Lemoore road.

LOCATION.

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

The developed oil territory commonly referred to as the Coalinga field is in the northern part of the district, in the foothill region around Pleasant Valley, where the town of Coalinga is situated. This is the only important settlement in the district or in the large surrounding region, the country being very sparsely inhabited. The names Oil City, Alcalde, and Dudley, which are marked on the map and often referred to in the text as if they represented places of importance, derive their chief importance from the scarcity of place names in the region and the necessity of having points of reference. Oil City is merely an area in which an oil camp is situated and in which development took place in an early part of the history of the field, Alcalde is the terminus of the Coalinga branch of the Southern Pacific Railroad near a farmhouse a few miles southwest of Coalinga, and Dudley is a stage station and post-office in McLure Valley. Oilfields is a post-office recently established in the field north of Coalinga.

The branch railroad mentioned joins Coalinga with the main lines of the Southern Pacific and Atchison, Topeka and Santa Fe railroads in the San Joaquin Valley, and wagon roads enter the district at several points from the valley on the east. Roads cross the Diablo Range from the west in the latitude of this district at four points—(1) over the Benito Pass at the head of Los Gatos Creek, (2) over the divide between Priest Valley and the head of Waltham Creek, (3) across the range between Stone Canyon and Waltham Creek, and (4) over Cottonwood Pass. The first enters the Coalinga district along Los Gatos Creek, the second and third along Waltham Creek, and the fourth down Avenal Creek and McLure Valley.

CLIMATE, DRAINAGE, AND VEGETATION.

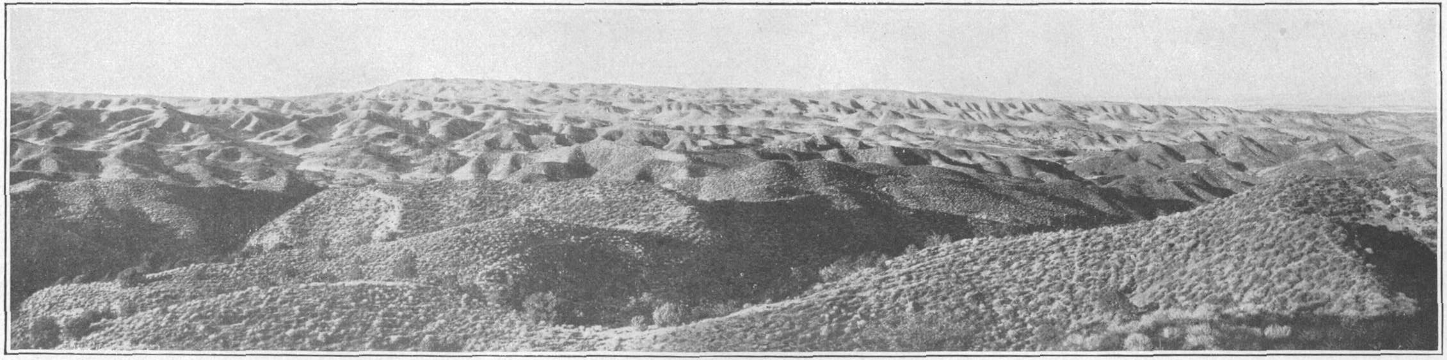
The climate in the region of foothills and plain along the western border of the San Joaquin Valley is arid. The rainfall is almost entirely limited to the "rainy season," chiefly from November to March, and is then slight. During the summer the days are hot and the atmosphere dry, the region becomes desiccated, and the streams dwindle and cease to flow on the surface before reaching the valley. They continue, however, to have an underground flow and the plains thus receive underground much of the drainage of the Diablo Range. Water is obtainable in wells at most places in the district, but it is generally poor. Large quantities of it are pumped from beneath the plain at various points and it is likewise found abundant at various depths in the oil wells drilled in the hills. Owing to the large original content of salts of various kinds in the formations, and the aridity of the climate, which allows this material to remain on and near the surface, the waters of the region are usually highly mineralized. Almost all water used for drinking purposes is brought by train from farther out in the San Joaquin Valley.

The vegetation, as shown in the landscape views accompanying the text, is very sparse. The large plain and lower hills are naturally treeless and are overgrown with herbaceous and shrubby perennial vegetation, in most places scantily, as illustrated particularly by Plates II, *A* and *B*, III, and XVIII. The higher hills and the narrower valleys have in addition to such vegetation a scattering growth of small trees, principally oaks and junipers, as illustrated in Plates XVIII, IX, *A*, and XI, *B*. The mountain slopes are dotted with numerous, although rarely thickly set pine, juniper, and oak trees and present an attractive background to the valley border region. Some of the trees attain a good size and are locally used on a small scale for lumber. The growth on the higher slopes as shown in Plate XVIII is fairly typical of the mountainous region. The character of the underlying rocks exerts a marked influence on the vegetation, and belts occupied by different formations or lithologic zones may frequently be traced by the abundance or sparseness or character of the plants.

RELIEF.

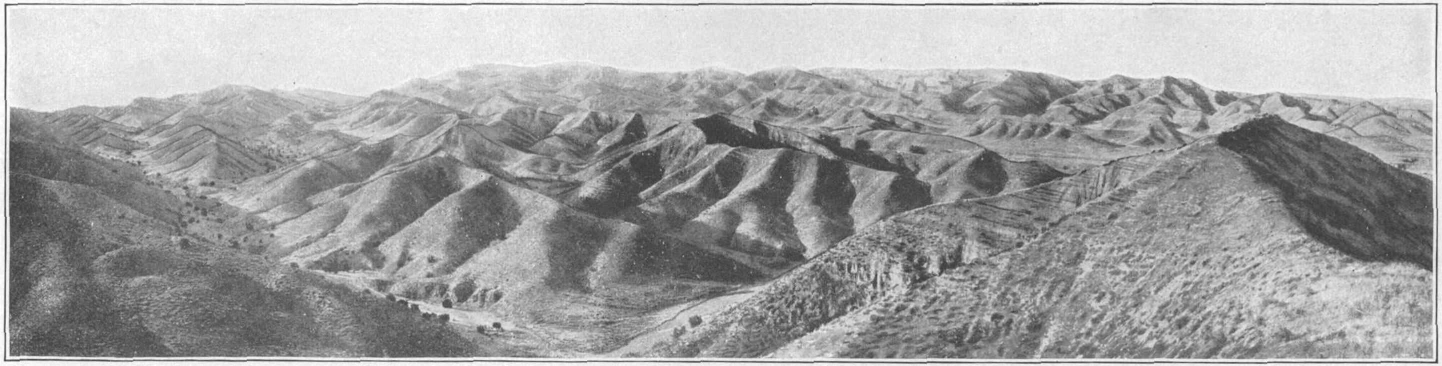
GENERAL TOPOGRAPHIC FEATURES.

The Coalinga district owes its broader topographic features to its position along the border between the Coast Ranges and the interior valley of California. It is largely a region of foothills that rise on the west into the mountains and merge on the east with the wide level plain. The plain stretches thence with unbroken sweep to the foot of the high wall of the Sierra Nevada, the snowy summit of which is



A. ARID FOOTHILL BELT OF TERTIARY FORMATIONS.

Looking northeast from Zapato Creek across Kreyenhagen Hills toward the valley. Photograph by Ralph Arnold.



B. MONOCLINE OF TERTIARY STRATA IN JACALITOS HILLS.

Looking north from Jacalitos Creek, along the strike of the beds on the left, and across the strike on the right. Photograph by Robert Anderson.

frequently part of the landscape in the early morning or during the whole of clear days. The foothills form a continuous belt, in places narrow but more commonly miles in width, along the base of the mountains, but are arranged in several groups along the base and around the ends of spurs descending southeastward from the Diablo Range, the groups being separated from each other by reentrant valleys that open out to the San Joaquin Valley.

Viewed from a distance across the dry, treeless plain the mountainous belt of the Diablo Range appears as a continuous, fairly even-topped ridge, covered with scattering vegetation and therefore blue in color, set back behind a broad belt of lighter-colored, grass-grown foothills that seem to form an inclined terrace sloping up gently toward the mountains. From nearer at hand broad valleys appear inclosed within outlying foothill spurs, the near-by hills assume great prominence and are seen to be sharply dissected, deep canyons appear within the mountainous belt, and the horizon line is observed to be formed not by one continuous mountain ridge but by a series of discontinuous overlapping ridges running into the range toward the northwest at angles slightly oblique to the general direction followed by the edge of the valley and the range as a whole.

The area included in the accompanying map is not a well-rounded topographic province. None of the larger stream courses are shown more than in part, and the area is bounded not by the main crest of the mountains but by overlapping sections of the outlying high ridges that face the valley.

Some of the prominent features of the landscape have been outlined and briefly described in the preceding discussion of place names.

DIABLO RANGE.

General features.—The Diablo Range in the latitude of the Coalinga district is a broad mountain group of moderate general profile but locally rugged character forming a continuous barrier 2,500 to 5,000 feet in height and 30 to 40 miles broad between the San Joaquin Valley on the northeast and the San Benito, Salinas, and Cholame valleys on the west and southwest.

The summit altitudes of the crests of the range decline from the region north of Los Gatos Creek in the San Carlos division toward the south in the Estrella division (these names being those applied by the Geological Survey of California under Whitney, as before mentioned), until finally declining along Avenal Ridge toward McLure and Antelope valleys, where the range comes to a stop and gives place on the southwest to the Temblor Range. Portions of the main watershed appear upon the accompanying map at only two points—in the northwest corner, which is marked by a peak nearly 5,000 feet in height that stands at the head of Joaquin Ridge, and in the southwest corner, where the much lower Avenal Ridge, the southernmost spur of the range, appears. In the intermediate region the ridges that are represented on the western edge of the area are in general separated from the main divide farther west by a region of lower relief determined by the presence of oblique structural valleys, of which Waltham Valley is the principal one.

Distinction from foothills.—The mountainous region within the Coalinga district is marked off topographically from the foothill region both by its higher altitudes and steeper slopes, which in many cases begin abruptly along a line at the margin of the foothill belt, and by its somewhat different type of topographic development. The two regions are geologically distinct, for the reason that the mountain tract is one almost entirely of older and harder rocks, and the foothills mark the belt of softer Tertiary and Quaternary formations. In some portions of the region, however, a line of separation between the foothills and features more properly called "mountains" is not naturally traced.

Outcrops and slopes.—The mountainous region affords abundant outcrops. It owes its topographic distinction from the foothill belt largely to the superior hardness of its constituent rocks, which stand out on ridge tops and canyon sides with bold relief. As examples may be cited the remarkable exposures of the sandstone strata on the flanks of Joaquin Ridge, along the face of Reef Ridge (see Pl. VIII), and on the escarpment of Castle Mountain. The ridges are usually fairly even-topped, and have gentle summit slopes descending toward the larger drainage lines that follow the lines of structure and toward the valley; their flanks where cut by erosion have steep sides that drop abruptly into V-shaped transverse canyons. Steep slopes also border the broader structural valleys as effects of the structure—for example, the southwest face of Juniper Ridge and Curry Mountain (Pl. V, *A*) and the northeast face of Castle Mountain, which are probably due to faulting, and the steep dip scarp of Reef Ridge (Pl. VIII). As suggested above, the lines of drainage are principally of two kinds, those paralleling the structural lines and directly consequent upon the structure, which are the main lines, and those transverse to the structure, which are more strictly erosional in origin and are the principal lines of sharp dissection. These second lines of drainage have small tributary courses due to erosion that run either parallel with or oblique to the strike of the beds, and likewise cut deeply, exposing dip slopes and strike faces.

Constituent ridges.—A peculiar feature of the Diablo Range, which has already been suggested, is the presence along its eastern flanks of numerous spurs running out toward the southeast and of reentrant valleys between these spurs. These ridges and valleys trend a little more nearly east and west than the range as a whole, which trends about N. 35° to 40° W. They are primarily due to structural causes and not to erosion. The main salients of the Diablo Range that project toward the San Joaquin Valley in the Coalinga district are Joaquin Ridge and its structural continuation in Anticline Ridge and the Kettleman Hills, Juniper Ridge and Curry Mountain, Reef Ridge, the mountain northwest of McLure Valley, between the drainage of Big Tar Canyon and Avenal Creek, which forms the southern extension of Castle Mountain, and Avenal Ridge. These, as well as the valleys or depressions separating them, are the topographic expression of folds and faults running obliquely to the main trend of the Diablo Range. These constituent ridges, which were mentioned under the subject of place names, will be described individually in the following paragraphs.

Joaquin Ridge.—Joaquin Ridge is anticlinal and exposes on its lower flanks the oil-bearing formations, thus determining the position of the oil field north of Coalinga. The ridge is structurally continued by the Kettleman Hills, which form a prominent isolated group rising over a thousand feet above the San Joaquin Valley. The spur formed by Joaquin Ridge and the Kettleman Hills is separated from the rest of the district by the synclinal and faulted depression of White and Los Gatos creeks and the synclinal Pleasant Valley and Kettleman Plain.

The ridge has a narrow but rounded crest that descends gradually from an altitude of nearly 5,000 feet in the northwest corner of the district toward the east and southeast, and then declines more steeply toward the head of Oil Canyon and the high foothills on which the Eastside oil field is situated. From a distance the summit appears smooth except for occasional notches and the sawtooth appearance presented by the outcrops of strata that dip down the ridge. One group of these outcrops forms the picturesque towers known as the Joaquin Rocks. On either side the ridge sends out long, smooth-topped, but steep-sided lateral ridges that decline by gentle stages toward the adjacent main lines of drainage and toward the valley. These ridges are separated by deeply trenched canyons transverse to the strike of the strata.

Toward its head Joaquin Ridge has a different topographic character, due to the different nature of the rocks. It assumes the gentle outlines everywhere characteristic of the areas occupied by the serpentine associated with the Franciscan formation. The flank extending down to White Creek appears like an inclined plain notched by widely separated shallow troughs. This portion of the ridge is made visible from a long distance by the white deposits of serpentine lying on the surface, and from near at hand it is seen to be covered over great areas by bare piles of white, yellow, gray, and brownish-red comminuted serpentine.

The length of Joaquin Ridge is nearly 20 miles and the extent of its flanks from side to side, roughly speaking, 10 or 12 miles.

Juniper Ridge and Curry Mountain.—Juniper Ridge and Curry Mountain form the next spur to the southeast, beyond the Los Gatos Creek and Pleasant Valley depression, belonging together as a continuous structural feature due in part to faulting on the southwest side and in part to the hard strata that strike along it and form the summit (Pl. V, *A*). Within the district this feature has a length of about 14 miles, and it extends much farther northwest. It gradually declines in altitude from elevations of about 4,000 feet at the northwest end to 2,400 feet on the summit of Curry Mountain. The sharp gap of Alcalde Canyon, which begins at the point shown in Plate V, *A*, divides the spur into the two portions named. In the southeastern portion of its extent this spur presents a steep scarp on the southwest side, where it bounds Waltham Valley, and on the northeast a gradual monoclinal slope into the Alcalde Hills. The end of Curry Mountain drops abruptly into a depressed area of low, rolling hills (the Jacalitos Hills) that is the continuation southeastward of the Waltham Valley depression.

Reef Ridge.—Beyond the low area last mentioned a prominent salient springs up along Jacalitos Creek and extends for about 23 miles southeastward as a high divide between the foothills bordering the Kettleman Plain and a belt of low relief, not shown on the map, in which Jacalitos, Zapato, Canoas, and Big Tar creeks head. This divide is Reef Ridge, and all the streams named, as well as their forks, cut sharp gorges through it to a depth of 800 to 1,200 feet. The cliffs on its northeast face and some of the minor canyons crossing it are well shown in Plate VIII. The ridge has a general monoclinal structure, the component strata dipping steeply northeastward as a general rule. The ridge is due in part to the strike of the hard strata and in part to faulting along the southwest side. At its southeastern extremity it gives place to the minor ridge of the Pyramid Hills, which is en échelon with it.

The summit of Reef Ridge rises with smooth but fairly sharp crest from the northwest end toward the central portion, but there breaks into a belt of salient peaks and ridges, some of which rise considerably over 3,000 feet above sea level between the deep canyons that cut across the ridge and the branch canyons that follow along the strike of the softer zones. At the southeast end the ridge narrows into a single sharp crest with even summit and declines gradually to an elevation of less than 1,000 feet. The northeast flank of Reef Ridge is formed by the steeply tilted hard "reef beds" of the Vaqueros (lower Miocene) sandstone, as shown in Plate VIII. Its slope reflects the high angles of the strata and forms a wall against which the comparatively low foothill belt stands in marked contrast. The canyons that are deeply cut at short intervals down the northeast flank of the ridge or completely across it have carved the reef beds into a row of serrate peaks, and parallel zones of hard beds in the Eocene and Cretaceous formations below are similarly although less prominently affected. From near and far Reef Ridge is a picturesque feature of the landscape, and from each changing view point it assumes a different striking aspect.

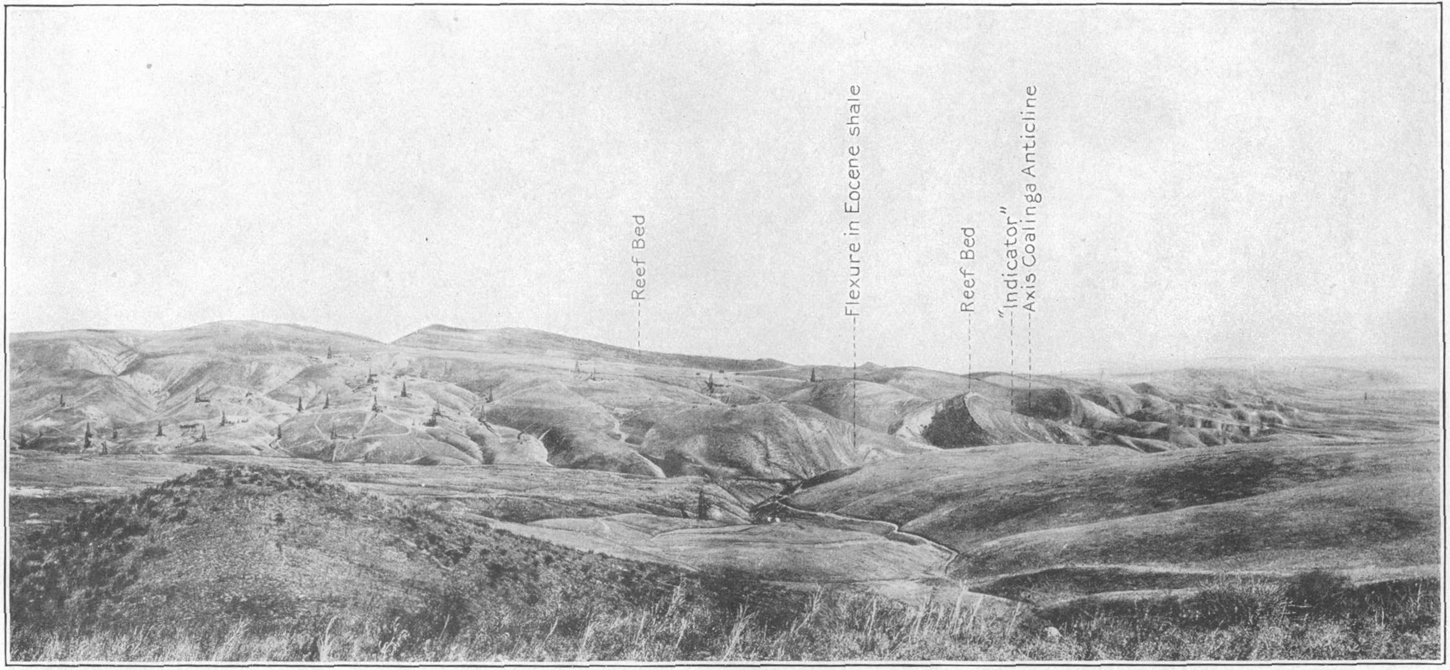
Castle Mountain.—The next salient of importance entering the area of the map is south of the head of Big Tar Canyon and the Castle Mountain fault zone. It is a high and prominent group of hills forming the southeastward continuation of the precipitous ridge of Castle Mountain. Castle Mountain itself is visible from almost all parts of the district as a high, sharp ridge with long, fairly even sky line and abrupt eastern face. It parallels Reef Ridge on the southwest and does not enter the area mapped. The hill group that continues the general line of relief toward the southwest juts out toward McLure Valley as a conically shaped mass reaching a height of over 2,500 feet and sloping away at a medium angle on the north, east, south, and southwest. Around about its base there is a peculiar double row of hills and concentrically arranged depressions that give the group a unique appearance. These features are due to the geologic structure of the spur, which, broadly speaking, is domelike, and to the curving strike around its base of the hard zones that have become weathered and eroded into relief.

Avenal Ridge.—Reef Ridge and the last-mentioned spur are separated from the next salient to the south, Avenal Ridge, by the wide plain of McLure Valley and by the valley of Avenal Creek. Avenal Ridge is the main divide of the Diablo Range. Its extent within the district is less than 9 miles, but it continues beyond, northwestward. It is formed by an important closely folded anticline that plunges steeply southeastward and brings the range to an end. It is a high, bare ridge with gently curving contours and broadly spaced features. It has a fairly even sky line at altitudes between 2,000 and 2,700 feet, which is continuous except for three or four canyon notches. The northeast flank of the ridge descends with fairly steep slope to the foothills, at an elevation of about 1,000 feet, within 1 to a little over 2 miles, but the slope is broken, and locally lessened and steepened, by benches that are due to the prominent relief of hard zones of strata forming longitudinal ridges and lines of hills. These benches are especially evident when seen in profile view, as in Plates IX, *A*, and XI, *A*.

THE FOOTHILLS.

GENERAL DESCRIPTION.

The foothills represent the eroded surface of the upturned Tertiary and early Quaternary formations along the edge of the valley. They form a belt, usually several miles wide, of rolling bare hills following the curving strike of the formations around the projecting ends of the mountain spurs and along the border of the intervening valleys. In the Guijarral and Kettleman hills they assume the character of isolated groups entirely disconnected from the mountainous tracts, around which those groups more properly called the foothills, form a fringe. A general similarity of elevation is characteristic of the foothill areas, and comparatively slight relative relief is the usual rule, the summits generally reaching higher and higher altitudes by degrees toward the mountainous belt. The majority of the summits range in altitude between 1,000 and 1,700 feet above sea, or usually between 400 and 1,100 feet above the neighboring valley surface, although a number of massive hills standing out above the general elevation or ridges rising toward the mountains reach as great a height as 2,100 feet. The hills gradually decline in general elevation toward the southern end of the district. The summits of the individual hills and ridges in the foothills belt appear to determine roughly a general plane that slopes upward gently toward the mountains and toward the major ridges, which coincide with the major axes of uplift, and to represent an old surface of erosional planation. This summit plane is in places sharply incised by narrow canyons that have left as much as half the original surface fairly intact or at least not greatly degraded. Instances of this are many in the northern part of the district. (See Pls. III, VII, *A*, and XIII, *A*.) Elsewhere remnants of the general summit are left only at isolated points, as is more commonly the case in the southern part of the district. (See Pl. II, *A* and *B*.) The soft formations of which the hills are largely composed lend themselves to minute, rapid, and fairly uniform sculpturing, which gives the hills the appearance of a wrinkled surface, especially when the obliquely falling rays of the sun have brought out the intricate scattering of light and shade. The hills owe their form chiefly to three causes—to the general reflection, on the surface, of the folds to which their uplift is due; to erosion along lines directed down the slope toward the valleys, at right angles to the structural lines, as a result of which a series of lateral ridges is formed; and to erosion along structural lines, particularly along bedding planes and lines of contact, as a result of which parallel longitudinal ridges and valleys and rows of hills are formed, and the lateral ridges are deformed or dissected into hills. Further detailed sculpturing is due to erosional wash along small channels tributary



OIL CITY FIELD AND RIDGE OF THE COALINGA ANTICLINE.

Looking east across Oil Canyon at hills of Cretaceous and Tertiary oil-bearing formations. Note gently dipping beds on left, overturned anticline in center, and steeply dipping beds along edge of Pleasant Valley on right. Photograph by G. H. Eldridge.

and at right angles or oblique to the streams determined by these two main directions of erosion.

The gently sloping surfaces of the hills are ordinarily smooth, covered with soil or sand, and overgrown sparsely with herbaceous vegetation, sagebrush, and other low plants. The underlying formations form much of the surface, however, especially on the steeper slopes, and although the individual outcrops are not always in prominent relief the appearance of the strata on the surface and their effect on the topography is one of the most striking features of the hills. This effect is chiefly in evidence where differential erosion has brought out certain beds or rapid dissection has left lateral bluffs or steep strike faces of hills exposed. Typical effects of this sort are illustrated by Plates X and XVII. Where the soft formations are traversed by hard zones or beds the latter stand out as hills by virtue of the protection against erosion that they afford to the associated beds, as may be noted in the hills shown in Plates VII, *A*, and XVII. The structure and stratification are in places both broadly and in detail reflected in the degree of relief, the slopes, and the vegetation of the hills. The gravelly and sandy beds, owing to their superior power of absorbing water and possibly also to other conditions, support vegetation where the clay beds do not, and the degree of coarseness of the beds is frequently to be made out by the varying abundance of vegetation, and by variable kinds as well. The result is a marked parallelism and alternation of belts and lines of vegetation. Plates VII, *A*, and XIII, *A*, give a good illustration of the sharp lines of bedding that are brought out by the plant growth, but in most other places the belts follow broader zones.

The foothills of the Coalinga district may be divided into several different groups according to their form, position, degree of distinctness from the mountains, and stage of degradation, although they all present similarities and each group merges in topographic character into the others. The hills toward the northern end of the district partake more of the character of the mountains than those to the south, whereas the latter are much more worn. The following descriptions of these groups will bring out some of their distinctive features.

HILLS NORTH AND SOUTH OF LOS GATOS CREEK.

The relief in the area of Cretaceous rocks northwest of Pleasant Valley partakes of the character of both the mountainous and the foothill belts, and owes its distinctive features to this intermediate position. The region is one of long, high, narrow ridges running out at right angles to the structural lines, from the main ridges to the north and south which parallel these lines. The component strata dip down the ridges and tend to produce angular forms. They also show their influence in giving rise to lateral extensions of the ridges and to high hills appearing along certain zones on successive ridges; and the manner in which the topography and the outcrops display the curving strike of the strata is remarkable. The ridges are separated by sharp V-shaped canyons at the bottoms of which the stream courses wind back and forth with short sharp turns. The summits exhibit a marked flattening and mutual equality in elevation, especially in the central portion of the Los Gatos Creek drainage basin.

A region of rolling hills carved in the filling of Tertiary deposits opens out toward the upper portion of White Creek, the relief here resembling somewhat that characteristic of the Waltham Valley.

HILLS AROUND THE END OF JOAQUIN RIDGE.

The hills north of Pleasant Valley are the continuation of those farther west and resemble them in that they are primarily formed by prominent ridges extending out from the higher tracts, across the strike of the beds. The ridges here, however, are more broken into individual hills, have broader and more rounded outlines, and reflect the strong influence of the formations and structural lines in spurs that extend out on either side along resistant zones, in hills formed by prominent beds, and in contact valleys. The ridges are thus made irregular and in their higher portions may be said to be rugged, as, for instance, those in the Eastside field shown in Plate XVII. A peculiar feature of these ridges is the irregular crest line which results from the appearance at short intervals of eminences due to the outcrop of hard beds. The knolls so formed present steep slopes or bluffs up the ridge on the strike face and smooth dip slopes down the ridge. Such bluffs are especially numerous on the east flank of Joaquin Ridge. (See Pl. X.) Long canyons that come down out of the higher hills between sharp slopes and with steep gradient gradually open out and become almost lost between the low tongues that reach out toward the valley.

The longest of the ridges is Anticline Ridge, the extension of the anticlinal dome of Joaquin Ridge. It is a low, broad, even-topped line of elevation with shallow sweeping concavities due to erosion, and slopes gradually toward the gap formed by Los Gatos Creek. Southeast of that gap the same area of relief is continued in the Guijarral Hills. These present an abrupt slope where cut by the gap, but on the summit resume the gradual slope of the surface of Anticline Ridge, forming an inclined plain toward the southwest and south and finally merging with Pleasant Valley and the floor of Polvadero Gap.

ALCALDE HILLS.

South of the gap in the foothills formed by the debouchure of Los Gatos Creek upon Pleasant Valley the valley is bordered by hills that rise more sharply than those on other sides, the slope toward the valley being a dip slope but little less in angle than that of the beds. The same factors that are of importance in determining the form of the hills before mentioned, namely, the course of the drainage across the line of strike of the strata and the tendency of the strata to form lines of relief paralleling the structure, are here important, but the latter factor begins to assume the greater importance, and the Alcalde Hills are formed largely, especially in their southern part, by longitudinal ridges, gulches, and lines of hills. The southern portion of these hills appears like an inclined plane sloping down toward Alcalde Canyon on the south and up to Juniper Ridge on the west, and intricately and irregularly dissected by long, shallow canyons and steep gullies that trend in general down the slope of the plane, the drainage of the hills being chiefly toward Waltham Creek. Nowhere are the planed summits of the hills more clearly observable than in the steeply inclined plateau-like surface that stretches northwest from Alcalde Canyon up to the flat-topped ridges on the flank of Juniper Ridge.

JACALITOS AND KREYENHAGEN HILLS.

South of Waltham Creek the Jacalitos Hills continue the Alcalde Hills. A difference in character is noticeable, due to more advanced dissection, a more pronounced development of the features reflecting the structure of the strata, and a more distinct differentiation from the mountains. The change increases farther toward the south. The foothill belt from Waltham Creek south is not so apparently a continuous area of relief as in the north, but is composed of fragments of strike ridges separated by broad, smoothly concave longitudinal ravines. These features are illustrated in Plate II, *B*.

The Jacalitos Hills present an abrupt face toward Waltham Creek on the north side of a hill 1,900 feet high southeast of Alcalde, but from the summit of that hill and its spurs the hills decline gradually toward Jacalitos Creek on the southeast and the valley on the east. The drainage is predominantly toward Jacalitos Creek. On the west these hills extend widely and join the rolling area in the region of the Waltham Valley depression and the gentle, irregularly gullied slope of the serpentine area that extends behind Reef Ridge up toward the main crest of the Diablo Range. A prominent feature of the latter area is the group of picturesque buttes of jasper which are scattered over it and which are colored a brilliant vermilion by the growth of lichen.

The Kreyenhagen Hills (Pl. II, *A*) form a long foothill belt following the course of the soft formations between Reef Ridge and Kettleman Plain and are divided into several groups, each a few miles in extent, by streams crossing them at right angles. They abut upon the steep face of Reef Ridge, as shown in Plate VIII, and are distinctly separable from the mountainous belt which begins there. To the northeast the strata form ridge after ridge, paralleling each other, and extending the length of the separate divisions between the main stream valleys. These ridges, where regular, may be compared to a series of waves advancing, as on a smooth beach, toward Reef Ridge as the shore, and elsewhere to broken waves, as in a choppy sea. The ridges are slightly asymmetric, the northeast flank being a dip slope and fairly smooth, while the southwest flank is a steeper, strike face that is in many places eroded so as to leave sharp gullies and conical intermediate ridges extending outward. The groups of hillocks so produced bear some resemblance to an encampment of tents or wigwams, and, as elsewhere suggested, the name Jacalitos, meaning the little wigwams, may have been applied to the creek owing to this feature of the hills through which it flows. The greatest symmetry of the parallel ridges appears in the portion of the Kreyenhagen Hills between Jacalitos Creek and Big Tar Canyon, and there the long, straight, smooth troughs between the ridges doubtless gave rise to the name Canoas, meaning canoes, applied to the creek passing across the central portion of the hills.

Toward the south the Kreyenhagen Hills become more and more worn, decline in elevation, and lose their relief. The prominent individual features are absent, and the foothill area is a rolling surface with low sweeping ridges and broad drains sloping gradually toward and merging imperceptibly with the Kettleman Plain.

In the northern group of the Kreyenhagen Hills, as in the Jacalitos Hills, the locus of points of greatest elevation is asymmetric in position, the slope toward Jacalitos Creek on the northwest being steeper and shorter than that toward Zapato Creek on the southeast. The major part of the drainage flows in the latter direction. In the groups of hills between the other streams farther south such a feature is not so clearly to be made out, but it is true that the course taken by the drainage is predominantly toward the southeast.

KETTLEMAN HILLS.

The Kettleman Hills form a small isolated range 30 miles long and 5 to 6 miles broad, about 700 feet above the Kettleman Plain and 1,100 feet above the San Joaquin Valley, extending from northwest to southeast and describing a broad curve toward the south in the southern half. The most striking features of the group are its isolated position in the midst of the surrounding plain, its long, narrow, regular extent, its almost horizontal summit line, which slopes gradually downward toward the two ends, its crescent shape, and its anticlinal origin. The topography is peculiar, and though in some ways similar to that of the hills in other parts of the district has various distinguishing features.

As a result of the difference of elevation of the plains at the foot of the hills on the two sides the flanks are of different topographic character. The crest of the range is not in a central position, but considerably nearer the western side, and is formed by resistant zones of strata. The slope toward the Kettleman Plain is trenched by many sharp gulches, which with their tributary gullies give a minute sculpture to the soft hills. In consequence of the direct course of the drainage toward the valley the ridges are of the transverse type. The eastern flank is of greater extent, is, in general, more worn away, and has more broadly developed topographic features. The drainage lines running to the valley are fewer in number, but of greater importance, and are more like the main streams crossing the Kreyenhagen Hills. The result, as in that case, is the development of tributary streams between strike ridges, these ridges assuming considerable prominence where supported by resistant strata. The flanks of the hills on the two sides and the gently declining elevations toward the two ends appear to determine smooth surfaces sloping away from the crest of the hills. These surfaces are broken, however, by almost level benches that are cut into them, especially at the foot of the main ridge on either side and over most of the eastern flank in the southern half of the hills. Toward the south end, as in the Kreyenhagen Hills, the range is much worn and the relief becomes obscure.

HILLS AROUND M'LURE VALLEY.

The most prominent foothills around McLure Valley are those of the Pyramid Hills type, formed of the siliceous shale of the Santa Margarita (?) formation. This shale is very hard and resistant and stands out as a zone of relief along its outcrop as a result of differential erosion. McLure Valley is surrounded by a fringe of hills produced by this shale, the Pyramid Hills on the east, the Tent Hills on the west, and a prominent wall of knobs circling the base of the mountain spur on the north. As the names given to these hills imply, they are of conical shape. They form continuous ridges, along the summit of which symmetrical cones are left between the heads of the gullies. (See Pls. IX, *A*, and XI, *A*.)

The hills at the head of McLure Valley between these lines of shale hills are very similar to those in the southeastern portion of the Kreyenhagen Hills. They are low and sweeping and merge with the valley floor. Prominent hills or buttes left by differential erosion occur here and there, and a belt of hills thus formed by a hard sandstone zone may be traced in front of the shale hill ridges. A terraced surface of the McLure Valley hills is well shown in Plate XI, *A*.

THE BROAD VALLEYS.

The boundary between the hills and the valley bottom is not abrupt, because the plain has been alluvially built up along the border and the structural angle is obscured. There is, however, a usual change within a quarter to a half mile from an appreciable or steep slope in the hills to the angle of the plain, which appears almost level to the eye. The floors of the valleys of the foothill belt begin at an elevation between 800 and 600 feet and slope gradually toward the San Joaquin Valley. The floor of the large valley begins at the edge of the hills at an elevation of 500 or 600 to 300 feet, and slopes within a short distance to the general level surface of the plain, which lies between 400 and 200 feet above the sea. Within the district the surface of the San Joaquin Valley slopes almost imperceptibly southward to the basin of Tulare Lake.

The side valleys that branch out from the San Joaquin Valley between the inclosing ridges of foothills and mountains are Pleasant Valley and its continuation in the Kettleman Plain, and McLure Valley. Just outside of the district are the analogous basins of Waltham Valley on the west, which is almost entirely inclosed by hills, and Antelope Valley southwest of Avenal Ridge. All these valleys are structurally basin-like depressions whose streams have gained outlet to the plain through gaps either newly produced or deepened by erosion during the progress of formation of the basins.

TULARE LAKE.

The only lake within the Coalinga district is Tulare Lake, which borders the southeastern portion of the district east of the Kettleman Hills. It is a broad, shallow body of water occupying a portion of the almost level floor of the San Joaquin Valley and deriving its supply of water from several rivers that descend from the Sierra Nevada and spread numerous distributaries over the valley. Little or no surface water reaches the lake from the mountains on the west, although they are much nearer. The lake has no regular outlet, but in periods of high water the whole central portion of the valley to the north and south becomes flooded and marshy. Formerly the lake was one of the largest bodies of fresh water in California, but in late years it has been gradually declining in size, owing largely to the use of the water of its tributary streams for irrigation, to the construction of dikes, and to the reclamation of the land formerly covered by it. In 1880 it spread over an area about 27 miles long from northwest to southeast and 20 miles broad from northeast to southwest. Nine years later it was about 20 miles long from east to west and 15 miles broad from north to south. In still more recent years successive dikes had been constructed, the lake had almost dried up, and most of the area formerly covered by it had been brought under cultivation. But the unusual precipitation of 1907 caused the whole central portion of the valley to be inundated, and extended the lake to approximately its old shore line of 1880, almost at the base of the Kettleman Hills. The accompanying topographic map (Pl. I), which was made in the summer of 1907, shows the abnormally high mark reached by the lake at that time.

During the late Quaternary period Tulare Lake covered a much greater area than at present, as is shown by the presence of an old beach at an elevation of more than 100 feet above its present level, 2 or 3 miles west of the northwestern corner of the lake as shown on the map, and also by marked shore lines at lower elevations. The old beach consists of a ridge of sand about 20 feet wide and 6 to 8 feet high, somewhat eroded and covered with low vegetation, which runs for a mile or so along the low slope flanking the Kettleman Hills. Its present elevation is probably due in part to the progress of recent relative uplift of the hill area. Benches marking other positions of the shore line are observable along the Dudley-Lemoore road between the lake and the Kettleman Hills, at an elevation of much less than 100 feet above the lake.

Tulare Lake marks the lowest area in the Coalinga district and, in fact, in the whole southern end of the interior valley of California. Its surface lies a few feet less than 200 feet above the sea. North of the lake a broad zone of greater elevation crosses the San Joaquin Valley and forms a barrier diverting the drainage from the southern portion of the Sierra Nevada southwestward into the lake basin. To the south the valley floor on the side toward the Coast Ranges has a general elevation between 200 and 300 feet. A line of depression west of the middle of the valley connects Tulare Lake, by a low tract subject to marshy inundations, with Kern and Buena Vista lakes, which lie in the southern end of the valley at an elevation of a little less than 300 feet.

The origin of the basin occupied by Tulare Lake is probably due to the building up of alluvial fans across the San Joaquin Valley north of it by the rivers of the Sierra Nevada, especially Kings River, and by Los Gatos Creek and the other creeks of the northern part of the Coalinga district, which have formed an unusually large alluvial fan for the Coast Range streams.

DRAINAGE COURSES.

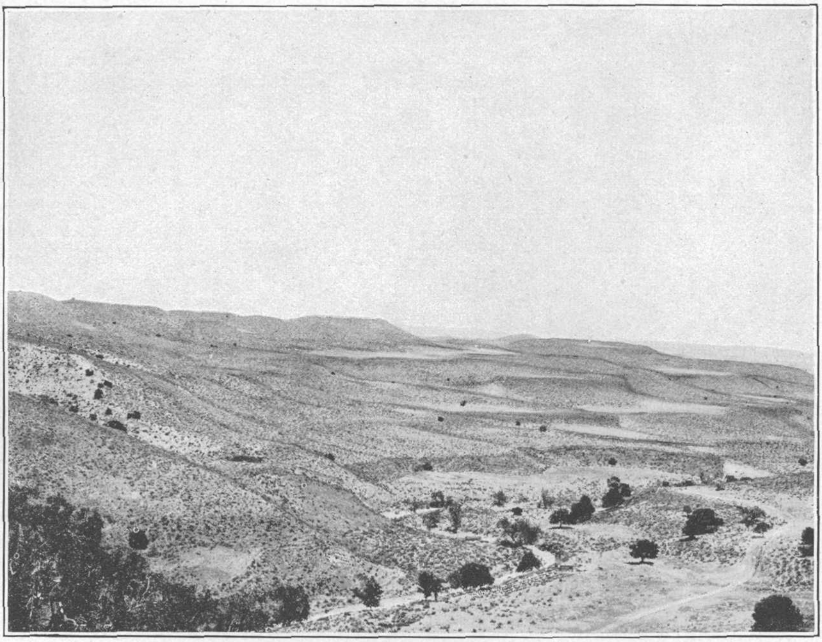
Character of streams.—The main streams within the Coalinga district partake of the nature of all the streams flowing off the eastern flank of the Diablo Range. They are comparatively short mountain streams of medium gradient that flow from the mountains at short intervals in broad V-shaped valleys between the mountain spurs, and have many tributary streams a few miles in length with steeper gradient and sharper valleys. Several terraces appear in many places along the sides of the stream courses within a few hundred feet above the present bottom, marking the position that the valley floor has occupied at different stages. (See Pl. IV, *A*.) The streams approach the plain through the lower hills with nearly graded or in places aggraded courses, emerge upon it over the gently sloping alluvial fans that they have built up, and form squarely cut, broad, shallow channels through the horizontal deposits of the valley floor or spread out and end as level washes. The dryness of the region does not allow them to reach any trunk stream, and the great valley is like a sea in bringing them to an end and forming a catchment basin. As before stated, none of the main streams in the Coalinga district heads within the area shown on the map. Owing to the slight rainfall and the prolonged drought in summer, none of these streams carries much water, and they all become nearly dry at the surface during that season.

The two most important streams of the district are Los Gatos Creek and Waltham Creek, which drain considerable tracts and flow through deep, structurally important valleys, in their lower portion nearly graded. These streams join in Pleasant Valley and pass out to the San Joaquin plain through a narrow gap cut across the uplift of the Coalinga anticline.

The next most important streams are Jacalitos and Avenal creeks, and these with four others, Zapato, Canoas, Garza, and Big Tar creeks, complete the list of main streams. Of all of these much the same may be said. A common feature is that the main upper forks of these streams flow at an oblique angle to the range from northwest to southeast or from west to east, and that they change their course toward the northeast in the lower portion and flow directly away from the range across the structural lines.

Los Gatos Creek.—Los Gatos Creek, the northernmost of the streams flowing off the Diablo Range in the Coalinga district, heads at Benito Pass, the divide between the San Joaquin Valley drainage and San Benito River, and flows southeastward with low gradient for about 30 miles to the plain. In the mountainous region it occupies a broad valley formed by well-worn ridges that slope gradually down into it from the flanks of the high ridges on the north and south. On reaching Pleasant Valley, like the other streams of this region, it forms a wide, shallow channel, with abrupt sides usually about 5 to 20 feet in height exposing the level deposits of the floor, and finally spreads itself out as a wash on the San Joaquin plain.

It is joined by an important tributary, White Creek, which heads on Joaquin Ridge, and after flowing off the flanks of this ridge follows the same general valley as Los Gatos Creek, the two streams being separated by a fairly sharp structural ridge 500 to 700 feet high above the valley bottom. The floor of the valley of Los Gatos



A. STREAM TERRACES ALONG ZAPATO CREEK.

The upper terrace is an important one throughout the hills. Photograph by Robert Anderson.

B. HARD REDDISH-BROWN SANDSTONE CONCRETIONS WEATHERING OUT OF MASSIVE UPPER CRETACEOUS SANDSTONE.

On flank of Joaquin Ridge north of Los Gatos Creek. Photograph by Robert Anderson.

Creek, which is a few hundred feet wide at the widest, is crossed and recrossed by the meandering stream, and along its sides at the lower levels terraces representing former positions of the floor are evident. White Creek, owing to its mineral nature, has formed a hard cemented pavement of the stream gravel and has left terrace cappings of hard conglomerate along its sides. The low hills at the head of Pleasant Valley on either side of Los Gatos Creek are distinctly terraced at different levels and capped with coarse deposits of stream wash.

Waltham Creek.—Waltham Creek, a few miles south of Los Gatos Creek, enters Pleasant Valley near Coalinga. It rises in the heart of the Diablo Range as the main drainage feature of Waltham Valley, which is a broad structural depression with low interior relief between the two main spurs in this part of the range, namely, Juniper Ridge and the ridge farther west that forms the watershed between San Joaquin Valley and the area that drains directly to the ocean through the Salinas Valley. The main forks in the upper portion of Waltham Creek run southeast. At the edge of the area shown on the map the stream leaves the open Waltham Valley and enters Alcalde Canyon (at the point shown in Pl. V, *A*) through a sharp gorge cut to a depth of 800 or 900 feet across the sandstone and shale strata forming Juniper Ridge and Curry Mountain. Thence for 3 or 4 miles the canyon extends toward the west as a curving gorge with steep sides and graded floor, in places several hundred feet wide, and then turns abruptly northeast and opens out in the foothill belt into a straight, wider valley. The straight course of this lower portion of Alcalde Canyon is continued backward as a belt of low relief along the southeast end of Curry Mountain, but instead of coming from this apparent structural continuation of the lower part of its course the stream has cut the gorge already mentioned across the higher area to the north.

Jacalitos Creek.—The next stream to the south is Jacalitos Creek, which is only a few miles from Waltham Creek and like it rises on the slopes surrounding the Waltham Valley line of depression, flows southeastward in that depression, cuts a canyon directly out into the foothill belt, and flows northeast to the plain in a broad, low, fairly graded valley. It joins Los Gatos and Waltham creeks in Pleasant Valley. A portion of its tributary, Salt Creek, is shown in the foreground in Plate II, *B*.

Avenal Creek.—The southernmost stream in the district is Avenal Creek, which flows southeastward in a canyon between Castle Mountain and Avenal Ridge and follows a well-graded course through the wide McLure Valley. Above the head of the valley it follows a ravine between Avenal Ridge on the southwest and a low ridge of knolls that forms a continuation northwestward of the Tent Hills, this ravine being along the contact between the Cretaceous beds and the middle Miocene (Santa Margarita?) white shale. (See Pl. IX, *A*.)

The structural axis of the McLure Valley is farther east and marks the course of a minor stream. Avenal Creek breaks eastward across the row of hills mentioned, to enter McLure Valley, as may be seen in the middle distance in Plate IX, *A*. On the east side of McLure Valley it passes out through Dagany Gap, and thence its drainage course extends over Kettleman Plain and across the line of uplift of the Kettleman Hills through Avenal Gap, becoming lost on the floor of the great valley beyond. It is said that Avenal Creek has been known within comparatively recent years to drain around the southern end of the Kettleman Hills.

Other main streams.—Zapato, Canoas, Garza, and Big Tar creeks are parallel and similar streams that cut V-shaped canyons through Reef Ridge and flow in fairly straight, low, open valleys across the foothills to Kettleman Plain. The canyons in Reef Ridge are sharp and deep and form marked features of the topography, as illustrated in Plate VIII. The drainage courses of the first three streams join and pass to the San Joaquin Valley through Polvadero Gap. Big Tar Creek drains southward down the Kettleman Plain and out through Avenal Gap. Stream terraces, as shown in Plate IV, *A*, have been formed along the courses of some of these streams.

Minor drainage courses.—In addition to a number of main forks toward the head of the streams already mentioned, which have courses similar to the main streams, there are a great number of minor drainage lines of different character that either pursue independent courses to the edge of the plain or form tributaries at right or nearly right angles to the main streams. In places these in turn are entered at sharp angles by tributary gulches of considerable size, but ramifications of a higher order have rarely developed above the stage of swales or steep gullies. In the mountains and higher hills the minor drainage courses are for the most part sharp V-shaped canyons and arroyos. In the more gently sloping hills they are open ravines with rounded contours. On entering the plain these streams cut sharp channels in the soft filling of the valley, as shown in Plate XII, *A*.

PHYSIOGRAPHIC DEVELOPMENT.

FACTORS INFLUENCING DEVELOPMENT.

The most apparent feature of the topography on the eastern flank of the Diablo Range is its reflection of the structure of the formations, the controlling factor in the development of the physical features having been the folding and faulting of the strata. The broader features of the relief as well as a large proportion of the minor ones have been formed in accordance with the structure. A further factor, the differences in the rocks, especially in degree of induration, has played an important part in regulating the rate at which development has taken place and in modifying the forms due to structural features.

The climate likewise has acted as a modifying factor in the weathering of the strata and as a cause of local variation in the processes of erosion.

The chief processes by means of which physiographic change has been brought about have been orogenic movements, aqueous erosion, and aggradation. A further process of importance, sufficient to warrant mention, is gravitational degradation, especially by means of landslides, which are numerous in the somewhat incoherent strata of this region. Forces producing changes of elevation, both broadly and locally, have been continually active up to late geologic time and have left no areas unaffected, and the progress of every physiographic change begun within the late Tertiary and the Quaternary periods has been complicated by modifying movements.

HISTORY OF PHYSIOGRAPHIC DEVELOPMENT.

Some of the broad physiographic changes of early periods in this region will be outlined in the discussion of the geologic history. In the present connection the evolution of the topographic features during the period subsequent to the first great movements of the Quaternary will be taken up. These movements took place at the close of the period represented by the Tulare formation, which comprises the youngest strata of the region that are markedly displaced from their original horizontal attitude. The movements were probably contemporaneous with those occurring in the early Quaternary along the California coast and were long continued. They brought about the uplift and tilting of all the post-Eocene formations, which up to that time had probably not been severely disturbed, and caused the older strata to be upheaved in the axis of the mountainous belt, which had been previously determined and over which processes of degradation had been at work in earlier periods. The mountains were thus given pronounced relief and their topographic youth was renewed. The later Tertiary and early Quaternary deposits, as yet in large part incoherent strata, were raised on the flanks of the mountains and probably locally on the crest. With this uplift came acceleration of the erosional processes. The old streams began to flow with greater vigor, to cut their valleys deeper into the mountains, and to extend them farther and farther outward upon the strata that were being lifted up out of the plain. The uplift was so gradual that these streams, and the others which began forming down the slope of the blocks that were being tilted, planed off large portions of the lower areas almost as fast as they were lifted, and were able to keep their course across lines of relief that were raised beneath them. The main preexistent streams probably followed the old structural lines that form the main valleys at present, such as those of Los Gatos and White creeks, Waltham Creek, and Avenal Creek.

The streams that were formed subsequent to the first of these movements, tributary to the main streams that followed the structural lines, were consequent upon the structure, in that they took their course down the dip slopes determined by the new movements. They thus became fixed in courses at right angles to the main valleys, and in turn they themselves acquired tributaries at right angles that were determined by the strike of soft zones of strata. In this way the present topographic forms both in the mountains and foothills were eventually developed in accordance with the folds and the stratification.

It can not be stated whether the process of uplift was continuous or whether one or more periods of quiet intervened, allowing part of the planation to take place during periods when no movement was affecting the region. As the movements continued the partly planed surfaces were warped along the axes of disturbance and new cycles of erosion commenced to affect them. The appearance of the surfaces so tilted in the foothill region has been mentioned. They reflect the major anticlinal and synclinal folds and their plunges. It can not be said, however, that all such remnants of surfaces of planation are relics of the erosion that took place in the Pleistocene. There are many that are older, especially in the mountainous belt. The slopes that have been mentioned on the eastern flank of Juniper Ridge and extending down into the Alcalde Hills give a good illustration of the preservation of the pre-Miocene surface of the Cretaceous rocks, and of the early Miocene surface of the beds locally preserved as a little-disturbed capping over them.

During the latter part of the Quaternary, and perhaps during most of it, the main synclinal troughs in their more depressed portions have acted as basins for receiving much of the large amount of material worn from the higher regions. They have thus become aggraded into wide, almost level plains, such as Pleasant Valley, Kettleman Plain, McLure Valley, and the great San Joaquin Valley. The smaller valley bottoms have also been aggraded to some extent, as in the case of the lower portions of Alcalde Canyon, the valley of Los Gatos Creek, and some others of the larger streams, but the filling is not so deep as in the main valleys, and the majority of the small stream courses are not filled. The latter fact, taken with the occurrence of stream terraces at various levels (such as shown in Pls. IV, *A*; IX, *A*; and XI, *A*) and of bluffs due to undercutting along stream banks, indicates that most of the streams are actively engaged in eroding their valley bottoms, the cause probably being the continuance of upward movement along the already existent belt of topographic relief.

The general stage of development of the topography is youthful, although some areas, especially in the foothill belt, have reached an advanced stage of youth approaching maturity. The course of physiographic development in the mountains and in the foothills has been similar, and the resulting type of topographic features due to the reflection of the structure is much the same. But modifications of the type have been caused by other factors, especially the difference in hardness and compactness of the strata in the two regions. In the mountains the Cretaceous strata which cover most of the region are well indurated and fairly homogeneous. The development has therefore been retarded, has been more even, and is now in a youthful stage. In the foothills the formations are largely soft, but are of various degrees of induration. Erosion has been rapid and has been able to gain a strong foothold along certain zones. In consequence, the features of certain parts of the hills, especially in the southern portion of the Kettleman and Kreyenhagen hills and along the soft zones elsewhere, are well worn and have an old appearance. The reason for the greater amount of wear to which the foothills in the southern portion of the Coalinga district have been subjected may be that the streams flowing off the Diablo Range were during much of the Quaternary period concentrated on that portion of the region by following a course southward along the synclinal depression of the present Kettleman Plain, being later directed into their modern channels by a warping across the northern portion of the Kettleman Plain determining the drainage divide in the plain and the rise of the anticline in the north-central part of the Kettleman Hills. It may be supposed that the streams wore down the southern portion of these hills as they were being uplifted, and cut the present Avenal Gap. The other similar gaps in the Coalinga anticline uplift, however, must be explained, and it is difficult to see how the streams on the north could have formed these gaps otherwise than by following their original courses continuously throughout the period of uplift. A possible hypothesis in explanation of the progressively greater amount of degradation that has taken place southward within the district is that a general tilting took place after the main original movements, causing the whole region to slope southward as it does at present. The mountains decline in height from the San Carlos division toward Antelope Valley, as has been brought out elsewhere; the foothills and the plains do the same, and the drainage, even where not determined by the main structural axes that plunge toward the southeast, has a predominant southeasterly course. The movement producing such a regional tilting, either through progressively greater depression toward the south or through uplift toward the north, might have been of similar nature to that occurring in former periods which caused the thickening and greater completeness of all the post-Eocene formations toward the south as compared with their continuation toward the north.

GEOLOGY.

GENERAL STATEMENT.

The eastern slope of the mountains bordering the San Joaquin Valley is formed by strata of great thickness dipping toward the valley. The oldest rocks exposed appear in the axis of the mountain range at the base of the monocline, and thence eastward successively younger formations appear as the edge of the valley is approached. The different formations that may be recognized as units in this series, with the time divisions to which they correspond, are as follows, from the oldest to the youngest: Franciscan (Jurassic?), Knoxville (Lower Cretaceous), Chico (Upper Cretaceous), Tejon (Eocene), Vaqueros (lower Miocene), Santa Margarita (?) (upper middle Miocene), Jacalitos (early upper Miocene), Etchegoin (uppermost Miocene), Tulare (Pliocene and early Pleistocene), and Quaternary alluvium and terrace deposits. These formations, with the exception of certain igneous and metamorphic rocks associated with the Franciscan, are of sedimentary origin. With the exception of the greater portion of the Pliocene and Quaternary and of minor amounts of the earlier Tertiary deposits, these sediments are marine. They indicate that the greater portion of the area included within the Coalinga district was beneath the sea during periods occupying probably the major portion of the time from the Jurassic to the end of the Miocene. Yet the unconformities separating all of these formations from one another show that intervals occurred during which no sediments were deposited, and that even with the enormous thickness of strata that is preserved the record is by no means complete. In general it is more complete in the southern than in the northern portion of the district, and most of the maximum thicknesses given are based upon the occurrences there. The record generalized in the columnar section may be more complete than the number of unconformities would seem to indicate, since probably not all are present in all parts of the district.

The accompanying columnar section (fig. 2) gives a generalized résumé of the lithologic character, relations, and maximum thickness of these formations as they appear in various parts of the Coalinga district. It can not, however, convey a conception of the variation of the formations in different parts of the district, which the descriptions of them that follow show to be a characteristic feature. Much detailed field work and paleontologic study have still to be accomplished before a final adjustment of the complex problems of correlation of the formations within the Coalinga district may be reached. The table on page 48 summarizes what is known of the age of the formations of the district and their time relation to the formations in other portions of the Coast Ranges.

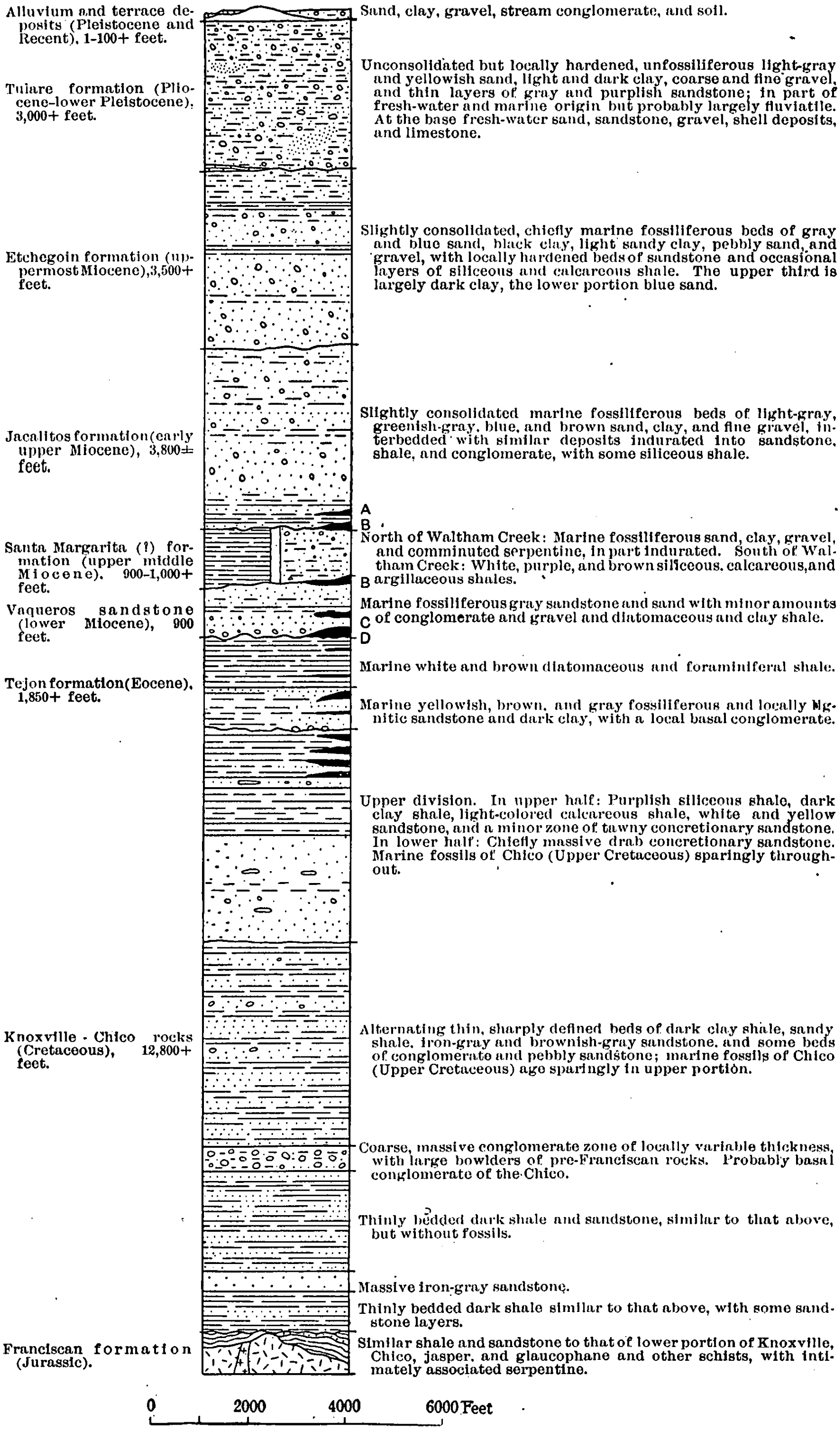


FIGURE 2.—Generalized columnar geologic section of the sedimentary rocks of the Coalinga district. Oil zones shown in solid black. Letters A, B, C, D at right of section indicate oil zones, so designated in text.

Tentative correlation of formations of the Coalinga district with the standard California Coast Range section and with those of other localities in California.

Era.	System.	Series.	Standard Coast Range section.	Coalinga district section.	Santa Maria district section.	Santa Clara Valley (Ventura County) section.	Los Angeles and Puente Hills section.	Santa Cruz Mountains section.
Cenozoic.	Quaternary.	Recent.	Alluvium.	Stream conglomerate and alluvium.	Alluvium.	Alluvium.	Alluvium.	Alluvium.
		Pleistocene.	San Pedro. —Unc.—	Stream deposits, valley fillings, and raised beach. —Unconformity—	Terrace deposits and dune sand. —Unconformity—	Terrace deposits, sand, and gravel. —Unconformity—	Terrace deposits, sand, and gravel. —Unconformity—	Terrace deposits, sand, and gravel. —Unconformity—
	Tertiary.	Pliocene.	—Unc.— Merced. San Diego.	Tulare. —Unconformity—				Merced / Santa Clara.
		Miocene.	San Pablo. —Unconformity (?)— Santa Margarita. —Unconformity— Monterey. —Unconformity—	Etchegoin. —Unconformity— Jacalitos. —Unconformity— Santa Margarita (?). —Unconformity— Lacking (with possible exception of a small part).	Fernando. —Unconformity— Monterey.	Fernando. —Unconformity— Modelo. { Shale. Upper sandstone. Shale. Lower sandstone.	Fernando. —Unconformity— Puente. { Upper shale. Sandstone. Lower shale.	Purisima. Santa Margarita. —Unconformity— Monterey. —Unconformity—
			Vaqueros. —Unconformity—	Vaqueros. —Unconformity—	Vaqueros.	Vaqueros.		Vaqueros.
		Oligocene.	San Lorenzo. —Unconformity (?)—	Wanting (?).	Sespe and Tejon, undifferentiated.	Sespe. { Upper beds. Red beds. Lower beds. Topatopa.		San Lorenzo. —Unconformity (?)— Undifferentiated Eocene, probably Martinez.
		Eocene.	Tejon. Martinez. —Unconformity—	Tejon. —Unconformity—				—Unconformity (?)—
Mesozoic.	Cretaceous.		Chico. —Unconformity— Horsetown. —Unconformity— Knoxville. —Unconformity—	Chico. Knoxville. —Unconformity—	(?) Knoxville. —Unconformity—			Chico. Knoxville. —Unconformity—
	Jurassic (?).		Franciscan. —Unconformity— Granitic rocks, schist, etc. —Unconformity—	Franciscan.	Franciscan.	—Unconformity— Granitic rocks, gneiss, etc.	—Unconformity— Granitic rocks, gneiss, etc. —Unconformity—	Franciscan. —Unconformity— Granitic rocks. —Unconformity—
	(?)		Schist; limestone.				Black schist.	Schist; limestone.

ROCKS IMPORTANT WITH RELATION TO PETROLEUM.

The strata older than the upper part of the Cretaceous are of little importance in this district in connection with the occurrence of petroleum. The uppermost Chico (Upper Cretaceous), Tejon (Eocene), and Vaqueros (lower Miocene) are the principal sources or reservoirs of the oil, and therefore of prime importance. The Santa Margarita (?) (upper middle Miocene) and Jacalitos (early upper Miocene) are petroliferous only at their base, and their higher beds together with those of the Etchegoin (uppermost Miocene) are the strata which overlie the oil sands and through which the wells are drilled, so that their relation, thickness, character, and structure have an important bearing upon the problem of accessibility of the oil and are worthy of detailed study. The Tulare (Pliocene-lower Pleistocene) is of less direct importance in this connection, but aids in throwing light upon the structure and the relation of the different formations.

ECONOMIC DEPOSITS OTHER THAN PETROLEUM.

The present report does not aim to discuss fully any of the economic deposits except petroleum.

The vicinity of Coalinga was known for its coal deposits before its rich oil resources were discovered, and an attempt was made many years ago to mine the coal. Two mines were started on the west side of Pleasant Valley by the San Joaquin Valley Mining Company, but the enterprise proved unprofitable. The coal is lignitic and occurs in thin local beds varying in thickness up to a foot or two. The lignite is usually crumbly and grades into seams of carbonized wood. It is interbedded with extremely varied gypsiferous sand and clay in the Tejon formation (Eocene), which is characterized by coal deposits at various other points in California.

There is a large quantity of gypsum in the Coalinga district. All the Tertiary formations are extremely gypsiferous and local seams of gypsum are present in the Cretaceous rocks as well. It usually occurs in the form of thin platy crystals filling joint cracks or occupying spaces along the bedding planes, or as crystal masses occupying irregular cavities. It is frequently so abundant that it permeates throughout certain beds, and either forms a hard cement for the original material or makes up almost the whole of the bed. Such deposits are of practically no economic value, owing to the impossibility of getting the material in a pure state. Gypsum likewise occurs locally in efflorescent surface deposits of soft white gypsite, as on the surface of the Tejon (Eocene) formation on a point of the hills at the edge of Pleasant Valley about 5 miles northwest of Coalinga and on the surface of the Vaqueros sandstone (lower Miocene) just east of Oil Canyon, 8 miles due north of Coalinga. An analysis of material from the former locality, made by R. C. Wells, of the United States Geological Survey, showed it to contain 71.6 per cent of calcium sulphate (equivalent to 42.2 per cent SO_3) and 0.8 per cent of silica. These deposits have been mined on a very small scale, but they are not extensive. The gypsum of the Coalinga district and the surrounding regions is discussed in a paper by F. L. Hess on the gypsum deposits of California, issued as Bulletin 413 of the United States Geological Survey.

SEDIMENTARY FORMATIONS.

FRANCISCAN FORMATION (JURASSIC?).

GENERAL DESCRIPTION.

The central portion of the Diablo Range is occupied by an old and for the most part much altered formation that is in every way similar to the well-known Franciscan formation of other parts of the State. It comprises the oldest rocks here exposed, as it antedates the Knoxville (Lower Cretaceous), but further than this little can be said regarding its age. There is no definite fossil evidence of the age of the Franciscan elsewhere, and in this region none has been found, but from evidence obtained in various places in the Coast Ranges the formation is believed to be certainly pre-Cretaceous.

The areas covered by the Franciscan formation are easily recognizable, as they are characterized by typical rocks and topography. The most characteristic feature of these areas is the invariable presence of serpentine, which is associated with the formation and is usually classed and described with it owing to its intimate relationship, although it is in reality intrusive in the sedimentary rocks, and therefore later in age. The original sedimentary rocks, which are sandstone, shale, and jasper, occur in detached areas and are greatly disturbed. They are intermingled in a complex way with glaucophane, actinolite, and other schists, serpentine, and other metamorphic rocks, and one area of soda-bearing hornblende syenite is shown on the map. In the portion of the Coast Range within and bordering the Coalinga district the metamorphic rocks of the Franciscan formation greatly predominate over the unaltered. In the small area of Franciscan rocks in the northwest corner of the region the alternating beds of sandstone and shale closely resemble the strata in the lower portion of the Knoxville-Chico and are difficult to separate from them. If a larger portion of the Franciscan areas were covered by these unaltered rocks the formation would not be as easily distinguishable as it is stated to be at the beginning of this paragraph. In fact, the dividing line between the Franciscan and Knoxville-Chico has been drawn arbitrarily, and it will require further work to discover their true relations. It is possible that some of the dark shale and sandstone strata that appear at the base of the Knoxville-Chico in other parts of the district, which have not been distinguished from that terrane owing to the absence of associated metamorphic rocks, may belong to the Franciscan, but the presence or absence of associated metamorphic rocks has been assumed as a basis of distinction between the formations.

The Franciscan beds in the northwestern corner of the district are chiefly sandstone. This rock is hard, gray, of medium coarseness, and somewhat thinly bedded and laminated so that it breaks into flat angular fragments. In places it appears to have undergone a process of alteration into a more quartzitic variety or to have been given a banded or flaky texture, as the result of crushing and elongation of the grains. The sandstone is interbedded with dark, fine-grained, thinly laminated clay shale, the laminæ of which are in places curved and smoothed as if by crushing. These rocks are exactly similar to those of the Franciscan farther north, in the mountains south of San Francisco Bay. Intimately associated with these beds are bluish glaucophane-bearing and micaceous schists in small patches. Jasper of green and variegated colors and both massive and banded structure is interbedded with the sandstone and shale in huge lentils. It was not observed within the area mapped, but forms striking outcrops farther west, especially in a group of picturesque buttes toward the head of Jacalitos Creek.

The serpentine covers a much larger area and extends far beyond the limits shown on the map, over a continuous stretch of high mountain country. The area that could be observed from the region at the head of Joaquin Ridge was estimated to be at least 40 square miles, and it is thought to be much more extensive. The Franciscan formation and associated rocks are considerably mineralized and contain deposits of cinnabar, asbestos, and the newly described gem mineral benitoite.[a]

IMPORTANCE WITH RELATION TO PETROLEUM.

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

KNOXVILLE-CHICO ROCKS (CRETACEOUS).

GENERAL DESCRIPTION.

The next to the oldest terrane exposed in the Coalinga district is a thick series of strata of sandstone, shale, and conglomerate overlying the Franciscan formation and covering a wide belt for the

[a] Louderback, G. D., Benitoite, a new California gem mineral, with chemical analyses by W. C. Blasdale: Bull. Dept. Geology Univ. California, vol. 5, July, 1907, pp. 149-153. Also Arnold, Ralph, Notes on the occurrence of the recently described gem mineral benitoite; Science new ser., vol. 27, Feb. 21, 1908, pp. 312-314.

most part west of the foothill region. It forms the high ridges bordering the Coalinga district on the west and may be easily recognized by the dark, thinly bedded, compact shale and sandstone of its lower portion and the massive drab concretionary sandstone of its upper portion. These strata are of Cretaceous age and comprise part or all of the two formations well known elsewhere on the west coast as Knoxville (Lower Cretaceous) and Chico (Upper Cretaceous). Owing to the insufficiency of fossil or stratigraphic evidence as yet obtained in the Coalinga district to form the basis for a separation between these two formations, they are mapped and described together for the present.

The Horsetown formation, which forms the middle portion of the Cretaceous in the standard Coast Range section, is not known to be represented in the Coalinga district, although it is not impossible that a portion of the great thickness of nonfossiliferous Cretaceous strata may be the equivalent of this formation. No evidence, however, has yet been found of its presence in this portion of the Coast Ranges.

A conservative estimate places the total thickness of the strata mapped as Knoxville-Chico at 12,800 feet. The maximum thickness is probably much greater. This succession of strata may be divided lithologically into three main divisions. The total thickness of the middle and upper divisions, which are probably to be referred together to the Chico formation, is at least 9,500 feet. A thickness of 8,300 feet is measurable in single sections, and even greater thicknesses may be found in single sections of the Knoxville-Chico as a whole. It is likely that at least two unconformities separating the Knoxville-Chico beds into important stratigraphic groups will be made out on further study. Their relation likewise to the Franciscan below will in all probability be found to be an unconformable one. They are overlain unconformably by the Tejon (Eocene) and the later formations.

The Knoxville-Chico areas were not studied in detail, but it is thought best to record such partial information as has been obtained as a guide to future work. The line of separation of the lower and upper divisions—that is, the line of the conglomerate zone to be mentioned—is shown roughly on the geologic map (Pl. I) along the flank of Juniper Ridge and Curry Mountain. The line between the middle and upper divisions is shown on both arms of the White Creek syncline, being marked on the south arm by the Los Gatos Creek fault line.

LOWER DIVISION.

DISTRIBUTION AND CHARACTER.

A zone of coarse conglomerate varying in thickness from less than 100 to over 1,000 feet extends intermittently from the summit of Juniper Ridge south of Los Gatos Creek to a point south of

Reef Ridge in Big Tar Canyon. It is overlain and underlain, in appearance conformably, by the thin-bedded dark shale and sandstone of the lower half of the Knoxville-Chico. The portion of the terrane lying below this conglomerate is here classed by itself as the lower division. The strata of this division are well exposed in the upper portion of Alcalde Canyon and on Juniper Ridge to the north and Curry Mountain to the south. There a thickness of at least 2,000 feet of alternating thin beds of grayish-black shale, shaly sandstone, and fine sandstone of a dark-gray color underlies the conglomerate. At the base of these predominantly shaly beds there is an abrupt change in the rocks to massively bedded sandstone which forms the prominent ridge of Curry Mountain and the southern end of Juniper Ridge at the western edge of the mapped area, as shown in Plate V, *A*. This sandstone is iron-gray, hard, homogeneous, of medium grain, and only rarely pebbly, and has a thickness of about 300 feet. Below it, on the west side of the ridges mentioned, on the steep flank represented in the center of Plate V, *A*, outside of the mapped area, similar shale beds to those above the sandstone begin abruptly and make up a thickness of at least 600 feet. How much more there may be is not known, as the series was not examined, but it is thought that the lowest beds in the Knoxville-Chico in this section can not be much more than 800 to 1,000 feet below the sandstone of the ridge. Thus the total thickness of the lower division as exposed in the Alcalde Canyon section is between 3,100 and 3,500 feet. The base of the lower division is not known to be exposed anywhere within the area shown on the map, nor is any portion of the division known elsewhere than in the vicinity referred to and in the region south of Reef Ridge below the conglomerate near the head of Big Tar and Garza creeks. In that region a complex mingling of rocks of doubtful ages occurs, among which some, such as dark-blue clays and red shales, are not similar to others known in the district. These rocks are supposedly of Cretaceous age, and are so mapped.

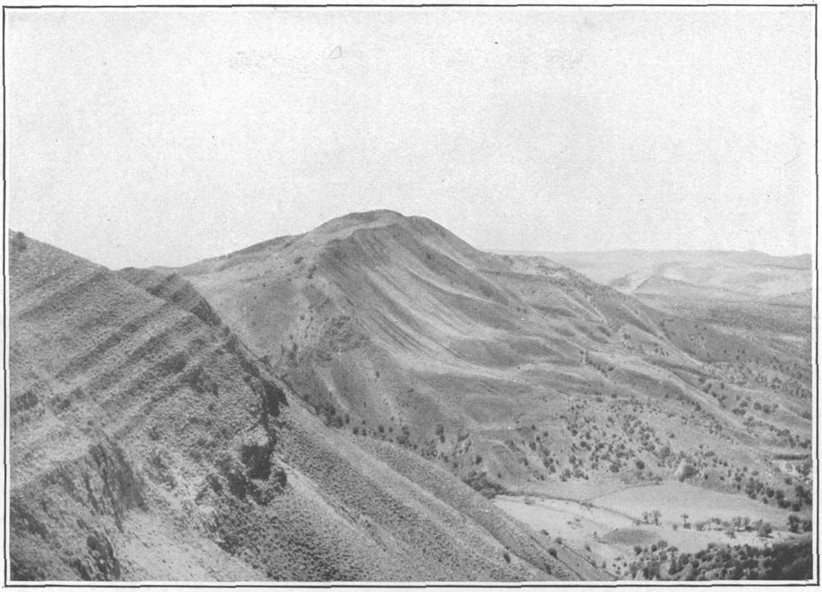
EVIDENCE OF AGE.

Fossils of Knoxville (Lower Cretaceous) age, such as *Aucella crassicollis* Keyserling and *Belemnites impressus* Gabb, have been found in beds of dark shale in the Devils Den region not many miles south of the Coalinga district, and there is little doubt that the lower division of the rocks here described as Knoxville-Chico is at least in part the equivalent of the Knoxville formation. It is possible that the great beds of conglomerate mark the base of the Chico or Upper Cretaceous and that the whole of the lower division below this line of separation represents the Knoxville formation.

MIDDLE DIVISION.

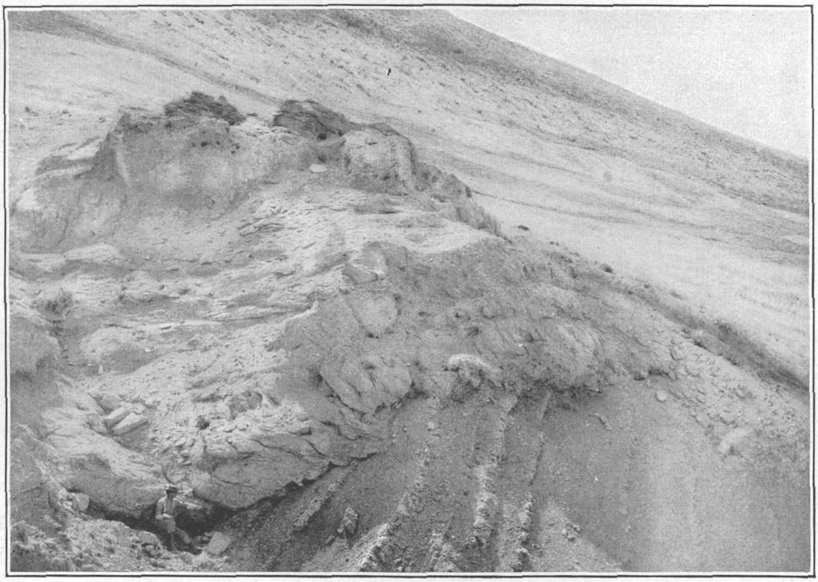
DISTRIBUTION AND CHARACTER.

The middle one of the main divisions into which the Knoxville-Chico rocks are divisible upon lithologic grounds comprises a thick series of alternating thin beds of dark shale and sandstone with the above-mentioned heavy conglomerate at its base, and with the characteristic massive, concretionary sandstone beds that form the upper division overlying. Its thickness, including the conglomerate zone, measures at least 4,800 feet in the Alcalde Canyon section and considerably more farther northwest on the flank of Juniper Ridge, because in the former section the upper portion is covered up by the overlapping Miocene and the full thickness can not be measured. The conglomerate is locally extremely variable and is not continuous. It may in places be traced directly into massive sandstone or even into thinly bedded sandstone and shale, as along Alcalde Canyon between 2 and 3 miles west of Alcalde. It represents throughout the district, however, an important stratigraphic horizon characterized by a coarsening of the sediments. On the northeast side of Alcalde Canyon and again about 4 miles south of the confluence of Los Gatos and White creeks it is a deposit of extremely coarse and well-hardened conglomerate 200 to 300 feet in thickness. Near the head of Big Tar Canyon, at the west edge of the mapped area, a thickness of 1,200 feet or more of coarse, hard conglomerate occurs within the Cretaceous shale, probably at the same position in the series. In this vicinity it runs out of the area shown on the map and does not appear within it again south of Curry Mountain. The dark shale above it is continuous along the southwest side of Reef Ridge and the conglomerate probably continues likewise. The thin-bedded shale and sandstone of the middle division are well exposed in the lateral ridges of Joaquin Ridge south and east of the serpentine area, and a heavy zone of massive conglomerate exposed near the head of White Creek may be the equivalent of the basal conglomerate elsewhere. The rocks of this division cover most of the north and northeast flanks of Juniper Ridge and Curry Mountain. South of Curry Mountain there is no evidence of the relations of the different members of the Knoxville-Chico such as is exposed farther north, the Cretaceous being covered up unconformably by the Miocene beds southward to Jasper Canyon. On Reef Ridge south of Jasper Canyon the upper portion of the Knoxville-Chico is lacking, and there is little direct evidence to indicate how large a portion is absent. The dark thin-bedded shale and sandstone of Reef Ridge may, however, be correlated with fair assurance with the middle member of the Knoxville-Chico farther north, because it is similar in lithologic character and because it is underlain in the region of Big Tar Canyon by the great



A. WESTERN FACE OF CURRY MOUNTAIN, FORMED BY CRETACEOUS STRATA.

Probably a fault scarp. Looking south across Waltham Creek, which cuts through ridge on left; Waltham Valley on right and crest of Diablo Range in distance. Photograph by Ralph Arnold.



B. UNCONFORMITY BETWEEN TEJON FORMATION AND VAQUEROS SANDSTONE.

The petroleum migrates from shales below and collects in sand and gravel above to form oil zone D. In canyon of Laval grade, 8½ miles north of Coalinga. Photograph by Ralph Arnold.

conglomerate zone before mentioned. The Cretaceous strata on Avenal Ridge are thought to belong chiefly to the middle division.

EVIDENCE OF AGE.

The beds of the middle division are for the most part nonfossiliferous, but here and there a few fossil mollusks are to be found in thin beds of conglomerate or scattered through the shale and sandstone. The fossils that have been obtained from this division of the Knoxville-Chico are listed under localities 4, 5, 6, and 10 (p. 60). Locality 11 is probably also in this division and locality 9 is possibly so. Among the fossiliferous beds of which the horizon has been stratigraphically determined those of localities 5 and 6 are the lowest, being about 2,000 feet below the top of the division, and the fossils prove the Chico or Upper Cretaceous age of the beds at least as far down in the terrane as this. As no break seems to occur in the middle division the whole is probably referable to the Chico, and the basal conglomerate the indication of a great time break between these beds and those of earlier Cretaceous time.

UPPER DIVISION.

DISTRIBUTION AND CHARACTER.

The uppermost of the three divisions of the Knoxville-Chico is predominantly concretionary sandstone in the lower part and shale in the upper part, and has a thickness of at least 4,700 feet. It is not known to be exposed in any but the northern portion of the district. It is separable into several members which show diversity of lithologic character, but no evidence points to any but a conformable relation between these members. On the contrary, the seeming intergradation between them and the recurrence at different horizons of peculiar types of deposits—such, for instance, as the concretionary sandstone—indicates continuity of deposition. Taken as a whole the upper division is strikingly distinct from other formations in the district and seems to represent a separate stratigraphic unit, although no unconformity has been made out at its base.

The lower half of the upper division consists chiefly of massive sandstone beds, often weathering cavernous, that stand out prominently and display the structure on the sides and tops of the ridges north of Los Gatos Creek and west of Coalinga. The sandstone is usually drab, medium grained, and not very hard. The rocks of this division may be easily recognized by these characteristic outcrops and by the numerous large, hard reddish-brown concretions of which the sandstone is full and which weather out and remain in patches upon the surface as shown in Plate IV, *B*. These concretions are of various forms, oval, round, flat, and lens-shaped, and of various unsymmetric shapes, and have a tendency, as noted by F. M. Anderson, "to split horizontally or to fall apart in concentric shells or laminæ." They vary from small sizes up to a thickness of 8 or 10 feet. The prominent sandstone strata are separated by softer beds and zones of sand and light-colored shale, which are poorly exposed. Thin seams of calcareous shale and sand are at some points interbedded with the softer beds. Locally the sandstone is conglomeratic. At the base of this member of the Knoxville-Chico the massive sandstone beds give place to thinner beds alternating with finer-grained sandstone and shale, and these grade over into the thin-bedded series described as the middle division. The transition takes place within a few hundred feet and in places a fairly sharp line can be traced between the beds that are chiefly sandstone and those in which the thin layers of fine grain predominate.

Above the succession of concretionary sandstone beds, and forming the upper half of the upper division of the Knoxville-Chico, comes a less prominent and less uniform succession of beds in which shale is predominant. These beds form the uppermost Cretaceous exposed within the Coalinga district and are only with difficulty separable from the overlying Eocene beds. This upper half of the upper division consists of two main members predominantly of shale, each approximating 1,000 feet thick, separated by a much thinner but more prominent member of concretionary sandstone, in general similar to that lower down. Both of the shale members form belts of low topography, whereas the intermediary sandstone forms a row of hills separating them.

The lower of the two shale members has few exposures but is notable for the presence in it of different kinds of deposits, such as blackish, thinly-bedded clay shale and yellowish and whitish calcareous and arenaceous shale and sand, and for the presence of *Ammonites*, *Baculites*, *Inoceramus*, and other fossils, which weather out in a fragmentary state on the surface of the clayey soil. According to a personal communication received from Mr. F. M. Anderson it is from this shale member that he obtained the fauna listed from "the yellow shales below the concretionary sandstones" in his paper on the Diablo Range.[a] This fauna is given on page 61.

The sandstone separating the two shale members varies from 200 to 300 or 400 feet in thickness and consists of yellowish-gray and brown sandstone full of large brown concretions. It is of the same type as the characteristic Chico concretionary sandstone farther down in the section, but differs slightly in that the outcrops have in general a more brownish aspect, and that the concretions are of larger average size and in many places have the character of elongated layers. This sandstone is without fossils so far as known. It occurs

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, 1905, p. 161.

typically on the 2,500-foot hill $1\frac{1}{2}$ miles northwest of Oil City, whence it is traceable northward beyond the northern edge of the area mapped and southwestward nearly to Los Gatos Creek.

The uppermost member is one of particular interest owing to its individuality among the known types of Cretaceous deposits, its large content of organic material, its petroliferous nature, and its similarity to the Eocene beds. It is at least 1,200 feet thick and consists principally of shale, but has a considerable admixture of sand and sandstone. For convenience it will be referred to as a whole as the purple-shale member. The most characteristic beds of this zone are of purplish-brown, fairly hard, thinly bedded, both siliceous and calcareous clay shale, in which the tests of Foraminifera are very abundant. This shale bears a resemblance to some of the less siliceous shale in the upper part of the overlying Tejon (Eocene), especially to that shale as it occurs in the southern part of this district, and is not unlike some argillaceous phases of the Monterey shale (middle Miocene) of the outer Coast Ranges and the shale mapped as Santa Margarita (?) (middle Miocene) along Reef Ridge and at other points in this district. It contains local thin, generally lenticular layers of grayish and yellowish calcareous shale and also large oval nodules of grayish-white limestone. These nodules are usually several feet in dimensions, and one was observed as much as 8 feet long and $2\frac{1}{2}$ feet thick. Seams of sandy shale and lenses of sand occur sparingly.

Purple shale such as that described is especially characteristic of the upper half of the member and forms a well-marked belt of low topography, and locally bare purplish slopes dotted with dark-green juniper and oak trees, at Oil City and both northeast and southwest of that place.

In the lower half of the member the shale is less markedly of the purplish type and ordinary grayish-black clay shale, like that below the underlying concretionary sandstone, is an important constituent. Most of the shale, however, has at least a trace of the purplish color and contains Foraminifera. Calcareous layers and lenses occur throughout. The beds are characteristically much crushed, filled with seams and veins of selenite along the small cracks, and traversed by irregular sandstone dikes. Somewhat irregular zones of whitish, yellowish, and grayish fine-grained sand and sandstone are interbedded with the shale in the lower part of the member. For the most part these are more varied than the sandstone characteristic of lower portions of the Chico, are more thinly bedded, and lack the large brown concretions. Some of the true concretionary sandstone is interbedded with the shale, however, and no sharp line of separation is to be drawn between the purple-shale member and the underlying concretionary sandstone. The contact is shown on the map (Pl. I) by the green line bounding the west side of the possible productive territory north of Los Gatos Creek.

Above the purple shale of the uppermost Cretaceous lie dark clay and clay shale beds aggregating several hundred feet in thickness, which appear to form an upward continuation of the shale of the Chico, but which are mapped with the Tejon (Eocene). Fossils recently found near the northern edge of the Coalinga district show that the higher of these beds belong with the sandstone of the Tejon above; but there is reason to believe that 200 feet or so of beds at the base belong in the Chico. Their inclusion in the Chico would make no appreciable difference in the mapping and for the present the line is drawn at the top of the purple shale, which is the only line that could be mapped with any approach to consistency. Whether the line of separation between the Cretaceous and Tertiary occurs at the top of the purple shale or somewhat higher, within the darker clay shale, it is noteworthy that it should occur within a zone of fine sediments and be marked by no break of evident stratigraphic importance.

However, in spite of the apparent transition between the shale of the Cretaceous and that of the Eocene in the northern part of the Coalinga district, it is believed that they are separated by an unconformity. The evidence of this is the progressive disappearance of the upper members of the Knoxville-Chico southward in the district, whereas the basal Tejon is believed to represent a fairly constant horizon. The upper half of the upper division of the Knoxville-Chico has been recognized only north of Los Gatos Creek, and south of Waltham Creek the whole of the thick concretionary sandstone terrane has disappeared likewise, the Tejon where next exposed south of Jacalitos Creek resting directly upon dark shales of a lower portion of the Knoxville-Chico. The beginning of the disappearance of the upper members of the Cretaceous is indicated by the gradual thinning of the purple-shale member at the top southwestward from Oil City until it is finally lost near Los Gatos Creek. This thinning and disappearance of the members is probably the effect of erosion upon them before the deposition of the Eocene.

In the preliminary report on the Coalinga district[a] the shale and interbedded sandstone here described as the uppermost member of the Chico (Upper Cretaceous) was treated as part of the Tejon (Eocene) owing to its similarity to and striking appearance of continuity with the beds of that age. The line between the Cretaceous and Eocene was arbitrarily drawn at the top of the concretionary sandstone immediately underlying this member. During the course of work done north of the Coalinga district by the junior author of the present paper and R. W. Pack in 1909 it was discovered that this shale zone is part of the Cretaceous, the fact being especially confirmed for the Coalinga district by the finding of Cretaceous fossils such as *Baculites* and *Hamites* in calcareous nodules in the purple shale

[a] Bull. U. S. Geol. Survey No. 357, 1908.

within one-half mile northwest of Oil City (on the west side of the SW. ¼ sec. 17, T. 19 S., R. 15 E.). The stratigraphic relations and fauna of this shale will be further discussed in a report that is in preparation on the territory north of the Coalinga district.

The beds here referred to as the purple-shale member of the Chico (Upper Cretaceous) were mentioned by F. M. Anderson in his first paper on the Diablo Range.[a] He considered them to represent the middle portion of the Eocene of this region and correlated them with the shale on Reef Ridge in the southern part of the Coalinga district, which was termed by him the Kreyenhagen shales and which is described in the present paper as the upper member of the Eocene. In a paper published subsequently[b] the purple-shale member was described as the lower shales in a fourfold division of the Eocene, the underlying concretionary sandstone, which outcrops typically on the 2,500-foot hill northwest of Oil City, being described as the lower sandstone and considered as the base of the Eocene. Higher beds than any here referred to the purple-shale member were included in F. M. Anderson's description, as is shown by the fact that Eocene fossils were stated to occur in this division.

The upper division of the Knoxville-Chico presents approximately the following section on Joaquin Ridge:

Section of upper division of the Knoxville-Chico rocks 10 miles north of Coalinga.

	Feet.
The purple-shale member: Petroliferous, purplish and blackish, foraminiferal, siliceous clay shale, with calcareous nodules; decidedly purple and siliceous in the upper part; more argillaceous and intermingled with whitish and yellowish sand and sandstone in lower part; overlain by clay and sand of Tejon (Eocene)	1,200
Hard golden-brown sandstone, largely made up of irregular elongated concretions, forms 2,500-foot hill northwest of Oil City	200±
Soft zone of whitish-gray and yellowish-gray sand and dark clay shale, with occasional thin layers of hard brown sandstone and hard calcareous shale; forms low topography, few outcrops, and loose, crumbly soil	1,000
Hard brown sandstone with large reddish-brown concretions of hard sandstone, interbedded with whitish and yellowish-gray sand full of small bullet-like concretions of gray sandstone	300
Light-colored calcareous shale	200
Hard brown sandstone with some large concretions, interbedded with much less prominent beds of yellow sand	300
Massive beds of fairly soft yellowish-gray sandstone full of large dark-brown concretions, forming outcrops such as that shown in Plate IV, *B*. Softer beds of sand and clay that do not outcrop are interbedded. This is the top of the typical massive concretionary sandstone of the lower portion of the upper division of the Knoxville-Chico	200
Chiefly massive yellowish-gray sandstone like the last, with several zones in which the concretions are abundant and with some conglomerate zones; forms rocky pinnacles; overlies thinly bedded shale and sandstone of middle division	1,300+
	4,700+

[a] Proc. California Acad. Sci., 3d ser., Geology vol. 2 1905, p. 163.
[b] Idem, 4th ser., vol. 3, 1908, pp. 13-14.

EVIDENCE OF AGE.

Fossils of Chico (Upper Cretaceous) age have been found by the writers at various localities in sandstone, conglomerate, and shale in this upper division of the rocks mapped as the Knoxville-Chico. Most of them are in a poor state of preservation. The following species, all believed to be characteristic of the Chico, have been found in the upper and middle divisions within the district:[a]

Chico (Upper Cretaceous) fossils from the Coalinga district.

Name.	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
PELECYPODA.											
Anomia lineata Gabb		×									
Anomia lineata? Gabb					×	×					
Arca vancouverensis Meek		×									
Avicula linguæformis Evans and Shumard										×	×
Inoceramus sp. indet.				×						×	
Mactra ashburneri Gabb			×								
Meekia sella Gabb			×								
Meekia sella? Gabb		×									
Nucula sp. indet.										×	
Pelecypod sp.	×										
Solen? sp		×									
Tellina? ooides Gabb			×								
Venus varians Gabb		×									
GASTEROPODA.											
Lunatia sp.			×								
Perissolax brevirostris Gabb				×							
Volutoderma gabbi (White)			×								
CEPHALOPODA.											
Ammonites[a]				×							
Baculites chicoensis Trask	×			×				×	×		
Pachydiscus n. sp.[a]							×				

[a] Fragments of indeterminate ammonoids have been found by several persons in the hills northwest of Coalinga.

1. Ten miles N. 27° W. of Coalinga, at elevation of 2,600 feet, on summit of long ridge north of Los Gatos Creek, in center of SW. ¼ sec. 15, T. 19 S., R. 14 E. About 1,000 feet stratigraphically above base of Chico concretionary sandstone series in a bed of conglomerate and pebbly micaceous sandstone.
2. Hills north of Los Gatos Creek; probably same locality as 1.
3. About one-fourth mile north of 1, on the same ridge. About 600 feet stratigraphically above base of Chico concretionary sandstone series in a conglomerate bed through massive sandstone.
4. On long ridge 3¾ miles north of junction of White and Los Gatos creeks, on north side of summit of 2,654-foot hill. Several hundred feet stratigraphically below base of Chico concretionary sandstone series in a coarse conglomerate through sandstone and shale.
5. Two miles north of White Creek, at elevation of 3,100 feet, one-fourth mile southeast of summit of 3,425-foot hill, southeast corner sec. 10, T. 19 S., R. 13 E. About 2,000 feet stratigraphically below base of concretionary sandstone series in a bed of pebbly sandstone through the shale series.
6. Two miles north of White Creek, at elevation of about 2,800 feet, on long ridge three-fourths mile south of 3,300-foot hill, east side of NE. ¼ sec. 14, T. 19 S., R. 13 E. About 2,000 feet stratigraphically below base of Chico concretionary sandstone series in a pebbly sandstone through shale series. Probably the same horizon as 5.
7. Hills northwest of Coalinga; locality indefinite. Specimens owned by J. H. Webb.
8. Float in creek 6 miles northwest of Coalinga, north of White Creek.
9. In Alcalde Hills, 3½ miles west-southwest of Coalinga in Anticline Canyon, central part of sec. 2, T. 21 S., R. 14 E. At contact of Cretaceous and Miocene in a thin bed of pebbly sandstone through thinly bedded sandstone and shale.
10. Alcalde Canyon, one-half mile southwest of Alcalde. In shale.
11. Head of Canoas Creek outside of the area mapped. About 1 to 2 miles east of the southeast end of Castle Mountain. In sandstone and shale.

The following additional species are reported by F. M. Anderson[b] from nodular limestone in the shales below one of the upper con-

[a] The fossils mentioned on p. 58 as occurring in the purple-shale member were found too recently to admit of their being listed here.

[b] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, p. 161.

cretionary sandstone zones of the upper division of the Knoxville-Chico at different points in the Coalinga region.

PELECYPODA.

Glycymeris veatchii Gabb+Pectunculus id.
Inoceramus whitneyi Gabb.

GASTEROPODA.

Architectonica sp.
Cinulia obliqua Gabb.
Gyrodes sp.

CEPHALOPODA.

Baculites sp.
Desmoceras sp., related to D. hoffmanni Gabb.
Lytoceras sacya Forbes.

The fossils prove the Chico age of the rocks throughout the upper division, leaving only a small thickness of strata at the summit, between the fossiliferous Chico beds and those containing Tejon (Eocene) fossils, of which the age is in doubt. These strata, which are at most a few hundred feet in thickness, might be either Chico or Tejon, or a transitional series corresponding in age to the Martinez formation in the vicinity of San Francisco Bay. A line of separation is drawn in the transitional portion on the basis of lithology, and it is believed that the beds below are with little doubt of Chico (Upper Cretaceous) age and those above, with the possible exception of 200 feet or so at the base, of Tejon (Eocene) age.

IMPORTANCE WITH RELATION TO PETROLEUM.

The purple-shale member of the Knoxville-Chico (Cretaceous) is of especial interest as the reservoir and presumably the source of the large amount of light oil that has been produced by the Oil City field. The wells obtain their oil from the sandy zones in the lower portion of the member and possibly in places also from the shale itself. The occurrence of petroleum in this formation affords the first instance known on the west coast of richly productive petroleum-bearing beds in the Cretaceous. The presence of oil may be detected in many places in the shale by the odor, especially in the calcareous layers and nodules, and it is not improbable that the purplish and chocolate-brown colors appearing throughout the member are due to petroleum staining. A seepage of light oil from the shale of this member within one-half mile northwest of the camp now called Oil City led to the first drilling for oil in the region and the consequent development of the Coalinga field. Another large seepage occurs near the forks of a canyon less than 2 miles northeast of Oil City (NW. ¼ sec. 9, T. 19 S., R. 15 E.).[a] There the oil is exuding from beds of dark clay in the middle of the clay zone already mentioned as overlying the purple-shale member. The beds at the horizon of the seepage are prob-

[a] Owing to an error in the engraving this seepage is shown one-fourth mile too far east on the geologic map (Pl. I).

ably in the Tejon (Eocene), but can not be far above the top of the Knoxville-Chico (Cretaceous), being, at most, within 400 feet stratigraphically above the top of the purple shale, from which the oil with little doubt comes. The seepage may be an indication of the horizon of the line of unconformity between the Cretaceous and Eocene.

No evidence of oil is known in the Knoxville-Chico strata at any horizon lower than the base of the purple-shale member. It is possible that traces of oil are to be found in them, as in most sedimentary rocks, but there is nothing to indicate that it will ever be discovered in this region in a quantity sufficient to make it of economic importance. No petroleum has been found by wells penetrating strata lower than the purple-shale member.

TEJON FORMATION (EOCENE).

GENERAL DESCRIPTION.

The formation mapped as the Tejon in the Coalinga district is made up entirely of sedimentary strata that dip toward the great valley in the monocline along the eastern flank of the mountains and are exposed on the surface in a narrow discontinuous belt between the Cretaceous beds which underlie them and those of the Miocene which overlie them. The beds so mapped have a thickness of 1,600 to 1,850 feet and are divisible into two main members of approximately equal thickness—a lower one consisting of sandstone in the southern part of the district and of dark clay shale and sand in the northern part, which is certainly of Eocene age, with the possible exception of a small thickness at the base, and an upper one of light-colored organic shale which affords few species of fossils and no conclusive evidence as to its age. This upper member may represent either Eocene or Oligocene time, but the facts that there seems to be a gradation from the beds of the lower member into those of the upper and that the two invariably occur together in this region favor its assignment to the Eocene. It is made up of thin beds of whitish and purplish siliceous, argillaceous, and locally calcareous shale, which is easily recognizable and which lends individuality to the formation. The shale is very similar, especially in some places, as north of Coalinga, to the siliceous shale of the formation along Reef Ridge that is described later as the Santa Margarita (?) formation, and the two must not be confused. It is also somewhat similar to the purple shale of the upper Chico. Where the Tejon formation is thick, shale and clay form a greater proportion of the whole than the sandstone, but a great local variation in the thickness of this member is noteworthy because due to the great unconformity between it and the overlying Miocene beds. A large portion of the formation had been worn away before the Vaqueros (lower Miocene) sandstone was deposited on its upturned surface. It is possible that an unconformity occurs within the beds mapped as Tejon at the base of the upper shale, but no discrepancy in dip between the beds of the two divisions has been found, and the succession of beds is seemingly continuous.

As already pointed out, an unconformity exists between the Chico (Upper Cretaceous) and Tejon (Eocene) beds, in spite of the facts that no sharp line of demarcation is to be drawn between the Tejon and the underlying Chico in the northernmost part of the district and that there appears to be a gradation from the beds of the former into those of the latter, as if they had been formed during a continuous period of sedimentation. In the southern portion of the district the Tejon overlies unconformably beds that belong to an earlier portion of the Cretaceous, either lower Chico or Knoxville, thus proving that a period of land conditions and orogenic disturbances preceded the Tejon.

Tejon group was the name applied by J. D. Whitney to the fossiliferous strata in the vicinity of Fort Tejon, Kern County, and Martinez, Contra Costa County, which were included by Gabb under his Division B, or Upper Cretaceous.[a] As the result of later studies the fossils of this formation are now considered to be of Eocene age. Strata of the same age occur extensively in the region of Carquinez Straits, east of Mount Diablo, and have been found at a number of different points along the western border of the San Joaquin Valley, notably at New Idria and in the region discussed in the present paper. It may therefore be said that in all probability an almost continuous belt of Tejon sedimentary rocks extends near the valley edge between Martinez and the type locality in Kern County, this formation composing an important middle member in the succession of terranes of which the easternmost mountain group of the Coast Ranges is built.

The rocks in this belt are chiefly of marine sedimentary origin and consist in the main of sandstone and shale. They are in many places such as to indicate a shallow-water or brackish-water origin, and lignitic seams are very characteristic.

The Eocene of the southern portion of the Diablo Range was described by F. M. Anderson, in his first paper[b] relating to this region, as made up of three members, namely, the Avenal sandstone at the base, the Kreyenhagen shales in the middle, and the Domijean sands at the top. The first two of these names were applied to the two members of the Eocene along Reef Ridge in the southern half of the Coalinga district. North of that region those members were correlated with the beds which have been above described as the upper concretionary sandstone and the overlying purple-shale member of the Chico (Upper Cretaceous). The third of these names was applied to

[a] Geol. Survey California, Paleontology, vol. 2, 1869, preface, p. xiii.
[b] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, pp. 162 et seq.

the Eocene sandstone near the Domengine ranch, just north of the Coalinga district, this sandstone being considered to represent an upper sandstone zone. In the present paper this sandstone is treated as the upper portion of the lower member, which is regarded as the correlative of the lower member in the southern part of the district. Although it may prove advisable to retain one or two of these names in future, the name Tejon formation is used in the present paper to include the whole succession of beds, for the sake of simplicity and to avoid confusion.

DISTRIBUTION AND LOCAL CHARACTER.

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

TEJON NORTH OF PLEASANT VALLEY.

In the northern region the Tejon is typically exposed in the hills directly north of Coalinga, in the vicinity of the camp called Oil City. The formation has a thickness of at least 1,850 feet where most completely exposed on the flanks of Joaquin Ridge, comprising a lower sandy and clayey member 850 feet thick and an upper organic shale member at least 1,000 feet thick.

The beds are markedly unconformable with those of Miocene age above, the unconformity being well displayed in the hills 8½ miles north of Coalinga and near the point pictured in Plate V, *B*. There the low-dipping and comparatively little-disturbed Vaqueros (lower Miocene) sandstone rests on the highly tilted, overturned, and fractured shale of the upper part of the Tejon. The unconformity is likewise evident in other portions of the hills, yet in places there is little variation in dip between the two formations, and the relation might be mistaken for a conformity if the contact were only locally observed. This fact illustrates the local nature of the phenomena in this region. Beds that were violently disturbed in one locality before the deposition of later sediments upon them may have been left comparatively little disturbed a short distance away, and little reliance is to be put in apparent conformities resulting from harmony in angle of dip between two formations.

The basal clay zone of the Tejon and its relation to the Cretaceous beds have already been mentioned in connection with the purple-shale member of the Chico. This zone comprises a thickness of about 700 feet and grades upward into a more sandy zone about 150 feet thick, the two together composing the lower member of the Tejon. The clay zone consists of blackish-gray, fairly compact fine-grained material and forms a massive, homogeneous deposit with inconspicuous bedding planes. It is on the border line between clay and shale but partakes more of the nature of clay. Considerable fine sand is intermingled, giving much of the clay a gritty character, and there occur occasional layers and lenses of fine sandstone. Tests and impressions of Foraminifera are abundant in this clay, but not so abundant as to cause it to lose its predominantly clayey nature or approach in character the more organic shale in the upper member of the Chico or the upper member of the Tejon of this region. Eocene fossils have been found in the upper portion of the clay zone just north of this district,[a] but as yet there is no certainty whether a small thickness at the base of the zone may not belong to the Cretaceous. At the top the clay grades almost imperceptibly into a very gypsiferous soft clayey sand which forms the upper 150 feet of the lower member. This sandy zone comprises alternating layers of varied character—light-gray sandy clay, dark clay, gray and yellowish sand locally hardened into sandstone, green sand, and hard white calcareous nodules. In places the beds are more hardened than elsewhere and calcareous sandstone predominates, giving the zone prominence. Tejon (Eocene) fossils have been found at a number of points in this zone, both in the sandstone and in the calcareous nodules.

The lower member of the Tejon is traceable southwestward nearly to Los Gatos Creek and is undoubtedly continuous beneath the alluvium with the belt exposed on the west side of Pleasant Valley. It becomes somewhat thinner in that direction and the lower clayey beds are not persistent as a distinct zone.

The upper member of the Tejon as mapped forms a prominent white belt from the region north of Pleasant Valley to and beyond the north edge of the district. Throughout the belt it has an exposed thickness of 400 to 1,000 feet, commonly about 700 feet. The variation is due to the erosion that took place before the deposition of the Miocene. It is probable that the complete succession of beds as originally deposited is nowhere exposed within this region. This member consists chiefly of white, siliceous, hard and brittle, thinly bedded diatomaceous and foraminiferal shale, interbedded with finely fractured, roughly bedded purplish-brown clayey shale, some fine and coarse sand, and thin calcareous shale layers. The typical siliceous shale is exposed in the overturned fold shown in Plate XIII, *A*, on the right in Plate VII, *A*, and with interbedded argillaceous shale in Plate V, *B*. The shale is locally variable in color, assuming different yellowish and reddish tints as the result of staining by petroleum. It contains an abundance of crystallized gypsum, with minor amounts

[a] Owing to the recency of their discovery these have not been listed.

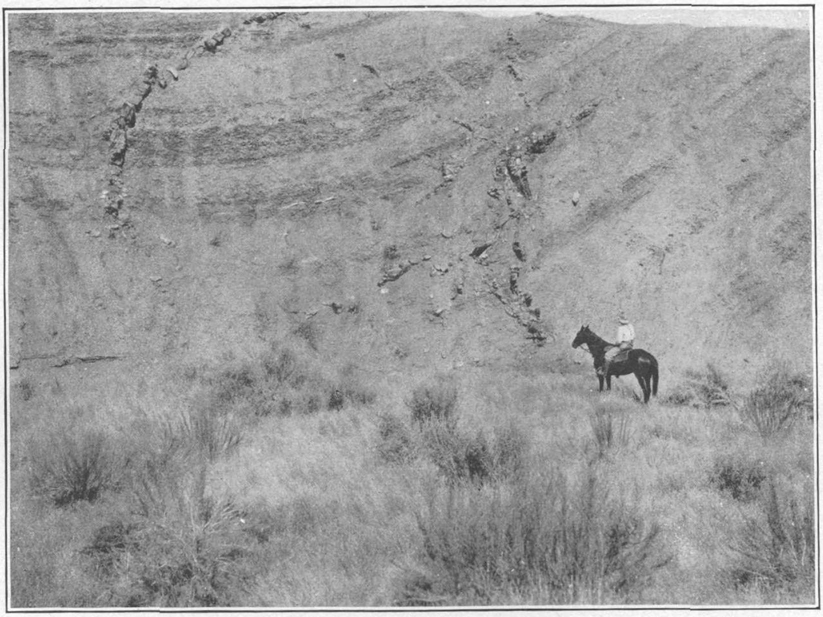
of alkaline mineral matter and sulphur along the intricate fracture planes. Some of the beds are largely composed of gypsum. Dikes of sandstone traversing the beds in various directions are so common as to be characteristic of the formation. An exposure of the shale penetrated by irregular dikes of hard sandstone is shown in Plate VI, *A*.

An analysis of a compact but comparatively soft and less siliceous specimen of chocolate-colored shale from the upper portion of the Tejon, near Oil Canyon, made by R. C. Wells, of the United States Geological Survey, showed the shale to contain approximately 78 per cent of silica. Under a lens it is seen to be composed largely of diatom remains with foraminiferal tests in minor number. The silica content is probably chiefly the product of the siliceous skeletons of the diatoms.

Southwest of Oil City the Miocene beds gradually overlap more and more upon the Eocene, leaving less of it exposed. Owing to lack of exposures of the rocks within 1 mile north of Los Gatos Creek, where it opens out to Pleasant Valley, the lines of contact drawn there are only approximately correct.

TEJON SOUTH OF LOS GATOS CREEK.

The outcrops of Tejon appear again south of Los Gatos Creek in a belt along the base of the foothills facing Pleasant Valley. The formation is conformable in dip with the Chico, and the rocks near the contact are fairly well exposed. The line drawn at the top of the concretionary beds, which are supposed to be at the top of the Chico (Upper Cretaceous), marks the base of some beds of light-yellow and white, soft, gypsiferous sand that are taken as the lowermost Tejon of this part of the area. Within 100 feet above this contact occurs a bed of calcareous sandstone locally greatly hardened and full of typical Tejon fossils. At the two coal mines northwest of Coalinga the yellow sand at the base of the formation is exceedingly gypsiferous and variable in character, and appears to be a shallow brackish and perhaps in part fresh-water deposit. It contains seams of lignite and carbonized wood which in former years have been mined. Above this sand, which has a thickness of about 200 feet, occur thin beds of light-colored, somewhat siliceous hard shale and soft, purplish-brown, gypsum-bearing argillaceous shale composing the upper half of the formation. The latter beds are steeply tilted and fractured and their truncated edges are overlain by Miocene beds with low dip. The unconformity is well exposed in the canyon of the San Joaquin Valley coal mine. At one place 4 miles northwest of Coalinga, within 500 feet above the base of the Tejon, there is exposed a bed of soft diatomaceous shale which probably represents



A. SANDSTONE DIKES IN PETROLIFEROUS SHALE OF THE TEJON FORMATION.

View 15 miles north of Coalinga. Similar dikes are characteristic of this formation. Photograph by Ralph Arnold.

B. PETROLIFEROUS SHALE AND SANDSTONE OF TEJON FORMATION BROKEN BY LOCAL FAULT.

Looking north in canyon of San Joaquin Valley coal mine. Photograph by Ralph Arnold.

part of the siliceous zone toward the top of the formation farther north, although it is not impossible that it occurs within the Miocene beds. Owing to the covering of soil over the undulating ground at the edge of the plain northwest of Coalinga, the thickness and extent of this diatomaceous material, or of the formation as a whole, can not be determined. It may be said, however, that the shale portion of the formation has a thickness in this part of the field of at least 300 feet below the highest horizon that the unconformably overlying Miocene leaves exposed. The Miocene spreads more widely over the Tejon farther to the south until the strike of the Tejon carries it completely beneath the Miocene beds at a point about 3 miles west of Coalinga.

TEJON ALONG REEF RIDGE.

Beds of Tejon age appear again on Reef Ridge, where the same broad lithologic characteristics may be noted—a sandy, frequently yellowish lower portion and a purplish shaly upper portion—although many minor differences are evident in the manner of occurrence north and south of the Miocene overlap. The Tejon beds of Reef Ridge, as compared with those in the northern locality, are in general more indurated and more regular and steeply tilted. The sandstone is more massively and regularly bedded and coarser at the base, and the shale is of different character and more homogeneous. The formation rests uncomformably on what is with little doubt a lower portion of the Cretaceous. An angular unconformity between the Tejon and the Miocene beds above it on Reef Ridge has not been found plainly in evidence along the contact, as it is in the Coalinga field, but an unconformable relation exists between the two formations here as well as farther north, as is shown by the facts that the tilting of the shale beds is in general steeper and the disturbance greater than in the Miocene above; that the Vaqueros (lower Miocene) overlaps at the northwest end of Reef Ridge and rests directly upon the dark shale of the lower portion of the Knoxville-Chico; and that the thickness of the shale of the Tejon exposed along Reef Ridge is varied owing to the overlapping of the Miocene upon different horizons.

The Tejon is exposed typically in the gorges that cut Reef Ridge between Zapato Canyon and Big Tar Canyon. The section (fig. 3) affords a graphic representation of the succession of beds in the latter canyon. The Tejon along Reef Ridge is made up of a basal zone of conglomerate varying in thickness from a few feet to over 100 feet, of a succession of sandstone beds aggregating about 550 feet in thickness, and of an upper shale portion of which a thickness as great as 900 to 1,000 feet is in places exposed. The Tejon becomes thinner west of Zapato Canyon and is not known to outcrop in that direction west of Jasper Canyon. Toward the southeast the Tejon passes under the overlapping shale of the Santa Margarita (?) formation (upper Miocene) near the extremity of Reef Ridge and disappears entirely. In the region mapped around McLure Valley no evidence of it exists. It

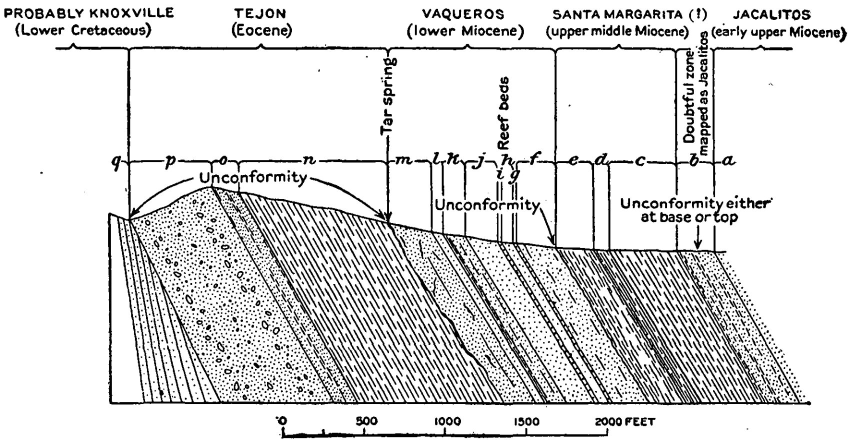


FIGURE 3.—Section of the Santa Margarita (?), Vaqueros, and Tejon formations along the west side of Big Tar Canyon.

	Feet.
a. Gray and brown sand of the Jacalitos formation.	
b. Unfossiliferous brown sand and sandy clay, with occasional layers of hard yellowish-brown sandstone, apparently grading into the Jacalitos above and the Santa Margarita (?) below; of doubtful age, but mapped as Jacalitos	200
Santa Margarita (?).	
c. Soft blue shale at top, grading below into soft brown shale; some brown sand at the top	350
d. Prominent thinly bedded hard white and purplish siliceous shale	100
e. Hard shale similar to that above, grading below into thinly bedded chocolate-colored shale	200
	650
Vaqueros.	
f. Soft gray sandstone and sandy shale	200
g. Prominent massive bed of hard gray sandstone, the upper one of "reef beds"	10
h. Less prominent gray sandstone	75
i. Very prominent massive bed of hard gray sandstone, the lower one of the prominent "reef beds;" this and the associated beds are locally fossiliferous (fossil locality 4627)	10
j. Coarse gray and brownish sandstone	150
k. Thinly bedded hard sandstone and shale, with 20 feet of reddish-brown shale at the base	100
l. Massively bedded, fairly soft grayish-brown sandstone	50
m. Soft grayish-brown sandstone, permeated throughout by veins of petroleum, and with a spring of heavy black oil at base forming tar	200
	795
Tejon.	
n. Thinly bedded purplish, dark grayish brown, and locally light-brown and yellowish siliceous, calcareous, and argillaceous shale	700
o. Grayish-brown sandy clay shale	125
p. Light-gray, yellowish, and brown, locally concretionary and fossiliferous sandstone impregnated with oil	500
	1,325
Total Santa Margarita (?), Vaqueros, and Tejon	2,770

may have been deposited over much of this region and later removed by erosion before the deposition of the Santa Margarita (?), which rests directly on the Cretaceous beds. This subject is discussed in the section dealing with the geologic history (p. 174). Rocks of Eocene age reappear still farther south on the southwest flank of McLure Valley, in the Devils Den region and beyond.

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

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

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

FOSSILS AND AGE.

LIST OF FOSSILS.

As indicated by the following list, the Tejon formation is well represented by fossils, and in several localities they are in a fairly good or even excellent state of preservation. Among the species collected by the writers within the Coalinga district are the following:

Tejon (Eocene) fossils from the Coalinga district.

Name.	4613.	4614.	4615.	4616.	4617.	4619.	4620.	4621.	4622.	4801.	5013.	5014.
FORAMINIFERA.												
Orbitolites sp. *a*	....	....	....	....	×	....	....	....	....	....	....	....
ECHINODERMATA.												
Cassidulus californicus F. M. Anderson	....	....	....	....	....	....	....	....	×	....	....	....
PELECYPODA.												
Barbatia morsei Gabb	....	....	×	....	....	....	×	....	×	×	....	....
Cardium breweri Gabb	....	....	×	....	....	....	....	×	×	....	....	....
Cardium cooperi Gabb	....	....	....	....	×	×	....	....	....	....	....	....
Cardium sp. indet	....	....	×	....	....	....	....	....	....	....	....	....
Corbula parilis Gabb	....	....	×	....	....	×	....	....	....	×	....	....
Crassatellites grandis Gabb	×	....	....	....	....	×	....	....	....	....	....	....
Leda gabbi Conrad	....	....	....	....	....	×	....	....	....	....	....	×
Meretrix gabbi Arnold	....	×	....	....	....	....	....	×	....	×	....	....
Meretrix hornii Gabb	....	....	....	....	×	....	×	....	×	....	....	....
Meretrix ovalis Gabb	....	....	....	....	....	....	....	....	....	×	....	....
Meretrix uvasana Conrad	....	....	×	....	....	×	....	....	....	....	....	....
Meretrix sp	×	....	....	....	....	....	....	....	....	....	....	....
Ostrea aviculiformis F. M. Anderson	....	....	....	....	....	....	....	....	....	×	....	....
Ostrea idriaenis Gabb	....	×	....	....	....	....	....	×	×	×	....	....
Ostrea sp. indet	....	....	....	....	....	×	×	....	....	....	....	....
Ostrea, very large	....	....	×	....	....	....	....	....	....	....	....	....
Petricola? n. sp	....	....	....	....	....	....	....	....	....	×	....	....
Pecten interradiatus Gabb	....	....	....	×	....	....	....	....	....	....	×	....
Pecten peckhami Gabb	....	....	....	×	....	....	....	....	....	....	....	....
Placunanomia inornata Gabb	....	....	×	....	....	....	....	....	×	×	....	....
Septifer dichotomus Gabb	....	....	....	....	....	....	×	×	....	×	....	....
Solen parallelus Gabb	....	....	....	....	×	×	....	....	....	....	....	....
Spondylus carlosensis F. M. Anderson	....	×	....	....	×	....	....	....	....	....	....	....
Tellina hornii Gabb	....	....	....	....	×	....	....	....	....	....	....	....
Tellina joaquinensis Arnold	....	....	....	....	....	....	....	....	....	×	....	....
Tellina sp. indet	....	....	....	....	....	×	....	....	....	....	....	....
Venericardia alticostata Gabb	....	....	....	....	....	....	....	×	....	....	....	....
Venericardia planicosta Lamarck	....	....	....	....	....	×	....	....	....	....	....	....
Venericardia sp. (small)	....	....	×	....	....	....	....	....	....	....	....	....
Venericardia sp. indet	....	×	×	....	....	....	....	....	....	....	....	....

Tejon (Eocene) fossils from the Coalinga district—Continued.

Name.	4613.	4614.	4615.	4616.	4617.	4619.	4620.	4621.	4622.	4801.	5013.	5014.
GASTEROPODA.												
Actæon sp. indet			×									
Amauropsis alveata Conrad						×				×		
Amauropsis oviformis? Gabb					×							
Cancellaria irelaniana Cooper						×						
Cylichna costata Gabb					×							
Dentalium cooperi Gabb						×						
Fusus remondii Gabb								×				
Galerus excentricus Gabb						×		×	×	×		
Loxotrema turrita Gabb							×			×		
Lunatia hornii Gabb										×		
Lunatia sp. *a*										×		
Nerita triangulata Gabb										×		
Pleurotoma domenginei Arnold						×						
Pleurotoma fresnoensis Arnold						×						
Pleurotoma guibersoni Arnold						×						
Potamides carbonicola Cooper										×		
Rimella canalifera Gabb		×				×						
Serpulorbis sp. *a*					×							
Spiroglyphus? tejonensis Arnold					×	×						
Tritonidea kreyenhageni Arnold										×		
Tritonium californicum Gabb						×						
Turritella pachecoensis Stanton					×							
Turritella uvasana Conrad		×			×	×		×	×			
Xenophora? sp					×							

4613. About 11 miles north of Coalinga, on west side of sec. 4, T. 19 S., R. 15 E. Top of lower member.

4614. East flank of Alcalde Hills, 3 to 4 miles northwest of Coalinga, along ridge within three-fourths mile of San Joaquin Valley coal mine, in northwest corner of sec. 26 and SE. ¼ sec. 22, T. 20 S., R. 14 E. Prominent medium-grained sandstone bed about 200 feet above contact with concretionary sandstone beds mapped as Cretaceous.

4615. High point on Reef Ridge, about 1 mile south of sharp turn in Zapato Creek and 1 mile east of Sulphur Spring Canyon, in sec. 25, T. 22 S., R. 15 E. Basal conglomerate of Tejon.

4616. Eight miles due north of Coalinga, one-half mile east of Oil Canyon road, and just north of Laval grade, near center of SE. ¼ sec. 20, T. 19 S., R. 15 E. Siliceous shale in upper portion of Tejon.

4617. On southwest flank of Reef Ridge, north of McLure Valley, 2¼ miles south-southeast of El Cerrito well, in sec. 27, T. 23 S., R. 17 E. Lower member.

4619. Fifteen miles north of Coalinga, southwest of Domengine's ranch. Sandstone at top of lower member.

4620. Coal mine, 4½ miles northwest of Coalinga, about 1 mile north of San Joaquin mine, SW. ¼ NE. ¼ sec. 22, T. 20 S., R. 14 E. In very gypsiferous variable sand and clay overlying coal seams, 200 to 300 feet above base of formation.

4621. About 5½ miles northwest of Coalinga, on point of hills (elevation 1,100 feet) south of mouth of Los Gatos Creek, in center of NE. ¼ sec. 15, T. 20 S., R. 14 E. In hard calcareous sandstone bed about 150 feet above contact with concretionary sandstone mapped as Cretaceous.

4622. Four miles west-northwest of Coalinga, on top of hill north of road and one-half mile south of San Joaquin Valley coal mine, west of center of SW. ¼ sec. 26, T. 22 S., R. 14 E. Prominent sandstone bed about 150 feet above concretionary sandstone mapped as Cretaceous.

4801. Three miles northwest of Coalinga, at San Joaquin Valley coal mine, in NW. ¼ sec. 26, T. 20 S., R. 14 E. Lower member.

5013. Eight miles northwest of Coalinga, in white siliceous shale at top of Tejon formation, east of center of sec. 25, T. 19 S., R. 14 E.

5014. About 13 miles north of Coalinga, on east side of sec. 29, T. 18 S., R. 15 E., in dark-colored shale just under Miocene oil sand.

OTHER SPECIES COLLECTED.

To the above list of species should be added the following, among others collected by F. M. Anderson [a] in the same region:

FORAMINIFERA.

Cyclammina sp.
Lagena? sp.
Nodosaria p.
Polymorphina sp.
Pulvulina sp.
Sagrina sp.
Vaginulina sp.

ANTHOZOA.

Ellipsosmilia granulifera Gabb (4).
Trochocyathus striatus Gabb + Trochosmilia id. (4).

BRACHIOPODA.

Terebratella sp. (2).

PELECYPODA.

Gari texta ? Gabb (4).
Modiola ornata Gabb (3).

GASTEROPODA.

Cancellaria elongata Gabb (1).
Architectonica hornii Gabb (1).
Fusus diaboli Gabb (1).
Fusus martinez Gabb (1, 3).
Morio tuberculatus Gabb (4).
Neverita globosa Gabb (1, 3).

1. Region southeast of Big Tar Canyon.
2. Conglomerate and coarse sandstone near base of Eocene at San Joaquin coal mine and northward to Los Gatos Creek.
3. Sandy beds associated with the carbonaceous strata above 2.
4. North of Los Gatos Creek.

FAUNAL RELATIONS AND AGE.

With the exception of the new Eocene species described by the senior author in Bulletin 396, certain species described by J. G. Cooper and F. M. Anderson from this region, and a few forms that occur in the Martinez or lower Eocene, the fauna of the Eocene of the Coalinga district consists of species heretofore known only from Tejon localities.

The new forms discovered by F. M. Anderson and the writers have so far escaped observation in other localities, but some of them, at least, may eventually be found elsewhere. The species occurring in the Coalinga district and also found at the type locality of the Martinez [b] are as follows:

Cardium cooperi Gabb.
Cylichna costata Gabb.
Dentalium cooperi Gabb.
Leda gabbi Conrad.
Lunatia hornii Gabb.
Morio tuberculatus Gabb.
Tellina hornii Gabb.
Turritella pachecoensis Stanton.
Venericardia planicosta Lamarck (V. hornii Gabb).

According to Merriam [b] *Cardium cooperi* is common in the Martinez and rarer in the Tejon; *Cylichna costata* is rare in the Martinez and

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, pp. 164-166.
[b] Merriam, J. C., Jour. Geology, vol. 5, 1897, p. 773.

common in the Tejon; *Dentalium cooperi* is common in the Chico (Cretaceous), Martinez, and Tejon; *Leda gabbi* is common in both the Martinez and Tejon; *Lunatia hornii* is rare in the Martinez and common in the Tejon; the occurrence of *Morio tuberculatus* is questionable in the Martinez; *Tellina hornii* is common in both the Martinez and Tejon; and *Venericardia planicosta* is common throughout the Martinez and Tejon and all through the Eocene for that matter. The *Turritella pachecoensis* from the Coalinga district is much smaller than the typical form from the Martinez. *Pecten peckhami* Gabb extends to the Miocene or even higher.

Of a total fauna of 52 recognizable species in the Tejon of the Coalinga district 10 are species so far known only from the district, 1 has heretofore been known only in the Martinez, 8 are found both in the Martinez and the Tejon (but all these except one are species of which the individuals are as common or commoner in the Tejon than in the Martinez), and 33 are known almost exclusively in the Tejon. It is obvious, therefore, that the bulk of the Eocene in the Coalinga district is of Tejon age, which probably represents a part of the middle Eocene. There is also evidence favoring the correlation of the fauna with that of the Jackson formation of Mississippi.

The faunas of all the localities in the Tejon in the Coalinga district, with the exception of those found associated with the carbonaceous beds west of Coalinga, indicate a marine origin for the deposits. The fauna of the carbonaceous beds (locality 4801, etc.) indicates brackish water at this locality during a part of the Tejon. This agrees with evidence from other parts of the west coast where the middle Eocene is characterized by brackish and even fresh water deposits, usually containing more or less coal. The brackish-water deposits in the Coalinga district are characterized by such species as *Barbatia morsei* Gabb, *Placunanomia inornata* Gabb, *Ostrea aviculiformis* Anderson, and *Potamides carbonicola* Cooper.

The molluscan fauna of the white diatomaceous and foraminiferous shale at the top of the Tejon in the Coalinga district consists of *Pecten interradiatus* Gabb, *Pecten peckhami* Gabb, and *Leda gabbi* Conrad. *Leda gabbi* is a common Tejon species, while *Pecten peckhami* is so far known elsewhere only in the Oligocene, Miocene, and possibly Pliocene. *Pecten interradiatus* is known elsewhere only in shales occupying a similar stratigraphic position to the shales in which it occurs in the Coalinga district. The stratigraphic evidence is strongly in favor of the diatomaceous shales being a part of the Tejon; the faunal evidence is about equally divided; therefore it seems most logical that the rocks in question be assigned to the Tejon, at least until the securing of further and more definite evidence.

Owing to the close resemblance of the shales under discussion to the Monterey (lower middle Miocene) shale of other portions of the

Coast Ranges and to the occurrence in them of the then supposedly characteristic Miocene fossil *Pecten peckhami* Gabb, the former were ascribed to that formation by Watts,[a] Eldridge,[b] and F. M. Anderson.[c] Later,[d] F. M. Anderson withdrew this correlation, suggesting that "the definite assignment of these shales to either the Eocene or the Oligocene in the time scale of California geology * * * must be reserved for further study and for some future time."

IMPORTANCE WITH RELATION TO PETROLEUM.

The diatomaceous and foraminiferal shale forming the upper member of the Tejon is thought to be the original source of the petroleum found in the Tejon and later formations of the Coalinga district. This shale is petroliferous practically throughout its extent in the district, whereas the purple-shale member of the Chico, which is the only oil-bearing zone lower than the Tejon, is present only in the very northern part of the district. The post-Eocene beds are petroliferous where associated with the Tejon. Where it is absent they are dry. In the northern portion of the district the shale forming the upper member of the Tejon is stained with petroleum, but as far as known the formation there does not contain any reservoirs of oil. The oil has migrated upward and collected in vast quantities in the more suitable reservoirs afforded by the Miocene beds. In the southern portion of the district the sandstone of the lower half of the formation is saturated with oil, in places through its whole thickness. The sand has a strong odor, and when a fresh fracture surface is exposed the beds are found to be stained brown throughout. Included layers of shale are stained purple. The wells which are drilled through the shale to this sandstone strike oil in it everywhere in small amounts. The great thickness of the sandstone through which the oil has permeated lessens the probability of its being found in large amounts locally. It is probable that this oil originated in the shale above and became absorbed in the sandstone both above and below. The occurrence of it in the overlying Miocene beds will be mentioned later.

The shale in the upper part of the Tejon contains a large proportion of material of organic origin. The calcareous facies is largely composed of foraminiferal remains, and the hard siliceous beds are very similar to the altered varieties of diatomaceous shale found in other formations in other parts of the State. In places in this district the shale is softer and less altered and may be seen to be composed largely

[a] Bull. California State Min. Bur. No. 3, 1894, p. 65; Bull. No. 18, 1900, p. 136.
[b] Bull. U. S. Geol. Survey No. 213, 1903, p. 307.
[c] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, p. 173.
[d] Idem, 4th ser., vol. 3, 1908, p. 16.

of diatom remains. In the opinion of the writers it is probable that these small marine organisms have been the chief source of the oil.

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

GENERAL DESCRIPTION OF THE POST-EOCENE FORMATIONS.

INTRODUCTION.

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

The periods following the Eocene are here represented by a great series of sandstone, shale, and conglomerate beds, all tilted at about the same angle, having usually similar characteristics, and presenting an appearance of conformity and intergradation. By means, however, of discontinuous fossil faunas, distinguishable lithologic groups, the absence in some places of formations or zones known elsewhere, as a result of erosion and the overlapping of later beds, and the appearance of fragments of older formations within younger ones, several important breaks may be definitely made out, which prove the intervention of periods of time during which land conditions existed over wide areas or locally. The important post-Eocene formations that represent the epochs of submergence of the land in the area now occupied by the Coalinga district are the Vaqueros (lower Miocene), the Santa Margarita (?) (upper middle Miocene), the Jacalitos (early upper Miocene), the Etchegoin (late upper Miocene), and the Tulare (Pliocene and lower Pleistocene) formations. The Tulare formation is probably in large part of different origin from the others, but is similar to them in the general features of its appearance. These formations are all united into one series in the monocline dipping down the east flank of Joaquin Ridge in the northern part of the district, and again in the monocline dipping away from Reef Ridge in the southern portion, but the character of the series is not entirely the same in the two regions.

DESCRIPTION OF THE SERIES IN THE NORTH.

In the northern part of the district the base of the Miocene-Pliocene is formed of coarse and fine oil-impregnated sands unconformably overlying the whitish and purplish petroliferous Eocene (Tejon) shales, these sands being overlain by prominent sandstone beds (the "reef beds"), a prominent zone of white siliceous shale (the "indicator"), and soft sand up to the base of a zone of bluish-gray and variegated clay, sand, gravel, and serpentine detritus locally known as the Big Blue. Up to this point the beds are fossiliferous, have a thickness of about 550 feet, and are mapped as Vaqueros (lower Miocene). The Big Blue has a thickness of about 300 feet and is nonfossiliferous. It corresponds in stratigraphic position to the Monterey shale (middle Miocene) of regions nearer the coast, but nothing has been discovered to indicate that it may belong to that formation. It is overlain by a thickness of about 175 feet of sand, sandstone, and conglomerate beds full of immense oysters, barnacles (*Tamiosoma*), scallop shells (*Pecten*), and other fossils. These fossiliferous beds will be referred to as the *Tamiosoma* zone. They are overlain by 400 to 500 feet of sand and gravel beds up to the base of a very prominent gravel zone full of petrified wood. The beds from the base of the Big Blue up to this point are mapped as the Santa Margarita (?) formation (upper middle Miocene). The gravel zone with fossil wood forms the base of a succession of sand, sandstone, gravel, and clay beds extending up to the base of a prominent zone of bluish-gray sand beds having near their base a rich fossil bed, the *Glycymeris* zone. The succession of beds up from the base of the fossil-wood gravel zone to this point has a thickness of about 1,600 feet and is mapped as the Jacalitos formation (early upper Miocene). The fossil bed (*Glycymeris* zone) and bluish sands immediately overlying grade upward into sand and clay beds, the whole forming a thickness of about 1,700 feet, which is mapped as the Etchegoin formation (uppermost Miocene), and this finally is overlain by poorly exposed coarse gravel deposits, which are mapped as the Tulare formation (Pliocene-lower Pleistocene). The total thickness of the succession in the Coalinga field thus outlined is about 4,600 feet, exclusive of the Tulare formation, which can not be measured in this portion of the district.

DESCRIPTION OF THE SERIES IN THE SOUTH.

In the southern part of the district the basal portion of the Miocene-Pliocene series consists of about 700 to 900 feet of steeply dipping hard sandstone and conglomerate beds forming the face of Reef Ridge. These overlie, with an important though usually not apparent unconformity, the shale of the Tejon (Eocene) and are locally petroliferous. At the summit they grade into softer beds which are overlain by hard siliceous shale. Up to this shale the beds are fossiliferous and are mapped as the Vaqueros formation. The overlying shales are hard and whitish, form a prominent zone varying up to 1,200 feet in thickness, and are mapped as Santa Margarita (?), although only tentatively referred to that formation. These shales are overlain by a great succession of beds of sandstone, shale, sand, clay, gravel, and conglomerate of many varieties, having a thickness as measured in a section south of Big Tar Canyon of about 9,500 feet. This succession is divided on the map, on the basis of criteria to be discussed later, into three approximately equal divisions corresponding to the formations in the north, namely, the Jacalitos (early upper Miocene), Etchegoin (uppermost Miocene), and the Tulare (Pliocene-lower Pleistocene). The total thickness of the Miocene, Pliocene, and lower Pleistocene series measurable in the above-mentioned single section is over 11,000 feet.

PREVIOUS CORRELATION.

In his paper entitled "A stratigraphic study in the Mount Diablo Range of California,"[a] F. M. Anderson adopted a classification of the Tertiary rocks in the hills around about Pleasant Valley, where Coalinga is situated, which in the light of more detailed studies has required some modification. To avoid confusion, an outline will here be given of the changes that it has been found necessary to make.

The white and brown shales in the Coalinga field that are in the present report mapped and described tentatively as the upper portion of the Tejon (Eocene) were very naturally considered to be "Monterey" (middle Miocene) by F. M. Anderson, owing to their resemblance to the well-known shales of that formation, and they were so described. The lower Miocene beds were considered to be lacking. The series of strata unconformably overlying the shales and extending nearly up to the fossiliferous beds, here referred to as the *Glycymeris* zone, were described by him as a stratigraphic unit under the name "Coalinga beds," and as upper Miocene in age. The thickness of this series he gave as varying from 2,180 feet 10 miles north of Coalinga to 1,556 feet 10 miles farther north, and to 4,490 feet 3 miles west of Coalinga. As will be discussed more fully in connection with the different formations, this series of strata has been found to be divided into several portions separated by unconformities and representing different periods of the Miocene. At least two of these portions correspond definitely to well-known formations in near-by portions of the State. The accompanying diagram will illustrate the classi-

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, pp. 174 et seq.

fications of the strata in the hills north of Coalinga adopted in the present report and by F. M. Anderson in the paper quoted:

Diagram of the middle Tertiary column north of Coalinga.

(Not drawn to scale.)

Present report.	Paper by F. M. Anderson.
Etchegoin (uppermost Miocene).	Etchegoin (Pliocene).
——— Unconformity ———	——— Unconformity ———
Jacalitos (upper Miocene).	
——— Unconformity ———	
Santa Margarita (?), including Big Blue (possibly Monterey) at base (middle Miocene).	Coalinga (upper Miocene).
——— Unconformity ———	
Vaqueros (lower Miocene).	
——— Unconformity ———	——— Unconformity ———
Tejon (upper part) (Eocene).	Monterey (middle Miocene).
	Temblor [=Vaqueros] (lower Miocene) absent here, but occurring in Kreyenhagen field.

The lower beds of the Miocene series, namely, those associated with the "reef beds," are equivalent to those described by F. M. Anderson in the Kreyenhagen field as the "Temblor beds" (lower Miocene), which are themselves equivalent to the widespread Vaqueros sandstone (lower Miocene) of the California Coast Ranges. This portion of the series north of Coalinga contains at several different horizons good faunas characteristic of the lower Miocene.

The middle portion of the series is unconformable upon the lower portion and contains rich fossil beds which have been referred to as the *Tamiosoma* zone. The fauna of these beds is typical of the Santa Margarita (upper middle Miocene) formation, well known in the Salinas Valley region. The Big Blue, which occurs below the *Tamiosoma* zone and which has been included at the base of the Santa Margarita (?) formation in the mapping, may possibly represent in part another well-known formation, the Monterey (middle Miocene), or may be part of the Vaqueros.

The upper portion of the series makes up an unconformably overlying, for the most part nonfossiliferous formation of upper Miocene age, the equivalent of a portion of an important succession of strata occurring well developed and with characteristic fauna in the southern portion of the Coalinga district, where the name Jacalitos formation has been assigned to it in the present report. The "Coalinga beds" were stated by F. M. Anderson to be lacking in the southern portion of the district.

The series termed the "Coalinga beds" was characterized by four lists of fossil species in the original description. The fossils in three of these lists were stated to come from the "reef bed," which has been shown to be Vaqueros (lower Miocene) in age. Those in the fourth were obtained north of the Coalinga district, from a stratum 400 feet above the "reef bed," in the continuation of the beds here mapped as Santa Margarita (?). As far as faunal characterization goes the "Coalinga beds" are therefore to be correlated with the "Temblor beds" described by Anderson—that is, with the Vaqueros—and with the Santa Margarita (?). In view of the fact that the series has been found divisible into distinct formations of different ages, for the most part equivalent to formations known elsewhere, the name "Coalinga beds" can not be retained.[a]

THE McKITTRICK FORMATION SOUTH OF THIS DISTRICT.

At most localities along the flanks of the Diablo and Temblor ranges south of the Coalinga district it has not been found possible to separate the post-Santa Margarita (?) Tertiary formations, owing to the facts that they are imperfectly exposed and that they are unusually poor in fossils. These beds are the continuation and at least the partial equivalent of the succession of beds in the Coalinga district which is divisible into the three formations Jacalitos, Etchegoin, and Tulare. The name McKittrick formation has been applied to these beds along the Temblor Range because of their importance as a cartographic and (in appearance) stratigraphic unit in and to the north and south of the McKittrick oil district.[b]

To the south of the Coalinga district the McKittrick formation is distributed over both sides of the Temblor Range along most of its length and forms the whole of the Buena Vista and Elk hills. It is particularly important economically, as its basal members are the productive beds for the McKittrick, Midway, and Sunset oil fields. On the east side of the Temblor Range the formation consists of coarse to fine conglomerates and coarse sands near its base, then a zone of bluish sandy clay, then medium to coarse sands and sandy shales, and at the top a succession of alternating coarse gravel and clay beds. The whole formation ranges from 1,300 to possibly 2,500 feet in thickness. It overlies the Monterey and Santa Margarita (?) unconformably, and is in turn unconformably overlain by late Quater-

[a] Since the preparation of this bulletin there has appeared a paper by Frank M. Anderson entitled "A further stratigraphic study in the Mount Diablo Range of California" (Proc. California Acad. Sci., 4th ser., vol. 3, Oct. 31, 1908, pp. 1-40). In this paper the description of the section given in his former paper is considerably revised. The white shales south and east of Oil City are recognized to be Eocene or Oligocene instead of Monterey (middle Miocene), and the unconformably overlying formation, in which the "reef beds" occur, to be lower Miocene. The application of the term "Coalinga beds" is changed so as to leave out the lower Miocene, which was the most typical portion in the original description, and the Big Blue, which is recognized as possibly representing the Monterey. Two faunal lists characterizing the "Coalinga beds" are given for the type locality north of Coalinga, the first being of the fossils of the *Tamiosoma* zone, which are typical of the previously named Santa Margarita formation, and the second being the same list of fossils given in the former paper as from 400 feet above the "reef bed." The thickness of the revised "Coalinga beds" is given as from 500 to 800 feet between Coalinga and Cantua Creek, which is 20 miles or so north. From this it appears that the intention is to restrict the name to practically the same beds north of Coalinga which are mapped in the present report as Santa Margarita (?) exclusive of the Big Blue. South of Waltham Creek these beds are correlated with a portion of the terrane mapped as the Jacalitos formation in the present report. The thickness of the "Coalinga beds" is stated to be "from 1,000 to 1,500 feet in the field between Waltham Creek and Tulare Lake."

[b] Arnold, Ralph, and Johnson, Harry R., Preliminary report on the McKittrick-Sunset oil region, California: Bull. U. S. Geol. Survey No. 406, 1910.

nary sand, gravel, and alluvial deposits. Evidence of an unconformity within the formation was obtained at one or two points.

VAQUEROS SANDSTONE (LOWER MIOCENE).

GENERAL DESCRIPTION.

The unconformity at the top of the Tejon (Eocene) marks an important lapse of time before the beginning of the Miocene period. In the early Miocene a sedimentary formation was deposited in the Coalinga district that is the correlative of the formation known as the Vaqueros in the region nearer the coast.

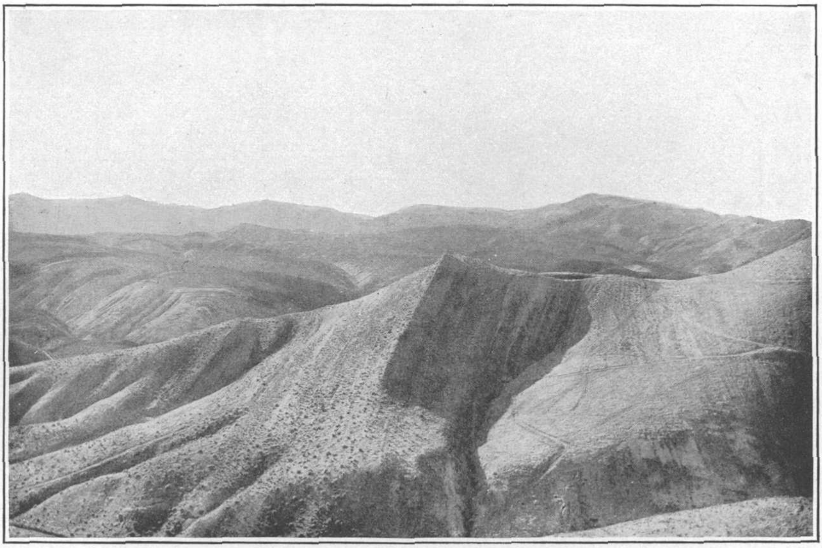
The Vaqueros in the area under discussion forms an elongated belt east of the belt of Tejon in the hills bordering the great valley. It has a thickness ranging from about 550 feet in the Coalinga field to 900 feet in the Kreyenhagen field of hard and soft sandstone, shale, and conglomerate, and may be easily distinguished from all the other formations by the protruding tendency of the hard sandstone beds, the "reef beds," in its central portion. These beds outcrop prominently in the northern portion of the district, as shown in Plate VII, *A*, and again in the southern portion assume such prominence as to dominate the landscape on the bold face of the long ridge that is named in the present report Reef Ridge. They are much more resistant to erosion than the soft associated beds, and dipping toward the valley on the northeast at an angle varying from 50° to 80° they form the scarp and double row of pinnacles of Reef Ridge fronting the foothills on that side, as shown in Plate VIII.

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

DISTRIBUTION AND LOCAL CHARACTER.

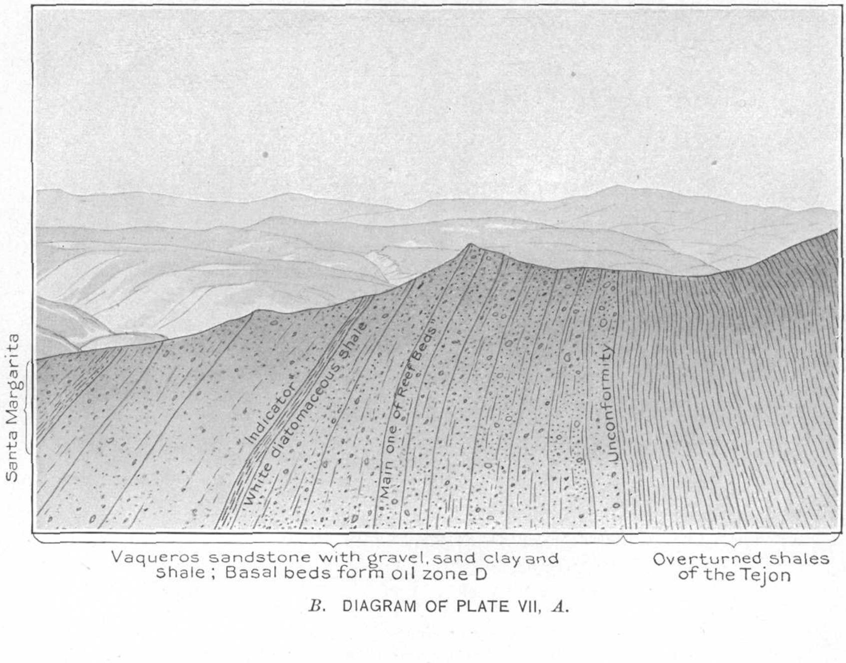
GENERAL STATEMENT.

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



A. "REEF BEDS" OF VAQUEROS SANDSTONE OVERLYING OVERTURNED SHALES OF THE TEJON FORMATION.

Looking northwest across foothills 8 miles north of Coalinga. Taken from hill shown in middle of Plate XIV. Photograph by Ralph Arnold.



B. DIAGRAM OF PLATE VII, *A.*

"REEF BEDS" OF VAQUEROS SANDSTONE FORMING SCARP OF REEF RIDGE.

Looking south across upper portion of Zapato Creek. Photograph by Ralph Arnold.

it is possible that a narrow belt of Vaqueros is exposed south of Waltham Creek, and that this joins the belt on Reef Ridge in the territory southwest of that shown on the map.

VAQUEROS NORTH OF PLEASANT VALLEY.

In the hills north of Coalinga the formation includes all the beds overlying the Tejon at least as far up in the series as the base of the zone locally well known as the Big Blue, and possibly to the summit of this zone, which is at the base of the *Tamiosoma* zone. The Big Blue is not known to be fossiliferous and presents therefore no definite basis for correlating it, but it is mapped for the present as a portion of the overlying formation (the Santa Margarita?) and the summit of the Vaqueros is placed at its base. The term Vaqueros as here used is thereby restricted to those beds which are known by their fossils as belonging to that formation. These beds have a thickness of about 550 feet.

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

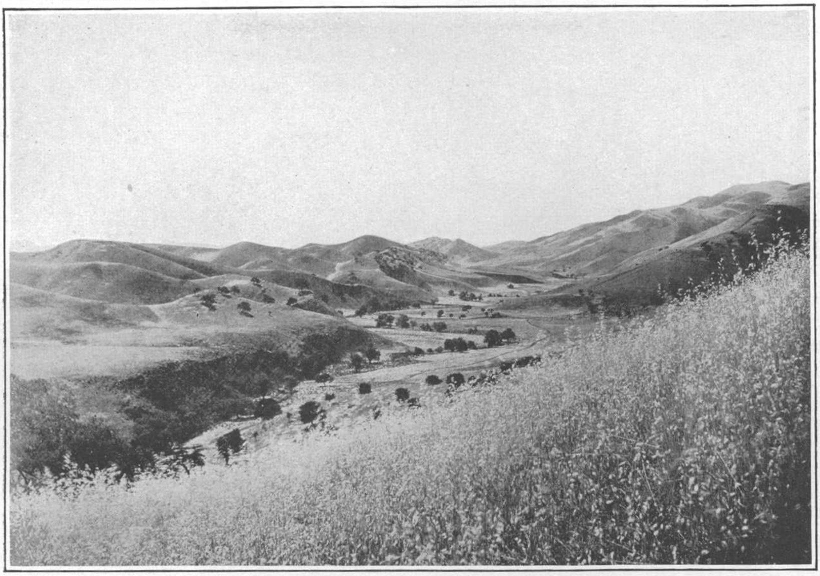
Similar hard and soft sandstone beds continue to about 425 feet above the base of the formation, where a bed some 10 to 20 feet thick of compact white, diatomaceous, and foraminiferal shale is sharply interbedded. This bed is prominent and so sharply marked off from the associated gray sand that it may be easily traced. It has been referred to throughout the field work as the "indicator," and the name was found so convenient that it may as well be used here. A good exposure of it is shown as a white outcrop running up the ridge to the right of the center in Plate XIV. The bed is continuous, always in the same relative position, from Oil Canyon to the northern edge of the area shown on the map, beyond which no attempt was made to trace it. Southwest of Oil Canyon it is continuous for a mile or two at least. It preserves its strong individuality throughout in spite of the fact that it changes in character locally from a soft though compact earthy deposit, both massively bedded and finely laminated, as on the east side of Oil Canyon near the point shown in Plate XIV, to hard, thinly bedded white porcelaneous or flinty shale and yellowish calcareous shale, as south of the Laval grade on the hill (elevation 2,024 feet) 8½ miles north of Coalinga in the western half of sec. 21. This bed, where not greatly indurated, may be seen with a lens to be full of diatom remains. It is strikingly similar to the siliceous shale characteristic of the upper Tejon, already described, and of the Santa Margarita(?) formation of Reef Ridge, to be described later. An analysis of a sample of the soft white variety from Oil Canyon made by R. C. Wells, of the United States Geological Survey, showed it to contain 48 per cent of silica.

Above the "indicator" bed soft gray and brown sandstone in thin layers makes up a variable zone about 125 feet thick. This sandstone has been found to contain typical Vaqueros (lower Miocene) fossils, and is the uppermost stratum in which they are found. In the central part of the Eastside field it is overlain by soft, fine grayish-white sand that looks bluish from a distance and is well known to the drillers as the Big Blue. Farther north the highest fossiliferous beds of the Vaqueros are overlain by coarse detrital deposits marking the same zone as the Big Blue. The line for the top of the Vaqueros formation is drawn at the base of the zone, which probably represents an important unconformity.

Southwest of Oil Canyon the Vaqueros beds become much thinner, and within about 2 miles they lose their prominence. In the hills for 2 miles north of the head of Pleasant Valley the beds are largely hidden by recent deposits of soil, alluvium, and gravel, but it is probable that a small thickness of beds, representing a part of the Vaqueros, is continuous. Their presence within a mile and a half north of Los Gatos Creek is doubtfully indicated by certain fossils that have been found (locality 4637).

VAQUEROS IN THE ALCALDE HILLS.

In the hills west of Coalinga the Vaqueros is absent north of the San Joaquin Valley coal mine, with the possible exception of a thin discontinuous zone locally exposed beneath the Santa Margarita (?)



A. VIEW LOOKING SOUTH DOWN AVENAL CREEK.

Showing Avenal Ridge, formed of Cretaceous beds, on the right and the hills of white Miocene shale on the left. Photograph by Ralph Arnold.

B. BED OF SAND DOLLARS IN PEBBLY SAND OF ETCHEGOIN FORMATION.

In Kreyenhagen Hills, between Garza Creek and Big Tar Canyon. Photograph by Ralph Arnold.

and Jacalitos formations. South of the coal mine incoherent fossiliferous beds of the Vaqueros formation overlap upon the Tejon and Chico (Upper Cretaceous) beds. They have a thickness of about 500 feet, as they have in the Eastside field. The beds are extremely variable and consist for the most part of incoherent yellowish and gray sand, both coarse and fine. The sand is roughly bedded and has partings and lenses of hard sandstone and of gravel. Fossils are abundant in it, but they are poor and not certain as indicators. The section in figure 8 shows some of the features of the formation in this portion of the district. Westward a capping of low-dipping beds extends over the ridges formed of steeply dipping beds of the Knoxville-Chico. This capping is for the most part only slightly indurated sand, gravel, and clay in irregular deposits and variable colors, such as green, blue, red, etc. A few marine fossils were obtained that point to a lower Miocene age, though they do not prove it. Fossil wood occurs in certain places in these beds, notably on the summit of Juniper Ridge, a few miles north of Alcalde Canyon, and it is thought that they may be in part nonmarine.

VAQUEROS IN THE JACALITOS HILLS.

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

VAQUEROS ON REEF RIDGE.

The Vaqueros sandstone overlies the shale of the Tejon on Reef Ridge and forms the steep face of the ridge. The beds show a thickening of the deposits of this period southward from the region around Pleasant Valley. They also have undergone a greater amount of induration and form a more conspicuous part of the landscape than the contemporary beds farther north. Their relation to the underlying shale of the Tejon is one of unconformity, although no wide disparity in dip has been observed in the strata of the two formations. There is even an apparent gradation from the shale below to the sandstone above in some places and it is difficult to place the exact contact between the two formations. This difficulty is largely due to the lack of continuous exposures near the contact.

The Vaqueros sandstone is subject to considerable variation from place to place, as will be shown in the accompanying tabulated sections. The formation may in general be divided into three zones, one of comparatively soft beds of sandstone and shaly sandstone at the base, comprising about one-fourth of the total thickness; a second of hard, fossiliferous beds of sandstone with some conglomerate, making up about half of the formation and producing the prominent outcrops of Reef Ridge; and a third zone similar in thickness and character to the first and grading into soft, fine-grained beds that are poorly exposed and lead the observer to think there is a transition to the shales above, which are described as Santa Margarita (?). Such a transition is not supposable if the correlations that have been made are correct. The third zone is much thicker on Canoas Creek than elsewhere and there makes up half of the formation. The Vaqueros as a whole is thicker in the southeastern than in the northwestern half of Reef Ridge. The thickest section observed was on Canoas Creek, where the formation comprises a thickness of 900 feet. The middle zone is marked by three principal horizons of hard, fossiliferous sandstone and conglomerate beds that stand out in strong relief. The lowest of these "reef beds" and the middle one are about 150 to 200 feet apart, and the middle and uppermost beds 100 feet apart on the average. They vary in relative prominence from place to place, and the exact horizon at which the induration is most pronounced is variable.

The following section, together with figure 3, gives an idea of the character of the Vaqueros formation as it occurs typically exposed along Reef Ridge:

Section of Vaqueros sandstone in Canoas Canyon.

	Feet.
Soft, fine sandstone with large oil seepages; "button beds" at base containing *Scutella*, etc. (locality 4772); overlain by siliceous shale of Santa Margarita (?).	180
Hard and soft, gray and brown stained sandstone with large oil seepages in upper half	300
Massive sandstone beds with thick, very prominent, hard beds at top and at base, the "reef beds;" *Pecten andersoni* bed at base (locality 4771)	100
Sandstone with very prominent hard bed, the *Turritella ocoyana* bed, at base (locality 4770)	200
Fairly hard, thin-bedded sandstone underlain by shale of the Tejon formation	120
	900

FOSSILS AND AGE.

LIST OF FOSSILS.

Throughout the Coalinga district the Vaqueros sandstone is at one horizon or another generally fossiliferous and yields a fauna of many species, sometimes in a fairly good state of preservation. The following species have been found by the writers in or immediately adjacent to the Coalinga district:

Vaqueros (lower Miocene) fossils from the Coalinga district, California.

Name.	4624.	4625.	4627.	4628.	4629.	4631.	4633.	4634.	4635.	4637.	4655.	4667.
ECHINODERMATA.												
Scutella merriami F. M. Anderson												
PELECYPODA.												
Arca obispoana Conrad												
Arca osmonti Dall												
Cardium vaquerosensis Arnold						×						
Chione conradiana F. M. Anderson						×	×					
Chione temblorensis F. M. Anderson		×				×						
Corbicula dumblei F. M. Anderson				×	×							
Dosinia mathewsonii Gabb												
Dosinia ponderosa Gray						×						
Macoma aff. secta Conrad							×					
Macoma piercei Arnold						×						
Metis aff. alta Conrad			×			×						
Mulinia densata Conrad		×										
Mulinia densata Conrad var. minor Arnold		×	×									×
Mytilus mathewsoni Gabb var. expansus Arnold												
Ostrea titan Conrad										×		
Pecten andersoni Arnold						×			×			
Pecten crassicardo Conrad												
Pecten estrellanus? Conrad											×	
Pecten miguelensis Arnold												
Phacoides acutilineatus Conrad						×						
Phacoides (Miltha) sanctæcrucis Arnold												
Saxidomus vaquerosensis Arnold			×			×						
Septifer coalingensis Arnold								×				
Tivela inezana? Conrad		×										
Venus pertenuis Gabb						×						
Yoldia impressa Conrad												
Zirphæa dentata Gabb		×	×				×					
GASTEROPODA.												
Agasoma kernianum Cooper						×	×					
Agasoma santacruzana Arnold						×						
Bathytoma piercei Arnold						×						
Cancellaria vetusta Gabb						×						
Cancellaria andersoni Arnold						×						
Conus owenianus F. M. Anderson						×						
Conus hayesi Arnold												
Crepidula sp						×						
Ficus pyriformis Gabb							×					
Neverita callosa Gabb						×						
Ocinebra topangensis Arnold						×						
Trochita filosa Gabb			×									
Trochita sp. indet						×						
Trophon (Forreria) bartoni Arnold												
Trophon (Forreria) gabbianum F. M. Anderson												
Trophon (Forreria) gabbianum F. M. Anderson var. cancellarioides Arnold												
Turritella ocoyana Conrad	×	×	×			×	×					
Xylotrya sp. *a*												
CIRRIPEDIA.												
Balanus sp												
CRUSTACEA.												
Branchiolambrus altus Rathbun												

4624. *Turritella* bed, or lower one of "reef beds," in Garza Creek gorge through Reef Ridge; southwest corner of the SE. ¼ sec. 3, T. 23 S., R. 16 E.

4625. Sulphur Spring Canyon, in "reef beds;" sec. 23, T. 22 S., R. 15 E.

4627. The "reef bed" just west of Big Tar Canyon; in north part of sec. 18, T. 23 S., R. 16 E.

4628. Oil sand series, in west fork of canyon west of well 3 miles southwest of Coalinga, sec. 12, T. 21 S., R. 14 E.

4629. Anticline Canyon about 3 miles southwest of Coalinga, in roughly bedded gypsiferous sand overlying fossiliferous Chico; in center of sec. 2, T. 21 S., R. 14 E.

4631. *Turritella* bed on east flank of high hill northeast of Oil City, in the SE. ¼ NE. ¼ sec. 16, T. 19 S., R. 15 E.

4633. *Turritella* bed just about 11 miles north-northeast of Coalinga, below the Big Blue, on ridge in sec. 10, T. 19 S., R. 15 E.

4634. Hill south of well sec. 12, T. 21 S., R. 14 E., about 3 miles southwest of Coalinga.

4635. Bed just below the Big Blue, 1½ miles northeast of Oil City, near the SE. ¼ SE. ¼ sec. 16, T. 19 S., R. 15 E.

4637. Six miles northwest of Coalinga, about 500 feet south of contact of Tejon and Miocene, in center of NE. ¼ sec. 2, T. 20 S., R. 14 E.

4655. About 3¾ miles due west of Coalinga, from prominent sandstone bed about 100 feet stratigraphically above contact of concretionary sandstone (Chico) beds with Vaqueros.

4667. The "reef bed" on Reef Ridge, about 1½ miles east of Jasper Canyon, one-half mile west of 2,700-foot hill 5½ miles south-southwest of Alcalde; 125 feet above Cretaceous; in east-central part of sec. 18, T. 22 S., R. 15 E.

Vaqueros (lower Miocene) fossils from the Coalinga district, California—Continued.

Name.	4764.	4770.	4771.	4772.	4773.	4774.	4775.	4777.	4803.	4859.	4860.	4861.
ECHINODERMATA.												
Scutella merriami F. M. Anderson				×		×	×		×		×	×
PELECYPODA.												
Arca obispoana Conrad									×			
Arca osmonti Dall										×		
Cardium vaquerosensis Arnold											×	
Chione conradiana F. M. Anderson												
Chione temblorensis F. M. Anderson									×		×	×
Corbicula dumblei F. M. Anderson												
Dosinia mathewsonii Gabb									×			
Dosinia ponderosa Gray												
Macoma aff. secta Conrad												
Macoma piercei Arnold												×
Metis aff. alta Conrad										×	×	×
Mulinia densata Conrad									×			
Mulinia densata Conrad var. minor Arnold		×						×				
Mytilus mathewsoni Gabb var. expansus Arnold									×			×
Ostrea titan Conrad	×				×				×		×	×
Pecten andersoni Arnold	×		×	×					×		×	×
Pecten crassicardo Conrad											×	×
Pecten estrellanus? Conrad												
Pecten miguelensis Arnold	×											
Phacoides acutilineatus Conrad									×	×	×	×
Phacoides (Miltha) sanctæcrucis Arnold												×
Saxidomus vaquerosensis Arnold												
Septifer coalingensis Arnold												
Tivela inezana? Conrad												
Venus pertenuis Gabb												×
Yoldia impressa Conrad										×		
Zirphæa dentata Gabb									×			
GASTEROPODA.												
Agasoma kernianum Cooper												
Agasoma sanctacruzana Arnold												
Bathytoma piercei Arnold												
Cancellaria vetusta Gabb												
Cancellaria andersoni Arnold												
Conus owenianus F. M. Anderson												
Conus hayesi Arnold												×
Crepidula sp												
Ficus pyriformis Gabb												
Neverita callosa Gabb									×			×
Ocinebra topangensis Arnold											×	
Trochita filosa Gabb									×			
Trochita sp. indet												×
Trophon (Forreria) bartoni Arnold									×			×
Trophon (Forreria) gabbianum F. M. Anderson									×		×	×
Trophon (Forreria) gabbianum F. M. Anderson var. cancellarioides Arnold												×
Turritella ocoyana Conrad		×										×
Xylotrya sp. *a*											×	
CIRRIPEDIA.												
Balanus sp	×										×	×
CRUSTACEA.												
Branchiolambrus altus Rathbun										×		

4764. Stone Canyon coal mine, Monterey County, Cal., 40 feet stratigraphically above the coal.

4770. *Turritella ocoyana* bed in Canoas Canyon, 1½ miles southwest of Hugo Kreyenhagen's, NE. ¼ SE. ¼ sec. 32, T. 22 S., R. 16 E.

4771. *Pecten andersoni* bed in Canoas Canyon, 200 feet stratigraphically above 4770.

4772. *Scutella merriami* bed ("button bed") in Canoas Canyon, 600 feet stratigraphically above 4770.

4773. About 8½ miles north of Coalinga, on Laval grade; "oyster bed" of variable sand, just above oil sand at base of Vaqueros.

4774. About 8½ miles north of Coalinga, on hill just east of Laval grade; "button bed" about 100 feet stratigraphically above 4773; NW. ¼ sec. 21, T. 19 S., R. 15 E.

4775. Garza Creek gorge in Reef Ridge, hard sandstone "button bed" 225 feet stratigraphically above 4624; southeast corner of sec. 3, T. 23 S., R. 16 E.

4777. Jasper Canyon through Reef Ridge, 1½ miles southwest of fork of Jacalitos Creek, in hard sandstone and conglomerate "reef beds."

4803. About 8½ miles north of Coalinga, "button bed" 200± feet above Eocene unconformity on Laval grade; SW. ¼ sec. 21, T. 19 S., R. 15 E. (Practically the same as 4774.)

4859. Wagon Wheel Mountain, Devils Den district, Kern County, Cal., dark gypsum-bearing shale 50 feet stratigraphically below "reef bed" or "button bed;" NW. ¼ sec. 36, T. 25 S., R. 18 E.

4860. Same locality as 4859; in hard sandstone "reef bed" or "button bed."

4861. Devils Den district, Kern County, Cal., "reef beds" one-fourth mile south and southeast of Barton's cabin, which is in the NW. ¼ sec. 23, T. 25 S., R. 18 E.

OTHER SPECIES COLLECTED.

To the list of fossils given above should be added the following species, among others, collected by F. M. Anderson[a] from the Vaqueros in the Coalinga district: *Agasoma gravida* Gabb, *Crepidula prærupta* Conrad.

FAUNAL ZONES.

Three distinct fossiliferous zones are recognizable in the Vaqueros section north of Coalinga. The lower one is but a short distance above the base of the formation and is represented solely by *Ostrea titan* Conrad (loc. 4773). The middle zone, that of the "reef beds," is about 225 feet above the base and is characterized by *Pecten andersoni* Arnold, *Arca osmonti* Dall, and *Scutella merriami* Anderson (loc. 4774 and 4803). The upper zone, which lies at the top of the Vaqueros and just below the Big Blue sandy shale, is characterized by a unique fauna, in which occur such forms as *Agasoma santacruzana* Arnold, *Cancellaria vetusta* Gabb, *Turritella ocoyana* Conrad, and several other species. The fauna at locality 4631 is characteristic of the last zone.

FAUNAL RELATIONS AND AGE.

In the Coalinga district the correlation of the sandstone formation, of which the "reef beds" are a part, with the Vaqueros formation of the outer Coast Ranges is based upon the large number of species common to the two. At one point in particular on the northeastern flank of the Temblor Range, near Antelope Valley, in sec. 36, T. 26 S., R. 17 E., a few miles south of the south line of the region under discussion, the "reef beds" contain a typical Vaqueros fauna with such forms as *Pecten magnolia* Conrad, *Turritella inezana* Conrad, *Pecten bowersi* Arnold, and many other typical Vaqueros species. The region from which this fauna comes is believed by the writers to mark an old lower Miocene strait joining the San Joaquin lower Miocene sea with the lower Miocene sea which once covered much of the territory now occupied by the outer Coast Ranges.

The lower Miocene (Vaqueros) formation in the Kreyenhagen field was described under the name "Temblor beds" (lower Miocene) by F. M. Anderson,[b] from its characteristic occurrence farther south along the border of the Great Valley near the Temblor ranch. Owing to the possibility of correlating[c] it with the lower Miocene in the Coast Ranges to the west the name Vaqueros, previously adopted in the literature for the beds of that age, is here used.

The assignment of a lower Miocene age to the Vaqueros sandstone is based upon the general similarity of certain members of its fauna

---

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, No. 2, 1905, pp. 171-172.

[b] Idem, p. 170.

[c] In a later paper (Proc. California Acad. Sci., 4th ser., vol. 3, 1908, p. 39) F. M. Anderson recognizes the correlation of his "Temblor beds" of the San Joaquin Valley with the Vaqueros of the outer Coast Ranges.

to species in the lower Miocene of the Atlantic States and upon its relative position in the geologic column of the Pacific coast. This correlation, first made by Conrad, has, so far as the writers are aware, never been questioned.

IMPORTANCE WITH RELATION TO PETROLEUM.

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

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

GENERAL DESCRIPTION.

A zone of beds full of fossil oysters and barnacles of very large size runs through the midst of the developed oil territory north of Coalinga, and is well known by those familiar with the field. (See Pl. XII, *B*.) Its fossils show it to belong in the same portion of the geologic column as the formation in the drainage basin of Salinas River, farther toward the coast, that has been named the Santa Margarita by H. W. Fairbanks.[a] This formation belongs in the upper part of the middle Miocene. No fossils have been found in the beds immediately below or above the *Tamiosoma* zone, as the fossil beds referred to may be termed from the typical and restricted occurrence in them of the large barnacle of that genus. But the beds below and above, for a thickness of several hundred feet, are for the present mapped in the same formation with the fossil beds because closely associated with them and because affording no sufficient basis for correlation with any other formation.

The basal portion of the formation so mapped is the zone known to the drillers as the Big Blue, the probable unconformable relation of which to the underlying Vaqueros (lower Miocene) has been pointed out (p. 82). The possible Monterey (middle Miocene) age of the Big Blue has also been mentioned (p. 76). This zone in some portions of its extent presents a very striking lithologic contrast to the *Tamiosoma* zone, which fact, coupled with the fact that it is overlapped by

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

the *Tamiosoma* zone on the west side of Pleasant Valley, indicates that it is a distinct unit. Mapping it alone, however, would have led to too great complexity. If it did originate in Monterey time it can at most represent but a brief fraction of that period.

In the Kreyenhagen field the portion of the series between the Vaqueros (lower Miocene) and Jacalitos (upper Miocene), corresponding to the portion occupied by the Santa Margarita (?) farther north, is made up of nonfossiliferous, hard, largely white siliceous shales, and it can not be stated definitely whether or not they are a continuation of the beds to the north. This shale is similar in lithologic character, mode of occurrence, and stratigraphic position to shale on the southwest side of Waltham Valley toward the head of Jacalitos Creek, a few miles west of the area of the map, and is believed to be a continuation of it. In that region the shale zone is underlain by sandstone beds containing fossils typical of the Santa Margarita, as listed under fossil localities 4805, 4841, and 4842. A similar shale zone is present in a similar stratigraphic position over the typical fossiliferous sandstone beds of the Santa Margarita on the opposite side of the Diablo Range on the slope draining to Salinas River. The siliceous shale of Reef Ridge and McLure Valley is therefore tentatively correlated with the Santa Margarita. Inasmuch as the fossiliferous Santa Margarita (?) beds in the northern part of the district and those underlying the shale zone in Waltham Valley may belong to the same horizon in the formation, it is possible that the shale on Reef Ridge is of later age than the *Tamiosoma* zone in the northern part of the district. The period of geologic time between the Vaqueros (lower Miocene) and Jacalitos (upper Miocene) is thought to be represented only in its later part by the *Tamiosoma* zone and associated beds of the Coalinga field and the siliceous shale along Reef Ridge and McLure Valley, the Monterey formation (early middle Miocene) of the region nearer the coast being wholly or at least in large part lacking.

DISTRIBUTION AND LOCAL CHARACTER.

SANTA MARGARITA (?) IN THE COALINGA FIELD.

The basal part of the formation mapped as the Santa Margarita (?) formation is the zone known to the drillers as the Big Blue. This consists in the central part of the Eastside field of about 300 feet of light-gray fine sand and clay that appear to have a light-bluish tinge, especially when moistened. Farther north other materials enter into this portion of the series, causing it to be one of the most varied zones in the region. No fossils have been discovered in it, and its peculiar features show that it was formed under unusual conditions. (See geologic history, p. 175.) It is recognized in the oil wells as a zone of sticky and frequently tough sand and clay immediately overlying the oil sands. Toward the northern edge of the area mapped it becomes coarser and is largely made up of fine-grained, coarse-grained, and bowlder beds composed of serpentine fragments, having evidently been derived from an area of serpentine that was in close proximity. Some of these serpentinous beds are extremely hard and they form prominent buttes colored by the decaying serpentine in a variety of shades of light blue, green, brown, and dark red. A typical row of these buttes is shown in Plate X. This zone of beds continues far northwest of the mapped area as a prominent feature of the hills.

The Big Blue is overlain by the *Tamiosoma* zone, which comprises a thickness of about 175 feet of fossiliferous, fine, medium-grained, and coarse, usually gray sand and minor amounts of conglomerate. This in turn is overlain by 400 to 500 feet of alternating beds of fine sand, sandy clay, coarser sand, and gravel up to the base of the prominent and thick gravel zone considered as marking the base of the Jacalitos. These upper beds are without fossils as far as examined and have little to characterize them. The succession of upper beds of the Santa Margarita (?) formation and the lower Jacalitos beds is shown in Plate XVII.

Toward the southwest the Santa Margarita (?) formation disappears east of Oil Canyon, being overlapped by the Jacalitos. It is not known just where the overlap is, because the beds are poorly exposed and have no distinguishing characters there. Beds of the *Tamiosoma* zone underlie Pleasant Valley toward its head, as shown by fossils obtained at depth in wells near the course of Los Gatos Creek. On the west side of Pleasant Valley a remnant of the *Tamiosoma* zone appears, resting directly and with pronounced angular unconformity upon the Tejon (Eocene) at the San Joaquin Valley coal mine. The traceable area of it is not large enough to allow its separation from the later beds on the map. This is the southernmost point at which the fossils of this zone have been found within the district, and south of it the *Tamiosoma* zone is either absent or hidden by the overlapping beds of later age, which are mapped with the Jacalitos formation. There is present, however, beneath the fossiliferous Jacalitos beds, between the coal mine and Waltham Creek, a zone of bluish and grayish clay, about 250 feet thick, mapped with the Vaqueros of that area, that may possibly represent the same horizon as the Big Blue in the Eastside field, though this is doubtful.

SANTA MARGARITA (?) IN THE KREYENHAGEN FIELD.

The Vaqueros sandstone all along Reef Ridge and the Cretaceous in the Pyramid Hills and around McLure Valley is overlain by a formation of white, purplish, and brownish siliceous and argillaceous shale, having a thickness varying between 50 and 1,200 feet. The

CHARACTERISTIC BLUFFS, WITH STRIKE FACE AND DIP SLOPE, FORMED BY VARICOLORED MIOCENE SANDSTONE, SHALE, AND CONGLOMERATE.

Looking northeast at outcrops of Big Blue, 11 miles northeast of Coalinga. Note local fault on the left. Photograph by Ralph Arnold.

thin, sharp beds of shale dip away from Reef Ridge on its northeast flank, and their upturned edges are exposed in a narrow belt which follows the face of the ridge. This belt is likewise a topographic feature, owing to the resistance of the beds, which produce a line of shoulders or knobs on the small lateral ridges descending toward the foothills. The zone occupied by these shales is well shown in the foreground on the right and all along in front of Reef Ridge to the left in Plate VIII. Southeast of Little Tar Canyon the ridge of the Pyramid Hills, which is entirely composed of the shale, is a still more marked expression of this topographic influence, which is likewise characteristic of the formation elsewhere, as, for instance, along the Tent Hills west of McLure Valley, as shown in Plate XI, *A;* in the peculiar curving line of knolls that circles around the base of the mountain mass at the head of McLure Valley on the northwest; and also in the region of Antelope Valley, south of the area of the map, and in the Waltham Valley, west of it. The features described make this shale formation easily recognizable as a lithologic unit with strong individuality, and in the Coalinga district distinguish its main portion markedly from the Vaqueros (lower Miocene) sandstone below and the soft sandstone beds of the Jacalitos (upper Miocene) above. This shale formation is tentatively correlated with the Santa Margarita. It may be a deep-water equivalent of the coarser sediments in the Coalinga field, which at the north end of the area mapped are of a strikingly littoral nature, or it may be of different age.

Lithologically this formation has strong affinities with the well-known Monterey (middle Miocene) shale, which is widely distributed in the Coast Ranges farther west, and its stratigraphic position above lower Miocene and below upper Miocene in this district corresponds to that of the Monterey shale elsewhere. But no proof is known of the contemporaneity of the two formations, whereas the fossil evidence already discussed indicates a lesser age. The shale is likewise very similar to the shale in the upper portion of the Tejon north of Coalinga. This mutual similarity has led previous observers to class the two together and to correlate both with the Monterey.

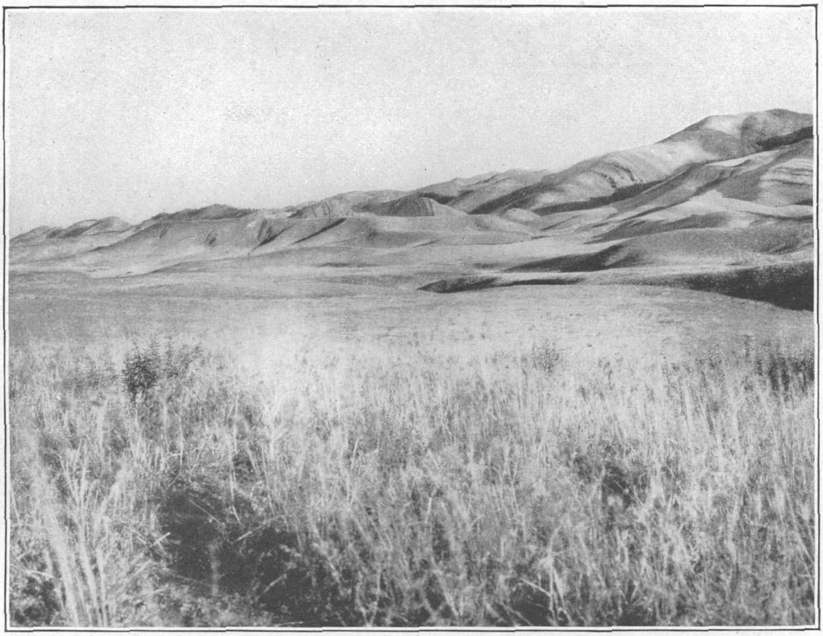
Along the greater portion of Reef Ridge no unconformity at the base of the shale is apparent, all the formations being similar in dip. But an unconformity is indicated by the fact that the shale overlaps upon the Vaqueros and Tejon at the southeast end of the ridge and that in the region of McLure Valley it lies directly upon the Cretaceous beds, the Vaqueros and Tejon having either never been deposited or else been worn away. As regards the relation of the shale to the overlying formation (the Jacalitos, upper Miocene), it may be said that no definite line of separation has been found and that in appearance a conformable gradation exists along Reef Ridge, although the pinching out of the white shale and finally the overlap of the Jacalitos beds directly upon the Vaqueros farther to the north indicate that an unconformity exists. The shale is lithologically distinct from the greater part of the Jacalitos formation, but there is a nonfossiliferous transitional zone of alternating sandstone and shale beds having a thickness of several hundred feet, which may belong to either formation. This has been tentatively included with the Jacalitos in the mapping, the beds to which the name Santa Margarita (?) formation is applied being restricted for the present to the underlying shale.

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

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

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

The two lower of these three zones differ largely in the proportion of hard beds that they contain, and, as this proportion varies from place to place, they do not form continuous belts distinct from each other. Together they make up the lower portion of the formation according to the division above referred to. The siliceous shale of the lower portion varies in amount of induration from a dull opaque rock that may be scratched with the finger nail to a subvitreous flinty variety that will not be scratched by a knife. It resembles very strongly the altered varieties of the Monterey shale (middle Miocene), that occurs nearer the Pacific coast, and of the shale of the Tejon formation and "indicator" bed of the Vaqueros of this district. Like these its less altered varieties show traces of thickly embedded round dots and flakes that are almost certainly the remains of diatoms, and the shale has the characteristic flaky texture of diatomaceous



A. AVENAL RIDGE AND TENT HILLS, SEEN FROM NORTHEAST ACROSS McLURE VALLEY.

Showing steeply dipping Cretaceous strata on Avenal Ridge, the conical hills of white Miocene shale extending into the distance, and the terraced surface of the Jacalitos formation flanking the hills. Photograph by Ralph Arnold.

B. SILICEOUS SHALE OF SANTA MARGARITA (?) FORMATION (MIDDLE MIOCENE) AT HEAD OF McLURE VALLEY.

Looking southeast along contact with underlying, less prominent Cretaceous shale on left. Note surficial overturn and typical vegetation of Miocene shale zone. Photograph by Ralph Arnold.

material. The more siliceous shale seems to be almost entirely made up of the crushed diatom tests. A sample of shale from the middle zone in the locality of the above section contained 86 per cent of silica according to an analysis made by R. C. Wells, of the United States Geological Survey. The shale contains also fish scales and other particles of organic origin, but almost no molluscan remains. The laminæ are locally yellowish and calcareous and similar to the foraminiferal shale of the Tejon.

Southeast of Little Tar Canyon the formation increases in thickness to about 1,200 feet, the increase being mostly in the brownish shale of the upper portion. The base of the formation is approximately at the axis of the anticline of the Pyramid Hills. The shale appears on both sides of McLure Valley, with a general steep dip toward the valley and with little change in lithologic character or thickness.

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

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

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

FOSSILS AND AGE.

LIST OF FOSSILS.

The Santa Margarita (?) formation, from a point 8 miles north of Coalinga northwestward for a distance of at least 6 or 8 miles, is exceedingly fossiliferous, the principal species being the big oyster *Ostrea titan* Conrad, the big barnacle-like *Tamiosoma gregaria* Conrad, and the scallop shell *Pecten estrellanus* Conrad. The names *Tamiosoma* zone and "big oyster beds" have been locally applied to these fossiliferous strata. The species found in this bed by James H. Pierce and the writers are among the following, which comprise the fauna for this formation in the district:

Santa Margarita (upper middle Miocene) fossils from the Coalinga district.

Name.	4632.	4651.	4766.	4805.	4841.	4842.	4848.
ECHINODERMATA.							
Astrodapsis whitneyi Rémond			×				
PELECYPODA.							
Chione conradiana F. M. Anderson							×
Cryptomya ovalis? Conrad	×						
Dosinia ponderosa Gray	×						
Hinnites giganteus Gray		×	×				
Macoma nasuta Conrad	×	×					
Ostrea titan Conrad	×	×	×	×	×	×	
Pecten crassicardo Conrad			×			×	
Pecten estrellanus Conrad		×	×		×	×	
Solen sicarius Gould	×						
Zirphæa dentata Gabb	×						
GASTEROPODA.							
Trophon (Forreria) carisaensis F. M. Anderson			×			×	
CIRRIPEDIA.							
Tamiosoma gregaria Conrad	×	×	×			×	

4632. At and northwest of San Joaquin Valley coal mine near Miocene-Eocene contact.

4651. *Tamiosoma* zone or "big oyster bed" in canyon between old Standard Oil Company and California Oil Fields Limited camps, sec. 28, T. 19 S., R. 15 E.; 8 miles north-northeast of Coalinga.

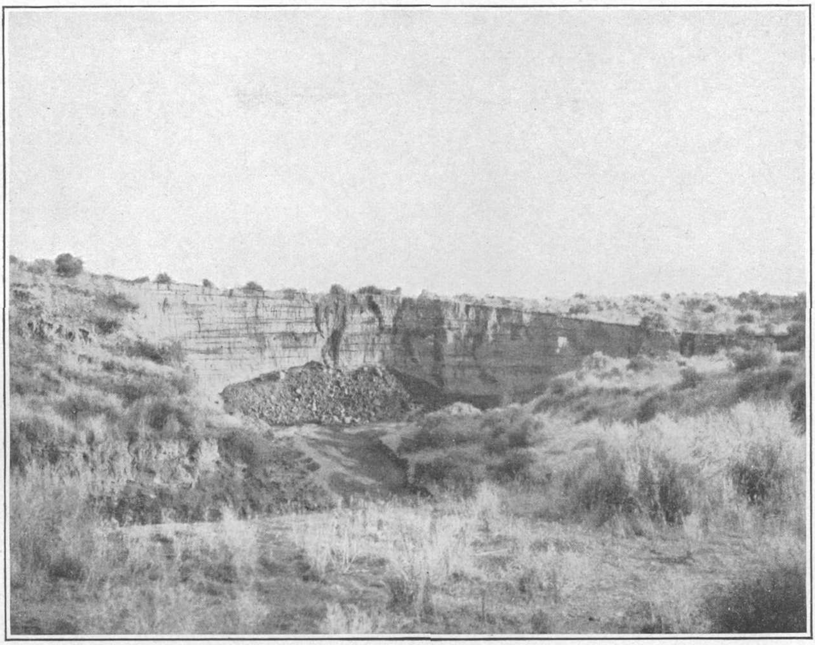
4766. *Tamiosoma* zone or "big oyster bed" above Big Blue, NE. ¼ sec. 21, T. 19 S., R. 15 E., west of Peerless Oil property, 9 miles north of Coalinga.

4805. Waltham Valley, 13 miles southwest of Coalinga; oyster bed 2 miles west of Elmer Frame's house; sandstone under shale.

4841. Sandstone next to serpentine, at head of Bray and Secords Canyon, 3 miles south of Waltham Valley.

4842. Sandstone at mouth of Bray and Secords Canyon, south side of Waltham Valley. This sandstone underlies the shale in this vicinity.

4848. Nine miles north-northeast of Coalinga, just above *Tamiosoma* zone or "big oyster bed," one-fourth mile northwest of Peerless wells.



A. ARROYO CUTTING PLEISTOCENE SAND AND CLAY THAT COVER SAN JOAQUIN VALLEY.

On plain east of Kettleman Hills, 2 miles southwest of Tulare Lake. Photograph by Ralph Arnold.

B. FOSSIL PECTEN ESTRELLANUS BED IN SANTA MARGARITA (?) FORMATION, 10 MILES NORTH OF COALINGA.

Part of Tamiosoma zone characteristic of the middle Santa Margarita (?) in the oil field. Note large Ostrea titan at the left. Photograph by Ralph Arnold.

FAUNAL RELATIONS AND AGE.

The fauna of the Santa Margarita (?), though small, is one of the most characteristic that is found in the southern Coast Ranges. The association and abundance of certain unique species such as *Tamiosoma gregaria* Conrad, *Trophon carisaensis* F. M. Anderson, and *Pecten estrellanus* Conrad at once indicate its correlation with the Santa Margarita formation of the Salinas Valley and Carrizo Plain regions. The correlation of the siliceous shale in Reef Ridge with the Santa Margarita is based upon the similar stratigraphic position of these shales to beds on the western side of Waltham Valley, near the mouths of Bray and Secords Canyon, which overlie sandstones at locality 4842, containing the following Santa Margarita fauna:

Mytilus aff. mathewsonii Gabb.
Ostrea titan Conrad.
Pecten crassicardo Conrad.
Pecten estrellanus Conrad.
Tamiosoma gregaria Conrad.
Trophon carisaensis F. M. Anderson.

For a number of years the Santa Margarita formation was believed to be the equivalent of the San Pablo formation of the Mount Diablo region, but the stratigraphic work in the Coalinga district seems to show it to be older. At least it is quite evident that the Etchegoin formation represents at least a considerable part of the San Pablo, and as the Etchegoin lies well above the supposed Santa Margarita it seems likely that the latter is, at least in part, of greater age than the San Pablo.

With the Etchegoin and Jacalitos formations correlated as upper Miocene, it seems most logical to place the Santa Margarita in the upper part of the middle Miocene, thus confining the Monterey to the lower part of the middle Miocene. Such an arrangement would assign the far-reaching post-Monterey diastrophic period to the middle of the Miocene. This classification and correlation is of course more or less arbitrary and necessarily tentative, but it seems to best fit the information now in hand.

IMPORTANCE WITH RELATION TO PETROLEUM.

In the Coalinga field the Santa Margarita (?) formation has an important relation in different ways to the occurrence of the petroleum. In the Eastside field its base is taken as extending down through the Big Blue. This zone caps the Vaqueros formation, or productive zone, and although small amounts of oil and tar are found above its base there is none in commercial quantities. The Santa Margarita (?) is of chief importance there as forming an impervious capping which has held the oil in. In the Westside field the formations are thinner, and sand beds of the Santa Margarita (?)

become part of the productive zone. In the Kreyenhagen field the Santa Margarita (?) formation acts, like the Big Blue, as an impervious capping that keeps the oil confined within the Vaqueros sandstone. The similarity of the shale so mapped to the organic shales that elsewhere have been considered the source of oil suggests the possibility that this formation has given rise to some petroleum, but no evidence has been found to bear out such a supposition.

JACALITOS FORMATION (EARLY UPPER MIOCENE)

DEFINITION AND GENERAL DESCRIPTION.

The formation overlying the shale mapped on Reef Ridge as Santa Margarita (?) consists of alternating beds and zones of both soft and indurated sand, gravel, and clay of many varieties which extend up to the base of the beds mapped as Etchegoin and which form a belt along the southwest side of the Jacalitos and Kreyenhagen Hills. This formation has a thickness that may be conservatively stated as being 3,500 feet. In places it is very fossiliferous, and on both sides of Jacalitos Creek especially there are characteristic exposures containing abundant well-preserved fossils. It forms a unit in the Tertiary series of the Coalinga district, and in order that it may be conveniently so treated it will be referred to in this paper as the Jacalitos formation, owing to the occurrence in it of typical faunas along the creek of that name. The fossils indicate that it originated in upper Miocene time and that it is chiefly marine. In part, however, it is probably of fluviatile or lacustrine origin. It is represented in the northern portion of the district by similar beds aggregating a much smaller thickness. Its fauna gives it individuality, and in portions at least of the Coalinga district it is separated from the beds above and below by unconformities. It is probably in part the equivalent of one or more of the upper Miocene formations known in other portions of the State, but until its definite relations to them have been worked out it is necessary to designate it by a local name.

MEANS OF RECOGNITION.

The most important features of the Jacalitos formation by which it may be recognized are its position in the series of Tertiary strata, as outlined on the geologic map and in the text, and the various fossils and fossiliferous zones that it contains. These are listed and discussed below. Owing to its lack of strong lithologic or topographic individuality, the fossils afford the only means which may be relied upon for separating it from the other sandy formations. The fossiliferous beds are frequently much indurated, and they occur at intervals on the surface as hard zones that project like saw teeth and by their resistance protect the beds immediately above and below them. Long parallel ridges are thus produced. The same feature, however, is characteristic of other formations in this region. The occurrence in all parts of the formation of a great number of sand and pebble beds full of sand dollars is typical of it in the southern portion of the district, though this likewise is a characteristic of the formation above. The usual character of the hills composed of beds of this formation is illustrated in Plates II, *B*, III, and XVII. In a rough way the formation may be distinguished as that portion of the series between the white shale of Reef Ridge below and the major beds of blue sand which throughout the district lie at the base of the formation (the Etchegoin) above it. This upper limit is indefinite, however, owing to the fact that through much of the district the Jacalitos includes a great thickness of blue sand beds in its upper portion.

The blue sand and pebble beds are a striking feature of the Jacalitos and Etchegoin formations in this district. The blue color is due to a thin coating over the individual grains. An analysis of this coating made by R. C. Wells, of the United States Geological Survey, indicates that it is probably vivianite. Its appearance suggests that it might be of similar origin to the blue color frequently noticeable in tuffaceous sands, notably in andesite tuffs of Nevada, and that it might be a product of the decomposition of the minerals of a tuff, but it is believed that the color is of entirely different origin in these two types of deposits.

From its locality of typical occurrence in the Kreyenhagen and Jacalitos hills the Jacalitos formation extends southwestward into McLure Valley, where it has a similar position above the shale of the Santa Margarita (?) formation. Toward the northwest it reaches into the interior of the Diablo Range in the depression formed by the Waltham syncline and toward the north it extends across Alcalde Canyon and into the region around Pleasant Valley. North of Jacalitos Creek it no longer rests upon the shale of the Santa Margarita (?) formation, those beds being lacking, and north of Alcalde Canyon the Jacalitos ceases to be completely represented. The question of the relations of the beds of this age in the northern and southern portions of the district is complex and can be decided only on the basis of detailed paleontologic evidence, aided by study of the structure. Lithology fails almost entirely to be of service. The formation will be discussed separately for the areas lying to the south and to the north of Alcalde.

STRATIGRAPHIC RELATIONS.

The Jacalitos formation in the Kreyenhagen field is unconformable with the shale mapped as the Santa Margarita (?) formation, as may be seen at the northwest end of Reef Ridge, where that shale becomes lost. Along the greater portion of Reef Ridge, however, a definite appearance of unconformity has not been found, and the line between the two formations is therefore drawn arbitrarily for the present where the beds that are predominantly shale give place above to sandy beds. Toward the head of Zapato Creek and thence westward is a succession of several hundred feet of alternating beds of brown sandstone and dark shale above the siliceous shale of the Santa Margarita (?) formation. These beds are mapped with the Jacalitos, tentatively, it being uncertain to which formation they properly belong.

In the northern part of the district the Santa Margarita (?) beds appear conformable with the beds above, but the overlap of the Jacalitos over the Santa Margarita (?) near Oil Canyon proves clearly that the relation is an unconformable one. Owing to the lack of persistence in the lithologic peculiarities or outcrops of the beds and the scarcity of distinguishing characters, such as fossils for different beds in the series between the *Tamiosoma* zone and the Etchegoin formation, it would be a matter of great difficulty to determine at what horizon the unconformity exists. The base of the Jacalitos formation in this part of the district is thought to be represented, however, by a prominent zone of gravel and conglomerate which contains an abundance of fossilized wood and which is fairly constant along the line mapped as the base north of Pleasant Valley. This zone has yielded a tooth of *Pliohippus*, an extinct horse. The writers are of the opinion that the zone represents a period of land in this area during which river or possibly lake gravels were deposited.

The relation of the Jacalitos to the overlying formation, the Etchegoin, is similar, in that the Etchegoin has the same dip and an appearance of conformity with it in most places, but overlaps upon it elsewhere. The line between these two formations is drawn at the base of the beds which overlapped the Jacalitos and were deposited upon the Cretaceous in the White Creek basin.

DISTRIBUTION AND LOCAL CHARACTER.

JACALITOS IN THE KREYENHAGEN HILLS.

From Jacalitos Creek southward the Jacalitos formation affords more complete exposures than elsewhere. The type locality for its fossils is along this creek, near which representative faunas have been collected from different horizons, as shown in the list of fossil localities (pp. 109–111). But the undisturbed monocline that continues the same beds immediately to the southeast in the Kreyenhagen Hills furnishes somewhat better sections of the formation as a whole, which has suffered considerable disturbance along Jacalitos Creek and in the hills to the north. Moreover, in the latter region the base of the formation does not appear within the area shown on the map and has not been definitely traced.

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

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

Section of the Jacalitos formation on Jacalitos Creek.

	Feet.
Bluish to brownish-gray clay and clayey sand, alternating with light-gray and olive-gray pebbly sand, with occasional hard fossil layers, and with *Pecten estrellanus* zone at base (fossil locality 4647); overlain by blue sand at the base of the Etchegoin	750
Massive beds of buff and olive-gray sandstone and sandy clay interbedded with thin and thick beds of olive-gray pebbly sandstone and gravel, and occasional sandstone layers. Sand dollars are numerous throughout, usually in the pebbly layers. (See fossil locality 4784.) At the base (at the forks of Jacalitos and Jasper creeks) is a bed of dark-brown sandstone containing a rich fauna; top of the big *Trophon* zone (fossil locality 4765)	1,300
Alternating heavy beds of coarse gray and brown sandstone and thin beds of fine sandstone and sand of the same colors, with some beds of gritty olive-gray sandstone and hard fossil layers. Two hundred feet above base is a bed with large *Astrodapsis* (fossil locality 4654), near the base of the big *Trophon* zone	500
Alternating beds of grayish and brownish sand and sandstone with some sandy clay and fossil layers in the sandstone	750
Alternating beds of soft gray and brown shale and sandstone, much tilted and fractured and in part overturned	500±
	3,800±

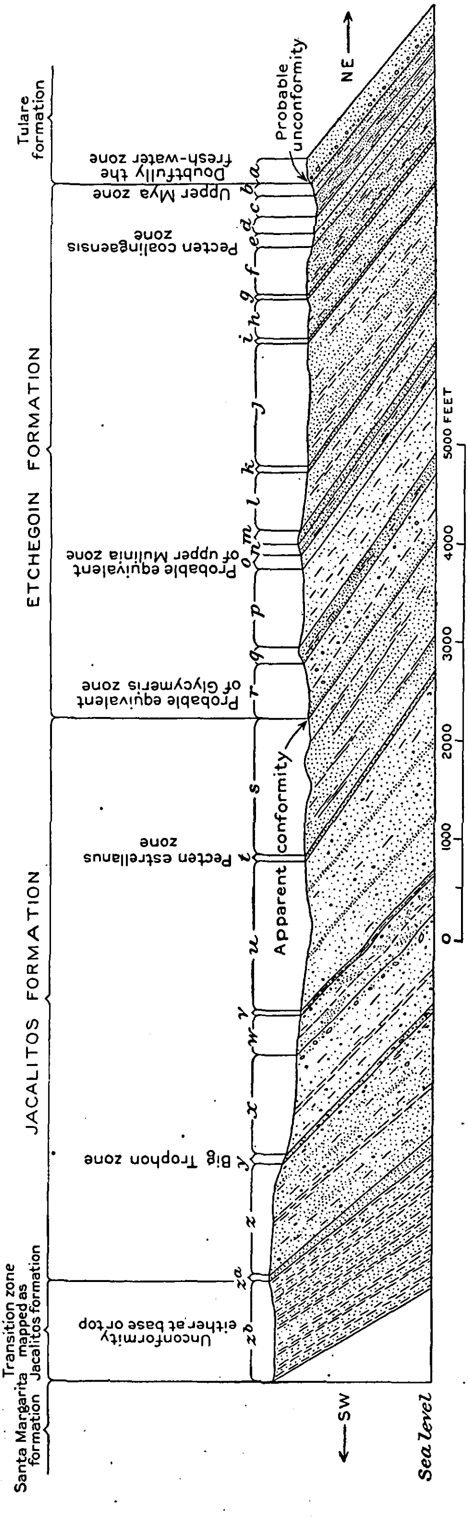


FIGURE 4.—Section of Etchegoin and Jacalitos formations in Kreyenhagen Hills east of Zapato Creek, along line M-M' on geologic map (Pl. I). (See footnote, p. 101.)

The basal portion of this section rests upon the steeply tilted Vaqueros beds that are the continuation of the prominent strata on the face of Reef Ridge. Shale similar to the typical shale mapped as Santa Margarita (?) is entirely lacking, but it is possible that the much disturbed basal zone of this section is unconformable with the Jacalitos and belongs with the Santa Margarita (?) formation. It may be the continuation of the similar thickness of alternating beds of brown sandstone and dark shale overlying the typical shale of the Santa Margarita (?) along Zapato Creek, at the base of the next section to be described.

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

The uppermost beds of the above section underlie the lowest one of a number of prominent blue sand beds that are a characteristic feature of the landscape in this district along the belt of Etchegoin beds. The line of contact between the Jacalitos and Etchegoin formations in the region of the above section is drawn on the basis of this lithologic break and of the characteristic fauna that occurs in a bed just above, at fossil locality 4761. The beds above and below the contact dip with apparent conformity at an angle of about 25°.

The section in figure 4[a] affords a summary description of the Jacalitos formation on Zapato Creek. The alternating sandstone and shale beds at the base of this section, as stated before, may belong more properly with the shale of the Santa Margarita (?) formation and represent a change that gradually takes place toward the northwest in the character of the sediments in the upper portion of that formation. Zone z^b in the section (fig. 4) is well exposed for several

---

[a] The letters in figure 4 indicate the following beds:

Tulare.	
a. Hill-forming incoherent sand and gravel at base of Tulare.	
Etchegoin.	Feet.
b. Gray sand, sandstone, and clay, with *Mya* bed at top and *Ostrea* bed at base (near localities 4722 and 4744); upper *Mya* zone	100
c. Largely clay and fine sand	150
d. Largely gray sand containing sand dollars and with *Arca* bed near base	100
e. Gray sand and pebbly gravel with locally harder beds of sandstone, forming a rich fossil zone (locality 4705); *Pecten coalingaensis* zone	100
f. Olive-gray fine sand and pebbly sand with thin sandstone layers, interbedded with clay	300
g. Bed of light-blue sand, the highest of the blue-sand zone	10
h. Massive beds of gray sand and sandy clay with occasional thick beds of blue sand	290
i. Prominent zone of pebbly sand with hard layers, *Arca* abundant	30
j. Massive gray, smooth-weathering sand like coarse beach sand, containing many inconstant laminæ of hard brownish-gray sandstone alternating with inconspicuous beds of clay, and with some blue sand	800
k. Prominent bed of massive, olive-gray, compact, irregularly bedded sand	20
l. Minor gray sand and clay beds	350
m. Prominent bed of cavernous-weathering blue sand	50
n. Alternating thick beds of gray sand and bluish clay, with thin layers of brown sandy clay and with two prominent beds of blue sand in middle. This is about the equivalent of the upper *Mulinia* zone	200
o. Prominent blue-sand bed	25
p. Olive and light-gray sand and sandy clay	425
q. Prominent group of blue-sand beds; three blue-sand beds close together forming a hill and associated with massive dark olive-gray sand, pebbly sand, and sandy clay with irregular bedding.	150
r. Prominent bed of blue sand at base, with prominent massive beds of olive-gray medium-grained and pebbly sand and minor beds of clay and blue sand above; this is the base of the blue-sand zone and approximately that of the Etchegoin	375
	3,475
Jacalitos.	
s. Soft, compact, massive, medium and fine-grained olive-gray and brownish sandstone, with some thin beds of clay shale and sandy shale, and with occasional pebbly beds. Overlain conformably by blue sandstone at the base of the Etchegoin	800
t. Calcareous sandstone with fossils, probably zone of *Pecten estrellanus*	10
u. Sandstone similar to that of *s*, with some hard layers of dark-brown sandstone	700
v. Fine-grained, gritty, white, ashlike shale	15
w. Sandstone similar to that of *s*, with occasional thick beds of cross-bedded pebbly sandstone and beds of sandy shale with flaky texture; at the top a hard bed containing *Pecten*	250
x. Similar sandstone and shale with concretions in sandstone near the top	650
y. Sandstone bed with *Pecten*, *Panopea*, sand dollars, barnacles, etc., the approximate equivalent of the big *Trophon* bed on Jacalitos and Canoas creeks	10
z. Soft, fine and medium grained, massive grayish and buff sandstone and sandy shale with occasional hard layers and pebbly beds; some coarse sandstone beds in upper part full of large fragments of petrified wood	740
za. Hard sandstone layers with poorly preserved fossils	50
zb. Alternating beds of fairly hard brown sandstone and dark clay shale, only doubtfully referable to the Jacalitos. It is underlain, to all appearance conformably, by the siliceous shale of the Santa Margarita (?) and may belong to that formation	600
	3,825
Total Etchegoin and Jacalitos	7,300

miles along the south side of the longitudinal valley of Zapato Creek, along that portion shown on the left in Plate VIII, the contact between this zone and the overlying soft sand zone being marked by the valley. Further work may show that the contact followed by this valley is an unconformable one. The abundant petrified wood in the beds above suggests their equivalence to the beds taken as the base of the Jacalitos north of Pleasant Valley and an origin other than marine. The big *Trophon* zone (*y* in fig. 4) above the fossil-wood beds forms a capping for a longitudinal ridge that extends in front of Reef Ridge on the north side of the valley. To the west of Zapato Canyon, where this longitudinal ridge coalesces with Reef Ridge, beds of the big *Trophon* zone continue to form prominent shoulders on the various lateral ridges that they cross.

Various other hard beds in the middle portion of the Jacalitos formation form similar lines of hills or partially continuous ridges along their strike and may thus be traced for a long distance, but most of them acquire greater induration only locally and give place to other beds as ridge formers after an extent of a few miles. In the hills between Jacalitos and Zapato creeks the middle portion of the formation is especially rich in sand-dollar beds, some of which are of fine gravel and form the most prominent hills. As the section explains, the top of the Jacalitos here as well as on Jacalitos Creek is marked by the overlying blue sands of the Etchegoin. In addition to this easy means of distinguishing between them an important fossil bed, the probable equivalent of the *Glycymeris* zone, may be traced most of the way between these two creeks near the base of the blue sand.

The following is a section along Canoas Creek from the top of the Jacalitos, which is immediately south of the house of Hugo Kreyenhagen, to its contact with the Santa Margarita(?) formation.

Section of the Jacalitos formation along Canoas Creek.

	Feet.
Chiefly grayish sand and soft sandstone, with thick pebbly zone at base containing *Pecten estrellanus* (fossil locality 4767). Overlain by rich fossil bed of locality 4769, at base of Etchegoin	650
Chiefly massive, gray and buff, coarse-grained sand; a prominent bed of friable dark sandstone with *Panopea*, etc., at base	1,000
Similar sand with prominent ridge-forming bed at base	350
Similar sand with prominent bed, the big *Trophon* zone, at base	400
Similar sand with occasional sandstone layers and with prominent sandstone bed at base forming first hill northeast of Reef Ridge	500
Similar sand grading below into sandy shale overlying the Santa Margarita (?) formation	600
	3,500

Between Zapato and Canoas creeks the beds follow low, gently rolling strike ridges and valleys, and although they are soft and not prominently exposed they may be traced by means of the topography and the belts of vegetation. A peculiar feature of the beds is that in several places those which form ridges west of Zapato Creek or part way across to Canoas Creek become transferred to strike valleys, and vice versa, the original tendency in some beds being reassumed farther along their course. This feature is equally characteristic of other portions of the Kreyenhagen and Jacalitos hills and of the overlying Etchegoin formation as well. This inconstancy frequently makes the task of tracing the beds a puzzling one.

The Jacalitos beds show every appearance of being conformable with the shale of the Santa Margarita (?) formation in the region of the foregoing section. The shale and sand 600 feet thick given at the base of the section are thought to be equivalent to the basal zone already discussed in connection with the previous sections. Northeast of the valley occupied by this zone there extends a prominent ridge formed by a succession of beds, containing numerous hard fossil layers and comprising a thickness of about 1,200 feet, that are the continuation of the similar beds found in the previous sections. In the central portion of this fossiliferous zone is the big *Trophon* zone.

The top of the Jacalitos here as elsewhere is marked by a typical association of fossils in the summit beds, and the usual basal Etchegoin fauna, which is of somewhat different character, occurs in the beds just above. The line is marked here as in the previous instance by being at the base of the blue-sand beds of the Etchegoin.

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

Southeast of Big Tar Creek the beds begin to lose in prominence and to form nearly uniform rolling hills of soft sand with few large exposures. The dip in this region becomes uniformly about 60°. The following section shows the character of the formation at about the farthest point southeast in the Kreyenhagen Hills at which a section of any completeness can be obtained from the surface exposures. Beyond this point the hills still preserve traces of their longitudinal strike structure, but much more faintly than farther northwest, and most of the beds are soft and weather out into surface sand that hides them. Fossils are only rarely to be found and there is next to no basis for separation between zones or formations.

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

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

JACALITOS IN THE REGION OF M'LURE VALLEY.

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

Around McLure Valley the more siliceous beds of the Santa Margarita (?) grade upward into 500 to 600 feet of soft brown argillaceous shale and some sand that reach up to the base of a prominent bed of brown sandstone which is mapped as the base of the Jacalitos. Further investigation may prove the upper portion of the succession of beds here included in the Santa Margarita (?) formation to be equivalent to the transitional shale and sandstone zone appearing at the base of the Jacalitos sections in the northern part of the Kreyenhagen Hills. Along the north side of McLure Valley and the valley of Avenal Creek the hard, prominent sandstone bed mentioned extends continuously with a dip toward the valley of about 50° and forms a succession of eminences. Along the southwest side it is not so easily traceable. Above this bed comes a succession of soft beds, chiefly of sand, aggregating about 2,600 feet in thickness up to the base of a prominent bed of soft, coarse blue sandstone like that in the upper portion of the Jacalitos and the lower portion of the Etchegoin, previously noted. This sandstone influences the topography by forming hills as much as 100 feet high. About 1,000 feet stratigraphically above it a similar blue bed makes its appearance in the axis of the plunging syncline near the head of McLure Valley, and continues to outcrop for 1 or 2 miles on either side of the fold along lines diverging from the axis. The lower of these two beds is the base of the blue-sand zone, and the strata between are in part of inconspicuous blue-sand beds. The upper bed is assumed as the approximate summit of the Jacalitos formation and is so mapped. The thickness of the formation so delimited is about 3,600 feet, the same as in the Kreyenhagen Hills, and the blue-sand zone has about the same thickness as in the section last given.

JACALITOS IN THE JACALITOS HILLS.

Passing now back to the region of the type locality for this formation, we may take up its occurrence from that locality northward. In the Jacalitos Hills a plunging anticlinal fold breaks up the regular monoclinal structure in the lower half of the formation, causing it to be folded at various angles and in various directions and to spread over a wider area toward the west. The base of the formation is not known to appear within the area mapped.

The regularity of dip of the upper half of the formation, however, is little disturbed and a continuous section is well exposed. This portion affords a great many excellent fossils, the principal zones of which are traceable directly into those south of Jacalitos Creek, and in general the formation here is similar to the occurrences already described. It preserves the general character of a great thickness of soft beds that are chiefly of sand and that vary rapidly both horizontally and vertically into all gradations of texture from that of clay to that of pebbly gravel. The beds are in places very gypsiferous, and yellow deposits of sulphur occur along the joint cracks. In the southern part of the Jacalitos Hills the lowest zone exposed in the axis of the anticline corresponds to the central portion of the zone of pebbles and sea urchins found on Jacalitos Creek.

In the central part of the hills, 700 to 800 feet below the top of the formation, there outcrops a prominent bed several feet thick of white, hard, gritty, very brittle, and much fractured shale somewhat similar to the hard variety of the "indicator" bed in the Vaqueros, north of Coalinga. It may be volcanic ash. It occurs at a horizon just above that of *Pecten estrellanus* in the uppermost zone in the section on Jacalitos Creek given above. The bed extends northward a little more than a mile from the northwest corner of sec. 31, T. 21 S., R. 15 E., following the east side of the road from Alcalde to Jacalitos Creek, and there becomes lost. It seems to be continued by a bed of white shale found at a similar horizon on the west side of the 1,900-foot hill southeast of Alcalde. It is underlain with fairly sharp contact by very fossiliferous fine clayey sand and medium-grained sand full of large pectens, cardiums, panopeas, etc., and overlain very sharply by gritty and gravelly sand full of sea urchins (fossil localities 4638 and 4639). This upper contact is wavy, the sand bending down a foot or two into concavities in the surface of the shale in places, but it is not thought that the contact represents an unconformity. The inequalities were more probably original variations of the surface of deposited material due to currents or other local causes.

The succession of beds exposed on the western flank of the 1,900-foot hill 1 mile southeast of Alcalde, east of the road leading southward from Alcalde toward Jacalitos Creek, comprises about 1,600 feet of sand, clay, gravel, and fossiliferous sandstone up to the base of the blue beds which mark the Etchegoin formation. Locally on the flank of this hill the beds have a slight stain resembling that due to the presence of oil. West of the road above mentioned the Jacalitos beds are chiefly sand, with some clay and gravel and with fossils. They overlap upon the steeply tilted Cretaceous strata and are warped into a number of low plunging folds. Still farther west the Jacalitos overlaps over a wide extent of country in the Waltham syncline, along which it has been traced 6 miles west of the area shown on the map, along Jacalitos Creek as far as the road to Stone Canyon.

JACALITOS IN THE ALCALDE HILLS.

North of Waltham Creek the Jacalitos formation has not the great thickness that characterizes it throughout its extent in the south, being only about 800 feet thick. This thinning northward is very rapid in the immediate vicinity of Waltham Creek as it is in the Etchegoin formation as well, indicating that the lower portion of Alcalde Canyon follows a line that has been an extremely important locus of orogenic movements. It has not been determined whether the change that takes place in the Jacalitos is a constant thinning affecting all the beds of the formation, or whether it is due to the absence of some large parts of the formation, owing either to their not having been deposited north of Waltham Creek or to their having been worn away. It may be that the zones full of fossil wood near the base of the Jacalitos in the Kreyenhagen Hills and north of Pleasant Valley are the same, but it is believed that the area north of Waltham Creek was land during the earlier part of Jacalitos time and that the lower portion of the formation was not deposited there.

The formation over the area of the Alcalde Hills retains the general character of the beds to the south. It is a varied formation of incoherent yellow, brown, and gray sand, sandstone, clay, and gravel, locally containing abundant fossils. The typical fauna of the lower part of the formation in the type locality along Jacalitos Creek is not present. The beds are evidently of near-shore origin, being in many places roughly bedded, cross-bedded, and varied. They are full of gypsum. The formation is described in connection with the section (fig. 4). The base, as mapped, is a fossiliferous bed containing *Pecten estrellanus*, etc., which is traceable southward from the San Joaquin Valley coal mine to Waltham Creek. It is underlain, with an appearance of conformity, by a zone of clay and fine sand about 300 feet thick, which has been mentioned before as possibly belonging to the horizon of the Big Blue (Santa Margarita?), but which is mapped with the Vaqueros. The summit of the Jacalitos formation is at the base of the *Glycymeris* zone, which is the equivalent of the basal Etchegoin as found elsewhere. The beds along this contact do not give evidence of unconformity.

JACALITOS IN THE AREA NORTH OF PLEASANT VALLEY.

The beds in the northern part of the district that have been correlated with the Jacalitos constitute that part of the series on Joaquin Ridge which lies between a prominent basal zone of gravel that outcrops typically on the hill where the tanks are situated above the Standard Oil Company's wells (in the northeast corner of the NW. ¼ sec. 28, T. 19 S., R. 15 E.) and the base of a zone of bluish-gray sand and abundant fossils (the *Glycymeris* zone) outcropping typically on the hill where one tank stands in the northwest corner of the SW. ¼ sec. 34, T. 19 S., R. 15 E. This portion of the series consists of about 1,600 feet of alternating fine gray sand and clay, pebbly and medium-grained sand and sandstone, and gravel. The basal pebbly zone has a thickness of about 150 feet, of which the lower half is a solid layer of pebbly gravel locally hardened to conglomerate and the upper half thinly bedded brown, gray, and, in some places, pinkish sandstone and sand intermingled with pebbles and with occasional shaly layers. This zone contains a great abundance of petrified wood in large fragments and at one place (locality 5015) a tooth of an extinct species of horse was found in it. An opinion as to the possible nonmarine origin of this zone has been expressed above. Owing to the great variety of constituents in these beds and the likelihood of their furnishing further fossils they would make an interesting subject for detailed study. The prominent basal beds are shown at the right of the center in Plate XVII. The rest of the formation is mostly soft sand, with which hard sandstone and conglomerate layers, pebbly sand, and sandy clay beds are frequently interbedded. The upper 700 feet consists of fine light-colored powdery sandstone, sandy clay, and clay, usually forming a belt of low topography but interbedded with several locally prominent 10 to 40 foot zones of blue pebbly sandstone like that in the Kreyenhagen Hills and in the overlying Etchegoin. The lowest of these blue strata are very conglomeratic and full of large fragments of silicified tree trunks. Impressions of leaves of deciduous trees were found in one of the lenses of clay common in this conglomerate, about 650 feet below the base of the Etchegoin 7½ miles north of Coalinga, on the west side of the SE. ¼ sec. 28, T. 19 S., R. 15 E. No marine fossils have been found in place in the Jacalitos beds north of Pleasant Valley.

FOSSILS AND AGE.

FOSSILS.

Like the Etchegoin above it, with which it is closely allied, the Jacalitos is fossiliferous in many localities in the Coalinga district and adjacent regions, especially in the Waltham Valley, 13 miles southwest of Coalinga. In the upper part of the formation the fossils are usually in a very good state of preservation; in the lower part the original shell has usually been leached out and replaced by other material, and some of the fossils are simply casts.

The following species have been found in the Jacalitos formation in the Coalinga district or in the Waltham Valley:

Jacalitos (upper Miocene) fossils from the Coalinga district.

Name.	4636.	4638.	4639.	4640.	4642.	4644.	4645.	4646.	4647.	4649.	4650.
ECHINODERMATA.											
Astrodapsis jacalitosensis Arnold											
Echinarachnius gibbsii Rémond		×	×		×					×	
PELECYPODA.											
Arca trilineata Conrad				×							
Cardium meekianum Gabb											
Cardium sp. *a*											
Cardium sp			×								
Chione securis Shumard					×						
Cryptomya ovalis? Conrad		×									
Diplodonta harfordi? F. M. Anderson											
Diplodonta parilis Conrad											
Diplodonta sp. indet	×										
Dosinia jacalitosana Arnold											
Glycymeris sp. indet	×										
Macoma secta Conrad											
Macoma jacalitosana Arnold											
Macoma vanvlecki Arnold											
Macoma sp. *a*											
Metis alta? Conrad				×							
Metis sp											
Monia macroschisma Deshayes					×						
Mulinia densata Conrad								×			
Mytilus (Mytiloconcha) coalingensis Arnold											

Jacalitos (upper Miocene) fossils from the Coalinga district—Continued.

Name.	4636.	4638.	4639.	4640.	4642.	4644.	4645.	4646.	4647.	4649.	4650.
PELECYPODA—continued.											
Ostrea atwoodi Gabb											
Panopea generosa Gould			X							X	
Panopea estrellana Conrad											
Paphia staleyi? Gabb		X	X								
Paphia jacalitosensis Arnold											
Paphia aff. tenerrima Carpenter											
Pecten estrellanus Conrad				X	X	X			X		X
Pecten crassicardo Conrad					X						
Pecten oweni Arnold									X		
Saxidomus nuttalli Conrad				X				X			
Schizodesma abscissa Gabb											
Schizothærus pajaroanus Conrad		X	X	X						X	
Solen sicarius Gould											
Tellina aragonia Dall											
Thracia jacalitosensis Arnold											
Zirphæa dentata Gabb											
GASTEROPODA.											
Chrysodomus imperialis Dall											
Chrysodomus portolaensis Arnold											
Crepidula princeps Conrad											
Lunatia lewisii? Gould									X		
Margarita johnsoni Arnold											
Melongena sp. *a*											
Neverita recluziana Petit											
Neverita sp.											
Thais crispatus Chemnitz											
Thais kettlemanensis Arnold											
Trophon (Forreria) ponderosum Gabb		X			X		X			X	
CIRRIPEDIA.											
Balanus sp.											
Tamiosoma gregaria? Conrad											
PISCES.											
Fish vertebræ											
MAMMALIA.											
Pliohippus sp. *a*											

4636. Hill 4 miles N. 85° W. of Coalinga, not far from contact with concretionary sandstone beds mapped as Cretaceous (Chico), on west side of sec. 35, T. 20 S., R. 14 E. Lower beds.

4638. Three hundred feet east of nose of 1,300-foot ridge, three-fourths mile southeast of Alcalde, in center of sec. 24, T. 21 S., R. 14 E. Olive-gray gypsiferous sand overlying white shale bed, about 700 or 800 feet stratigraphically below top of the Jacalitos formation as mapped. Upper beds.

4639. About 2 miles south of Alcalde on south side of 1,548-foot hill, in sand immediately above and below white shale bed, in sec. 25, T. 21 S., R. 14 E. Same horizon as 4638, upper beds.

4640. Near Commercial Petroleum well, 3 miles southwest of Coalinga. Upper beds.

4642. About 20 miles south of Coalinga, in Kreyenhagen Hills. Gray sand 500 feet southwest of top of 1,053-foot hill, four-fifths mile southwest of El Cerrito well, in NW. ¼ SW. ¼ sec. 15, T. 23 S., R. 17 E. *Pecten estrellanus* zone, or upper beds.

4644. Southeast base of 1,300-foot hill, on north side of Jacalitos Creek, just north of old adobe house two-thirds mile above fork of Salt Creek, in center of south side of sec. 31, T. 21 S., R. 15 E. Upper beds.

4645. One mile west of Garza Creek on top of ridge north of Clark's place, in the NW. ¼ NE. ¼ sec. 3, T. 23 S., R. 16 E.; big *Trophon* zone, about 900 or 1,000 feet stratigraphically above shale of Santa Margarita (?) formation. Lower beds.

4646. About 3 miles west of Coalinga, just north of Commercial Petroleum well No. 1, in canyon. Middle or upper beds.

4647. On top of ridge between Salt Creek and Jacalitos Creek, about 5 miles south-southeast of Alcalde, at elevation of 1,300 feet, on north line of sec. 6, T. 22 S., R. 15 E., hard sandstone layer through pebbly olive-gray sand. *Pecten estrellanus* zone about 700 to 800 feet stratigraphically below summit of formation. One of typical Jacalitos localities. Upper beds.

4649. West point of 1,308-foot ridge three-fourths mile southeast of Alcalde, SW. ¼ NE. ¼ sec. 24, T. 21 S., R. 14 E. Middle beds.

4650. Lowest fossil bed on west face of 1,900-foot hill southeast of Alcalde. Middle beds.

Jacalitos (upper Miocene) fossils from the Coalinga district—Continued.

Name.	4652.	4653.	4654.	4745.	4745*a*.	4746.	4747.	4763.	4765.	4767.	4784.	5015.
ECHINODERMATA.												
Astrodapsis jacalitosensis Arnold			×	×								
Echinarachnius gibbsii Rémond					×	×	×		×	×		
PELECYPODA.												
Arca trilineata Conrad								×	×			
Cardium meekianum Gabb								×	×			
Cardium sp. *a*									×	×		
Cardium sp												
Chione securis Shumard		×							×			
Cryptomya ovalis? Conrad												
Diplodonta harfordi? F. M. Anderson				×								
Diplodonta parilis Conrad								×	×			
Diplodonta sp. indet												
Dosinia jacalitosana Arnold								×				
Glycymeris sp. indet												
Macoma secta Conrad									×			
Macoma jacalitosana Arnold									×			
Macoma vanvlecki Arnold								×	×			
Macoma sp. *a*								×				
Metis alta? Conrad								?				
Metis sp				×								
Monia macroschisma Deshayes										×		
Mulinia densata Conrad								×	?			
Mytilus (Mytiloconcha) coalingensis Arnold	×											
Ostrea atwoodi Gabb										×		
Panopea generosa Gould		×						×	×			
Panopea estrellana Conrad		×							×			
Paphia staleyi? Gabb												
Paphia jacalitosensis Arnold									×			
Paphia aff. tenerrima Carpenter									×			
Pecten estrellanus Conrad	×			×		×			×	×		
Pecten crassicardo Conrad												
Pecten oweni Arnold		×								×		
Saxidomus nuttalli Conrad												
Schizodesma abscissa Gabb									×			
Schizothærus pajaroanus Conrad												
Solen sicarius Gould								×	×			
Tellina aragonia Dall									×			
Thracia jacalitosensis Arnold								×				
Zirphæa dentata Gabb				×								
GASTEROPODA.												
Chrysodomus imperialis Dall										×		
Chrysodomus portolaensis Arnold								×	×	×		
Crepidula princeps Conrad								×				
Lunatia lewisii? Gould								×				
Margarita johnsoni Arnold									×			
Melongena sp. *a*				×								
Neverita recluziana Petit								×				
Neverita sp									×			
Thais crispatus Chemnitz								×				
Thais kettlemanensis Arnold								×	×			
Trophon (Forreria) ponderosum Gabb				×					×			
CIRRIPEDIA.												
Balanus sp				×					×	×		
Tamiosoma gregaria? Conrad										?	×	
PISCES.												
Fish vertebræ		×										
MAMMALIA.												
Pliohippus sp. *a*												×

4652. On point of ridge three-fourths mile south-southwest of Alcalde, one-fourth mile south of south bend in road, SE. ¼ sec. 23, T. 21 S., R. 14 E. Middle beds.

4653. Nearly 4 miles southwest of Coalinga, one-third mile south of Commercial Petroleum well at point of hills on north side of Waltham Creek, just east of Anticline Canyon road, in the very southwest corner of sec. 7, T. 21 S., R. 15 E. Middle or upper beds.

4654. On Jacalitos Creek, one-half mile above confluence with Jasper Canyon, on south side of sec. 1, T. 22 S., R. 14 E. Lower beds.

4745. On ridge south of Garza Creek, 1 mile southeast of Mr. Clark's place, NE. ¼ SW. ¼ sec. 2, T. 23 S., R. 16 E.; big *Trophon* zone about 800 feet stratigraphically above shale of the Santa Margarita (?) formation. Lower beds.

4745*a*. Big *Echinarachnius gibbsii* zone about 800 feet stratigraphically above 4745, in NW. ¼ SE. ¼ sec. 2, T. 23 S., R. 16 E. Middle beds.

4746. Sixteen hundred feet stratigraphically above 4745, on ridge east of Garza Creek, NE. ¼ sec. 2, T. 23 S., R. 16 E. Upper beds.

4747. Same locality as 4746, 150 feet stratigraphically higher. *Pecten estrellanus* zone, or upper beds.
4763. Southwest of Coalinga district, on little ridge 200 yards north of Stone Canyon and Waltham Creek road where it crosses a little stream before reaching Waltham Valley from the west. Lower zone.
4765. Big *Trophon* zone on Jasper Creek just above fork of confluence with Jacalitos Creek, on west side of center of the SW. ¼ sec. 6, T. 22 S., R. 15 E. About 2,000 feet stratigraphically below summit of formation. One of typical Jacalitos localities. Lower beds.
4767. On southeast side of Canoas Creek, three-eighths mile above Hugo Kreyenhagen's house, in the NW. ¼ SW. ¼ sec. 27, T. 22 S., R. 16 E.. *Pecten estrellanus* zone, or upper beds. Abundance of beautifully preserved specimens.
4784. On Jacalitos Creek, about 7 miles southwest of Coalinga, shaly sandstone a few hundred feet stratigraphically above big *Trophon* zone of 4765.
5015. Basal gravel bed of the Jacalitos, SE. ¼ sec. 15, T. 19 S., R. 15 E., northeast of Octave oil wells.

FAUNAL ZONES.

Three rather easily distinguishable fossiliferous zones occur in the Jacalitos. The lowest one of these, sometimes called the "big *Trophon* zone," is characterized by such forms as *Trophon* (*Forreria*) *ponderosum* Gabb, *Macoma vanvlecki* Arnold, *Panopea estrellana* Conrad. *Dosinia jacalitosana* Arnold, and *Astrodapsis jacalitosensis* Arnold, The fauna of this zone is typically developed at locality 4765. The same zone is also represented at the following localities: Nos. 4636, 4645, 4654, 4745, 4763, 4765, and 5015 (?).

The middle zone has a less well characterized fauna, but usually yields very large specimens of *Echinarachnius gibbsii* Rémond, also *Panopea generosa* Gould and *Schizothærus pajaroanus* Conrad. It is represented by the localities Nos. 4646(?), 4649, 4650, 4652, 4653(?), and 4745*a*.

The upper zone, or *Pecten estrellanus* zone, as it is sometimes called, is characterized by large specimens of *Pecten estrellanus* Conrad, *Pecten oweni* Arnold, and large individuals of *Echinarachnius gibbsii* Rémond. The species common in this zone are beautifully preserved at locality 4767. The zone is also represented at localities 4638, 4639, 4640, 4642, 4644, 4646, 4647, 4653, 4746, 4747, and 4767.

FAUNAL RELATIONS AND AGE.

The fauna of the Jacalitos formation not only contains a considerable number of unique species, but the association in it of species known elsewhere in other formations is peculiar.

The species which are characteristic of or found more commonly in the Jacalitos than elsewhere, in addition to the new species described from it in Bulletin 396, are *Chione securis* Shumard; *Echinarachnius gibbsii* Rémond, large variety; *Melongena* sp. *a*; *Schizodesma abscissa* Gabb; *Tellina aragonia* Dall; and *Trophon* (*Forreria*) *ponderosum* Gabb.

The species which are found in the Jacalitos and the underlying Santa Margarita(?) formation, but which it is believed do not extend into the overlying Etchegoin, except possibly in rare instances, are *Pecten estrellanus* Conrad, *Pecten crassicardo* Conrad, *Tamiosoma gregaria?* Conrad, and *Zirphæa dentata* Gabb. The forms noted as questionably *Tamiosoma gregaria* are different from the typical *Tamiosoma* and are possibly large specimens of *Balanus*, but the few examples found were too poor for identification.

Numerous fragments of *Tamiosoma gregaria*, *Ostrea titan*, and *Pecten estrellanus* are scattered over the surface of the fossil-wood bearing conglomerate beds of the upper Jacalitos in the low hills south of Oilfields and 7 miles north-northeast of Coalinga, in the SE. ¼ sec. 34, T. 19 S., R. 15 E. They have the appearance of being in place in these beds, but it is believed to be more probable that they are either inclusions in the Jacalitos of fossils derived from the Santa Margarita(?) beds or recent float from the higher hills.

The species which are common to the Jacalitos and the overlying Etchegoin, but which do not extend below into the Santa Margarita(?) are *Arca trilineata* Conrad, *Cardium meekianum* Gabb, *Cryptomya ovalis?* Conrad, *Diplodonta harfordi* F. M. Anderson, *Diplodonta parilis* Conrad, *Echinarachnius gibbsii* Rémond, *Chrysodomus portolaensis* Arnold, *Macoma secta* Conrad, *Monia macroschisma* Deshayes, *Mytilus (Mytiloconcha) coalingensis* Arnold, *Ostrea atwoodi* Gabb, *Pecten oweni* Arnold, *Schizothærus pajaroanus* Conrad, *Paphia staleyi?* Gabb, and *Paphia tenerrima* Carpenter.

Thais kettlemanensis Arnold properly belongs in the list of the species unique in the Jacalitos, as it occurs alone at the type locality of the species (locality 4680, which is included in the general locality 4679), which is on the axis of the Coalinga anticline and in beds below the lowest fossiliferous horizon that is certainly Etchegoin. It is abundant toward the base of the Jacalitos.

All the determinable fossils that have been found in the Jacalitos in the southern portion of the district are of salt-water species, which indicate the marine origin of the greater part of the formation. The basin of deposition, however, appears to have been a shallow one, and it is not unlikely that portions of the great thickness of beds were deposited outside of the area occupied by the salt water at times when subsidence did not keep pace with deposition and the consequent encroachment of the land upon the sea. Beds formed at such times may be represented by the fossil-wood zones noted and possibly by some of the gravel and sand deposits in other parts of the formation.

The Jacalitos may be defined as a formation embracing about 3,600 feet of sand, gravel, clay, and sandstone, lying between the Santa Margarita (?) formation below and the Etchegoin above, and containing in its fauna among others at least 15 species which are unique, 4 which are common to it and the Santa Margarita but do not extend up into the Etchegoin, and 15 which are common to it and to the Etchegoin but do not extend down into the Santa Margarita fauna. The age of the Jacalitos is believed to be the early part of the upper Miocene. It has a known range of about 75 miles along the Diablo and Temblor ranges, from Coalinga to the Elkhorn Plain. Whether it will be possible to recognize the fauna outside of this area is not known; for the present it seems advisable to use the name only in a local way and in the general geologic column to place it tentatively as an equivalent for the upper part of the Santa Margarita and the lower part of the San Pablo.

IMPORTANCE WITH RELATION TO PETROLEUM.

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

ETCHEGOIN FORMATION (UPPERMOST MIOCENE).

DEFINITION.

ORIGINAL DESCRIPTION.

The name Etchegoin series was applied by F. M. Anderson[a] to a great thickness of beds of little-consolidated sand, gravel, and clay, characteristically blue at the base, extending a long distance both northwest and southeast from Coalinga along the border of the Diablo Range. The name of the formation was "derived from its characteristic development in the vicinity of the Etchegoin ranch, some 20 miles northeast of Coalinga." This is an abandoned sheep ranch at the northern edge of the area mapped, 12½ miles northeast of Coalinga (NW. ¼ sec. 1, T 19 S., R. 15 E.). A general description of the formation was given. Its upper limit was stated to be at the base of the fresh-water deposits in the vicinity of Tulare Lake and the Kettleman Hills, described as the Tulare formation.

Mr. Anderson states that "one or two fossil horizons are to be recognized in the Etchegoin sands, one near their bottom and another some distance above." The one near the bottom is stated to be the more characteristic horizon. It is the one that will be later described as the *Glycymeris*[b] zone and as the base of the formation. The nearest locality to the Etchegoin ranch for which a description or section was given is 9 miles north of Coalinga, and this may therefore be taken as the type section. In this section the base of the forma-

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

[b] To avoid confusion it should be stated that this same genus was referred to as *Pectunculus* in the paper quoted. That name has been replaced by the one here used owing to the fact that *Glycymeris* was the original designation of the genus.

tion was shown considerably above the *Tamiosoma* zone, which is described in the present report as part of the Santa Margarita (?) formation. The position of the lower portion of the Etchegoin was further indicated by the statement in the general description that it was characteristically a zone of bluish sand. The whole formation was referred to the Pliocene and was stated to be unconformable with the beds below.

PRESENT DEFINITION.

In accordance with the original description, and on the basis of the reasons stated below, the Etchegoin formation is mapped and described in the present paper as the succession of beds of sand, gravel, and clay, in part indurated, occurring in the oil field northeast of Coalinga above the base of the hill-forming sandstone beds referred to for convenience as the *Glycymeris* zone, and in the Kettleman Hills below the fresh-water beds described as the base of the Tulare formation. The upper limit is not defined for the hills north of Coalinga owing to the indefiniteness of the line between the Etchegoin and Tulare there. The base of the formation may be still more sharply defined as the lowest horizon of the Tertiary beds that rest directly upon the Cretaceous in the basin of the White Creek syncline, about 15 miles northwest of Coalinga, for there no question can exist of the individuality of the Etchegoin as a stratigraphic unit or of its proper delimitations. Such a definition on the basis of the White Creek occurrence seems permissible, inasmuch as there can be little doubt that the fossiliferous beds at the base of the formation in the White Creek basin are equivalent to those north of Coalinga referred to as the *Glycymeris* zone. This fossil zone was probably at one time continuous between the two localities.

Strata in other portions of the Coalinga district are referred to the Etchegoin formation on the basis of paleontologic correlation with the basal beds on Anticline Ridge and in the White Creek basin and with the upper beds in the Kettleman Hills. The formation so described probably belongs as a whole in the Miocene, though its uppermost beds may reach into the Pliocene. It is very rich in marine fossils and is chiefly of marine origin, but evidence will be mentioned later pointing to the origin of portions of it in bodies of nearly fresh water.

BASE OF THE FORMATION.

The *Glycymeris* zone is an extremely fossiliferous bed of somewhat indurated sand that forms the summit of the hill at the northwest end of Anticline Ridge (fossil localities 4656, 4658, and 4659) and extends continuously from that point along the line mapped as the base of the Etchegoin formation. The beds of this zone are shown on the right side of Plate XVIII, along the summit of Anticline Ridge, in the middle distance in the picture. The zone is underlain at this locality by clay that forms a belt of low relief in the topography and that is classed in the Jacalitos formation. It is overlain by a thick succession of bluish-gray sand beds interbedded with dark-gray sand. The zone affords almost perfect specimens of many species of fossils that make up a distinctive fauna. It is called the *Glycymeris* zone for ease of reference, because it is an important datum line that may be recognized by the association of fossils contained in it. It could not be identified surely by the *Glycymeris* alone, for although the genus is perhaps more characteristic of this zone than of any other, its distribution at other horizons is wide. Approximately, if not exactly, the same horizon marks the base of the beds overlying the Cretaceous sandstone in the synclinal basin of White Creek, as shown by the typical association of fossils (fossil localities 4662, 4663, and 4664). Somewhere between Oil Canyon and the White Creek area an overlap of the Etchegoin upon the Jacalitos and earlier Tertiary formations must have taken place.

It is therefore appropriate to consider the beds above the base of the *Glycymeris* zone as a distinct formation, although on Anticline Ridge and in the greater portion of their extent in the region north of Coalinga, as well as to the south as far as they have been studied, they appear to rest conformably upon the beds below. The fact that the *Glycymeris* zone or fossil beds that are approximately equivalent to it are traceable throughout the district gives it great value in distinguishing the Etchegoin from the formation below.

TOP OF THE FORMATION.

In the section of this formation in the hills north and northwest of Coalinga the summit has not been found clearly marked, but it is overlain around the edge of the valley by gravel, sand, and clay deposits that are with little doubt the equivalent of part of the formation which has at its base a clearly marked bed of fresh-water fossils at the northern end of the Kettleman Hills, less than 10 miles to the south. That formation, the Tulare, is widespread along the border of the Diablo Range in contact with the Etchegoin. The occurrence of the Etchegoin, especially of the upper portion, is typical in the Kettleman Hills, and the contact is distinctly traceable between its uppermost beds, which are full of marine or estuarine fossils, and the fresh-water bed immediately overlying. There is reason to believe that if the beds of these formations were well exposed near their contact in the hills northeast of Coalinga the same fossil zone would be found and the summit of the Etchegoin would be well defined, as it is in the Kettleman Hills. An appearance of conformity and intergradation between the Etchegoin and Tulare exists along the contact in the Kettleman Hills, although a time break may have intervened without leaving any marked evidence as yet observed. In the Kreyenhagen Hills there may be an unconformity, and that will be discussed later.

GENERAL DESCRIPTION.

In the description of the Jacalitos (early upper Miocene) frequent reference has been made to the overlying Etchegoin (uppermost Miocene). In fact, these formations are so closely related and so similar that the one can not well be described without reference to the other. In the southern part of the district they seem to have originated as a chronologically continuous succession of deposits and are only arbitrarily separable on the basis of the associations of faunas, whereas in the northern part of the district they are not so completely represented, and movement of the land took place that caused the later deposits to spread more widely than those of the earlier period. Many of the features of structure, influence upon topography, and lithologic variation mentioned in connection with the Jacalitos are common to both.

The surface exposure of the upturned beds of the Etchegoin formation, as shown by the map, forms a belt along the foothills similar to that of the Jacalitos, the beds lying above those of the Jacalitos in the general monoclinal succession. Along the main belt where the beds of the Etchegoin lie they dip at all angles, varying from a few degrees to the vertical, but generally with regularity at each locality. The formation attains its greatest thickness in the southern part of the district, in the Kreyenhagen Hills, where it is at least 3,500 feet thick. In the northern portion it is at most only half as thick.

The formation is made noticeable by the dominant grayish-blue color of the massive sand beds that are dispersed through several hundred feet of beds at its base, but an examination of its characteristic fossils, which abound at several different horizons, is the only means of distinguishing it accurately from the associated formations. The blue color of the sands has been mentioned above (p. 115). An exposure of soft sandstone and gravel beds in the middle of the formation is shown in Plate IX, *B*. The outcrops and general topography at the point where this picture was taken are characteristic, although the sand dollars are somewhat more numerous than in most places.

One of the most important of the broad features of the formation in the Coalinga district is the usual predominance of coarse material, such as sand and pebbly deposits, in its lower portion, and of finer material, such as extremely fine sand and clay, in its upper portion, but this feature is characteristic in various degrees according to the locality, and in some places is hardly noticeable. It can not be said of any locality that either portion is free from an admixture of the elements of the other, and, moreover, the uppermost beds of the formation are in large part composed of sand and sandstone wherever they have been found exposed.

F. M. Anderson divided his Etchegoin series into the Etchegoin sands below and the San Joaquin clays above, corresponding to the rough divisions already outlined; but inasmuch as these names are not applicable throughout the area under discussion and do not represent a complete division of the formation they are not used in the present paper.

DISTRIBUTION AND LOCAL CHARACTER.

ETCHEGOIN IN THE COALINGA FIELD.

In the oil field north of Coalinga the Etchegoin has a maximum thickness of about 1,700 feet. The *Glycymeris* zone already described is at the base and a number of other fossiliferous beds lie within several hundred feet above this, affording altogether a rich fauna. (See fossil localities 4657, 4671, and 4688.) The lower portion of the formation is composed largely of beds of compact coarse and fine bluish-gray sand alternating with zones of pebbly sand, fine gray sand, and some clay, with occasional more hardened beds. The clay increases toward the upper part of the formation, being interbedded with unconsolidated light-gray sand that spreads over the surface and obscures the structure. The formation occurs in the low hills bordering the valley and passes beneath the alluvium of the floor.

The Etchegoin forms a belt along the edge of the Alcalde Hills west of Coalinga and is overlapped by the recent valley deposits. The formation is described in connection with the section (fig. 4), which represents its exposures on the summit and east slope of the 1,410-foot hill 2 miles southwest of Coalinga. The beds there are chiefly of yellowish and gray gypsiferous sand, sandstone, and gravel of various degrees of coarseness, and have an exposed thickness of about 750 feet. A fossil bed about equivalent to the *Glycymeris* zone at the base of the formation farther northeast outcrops near the top of the hill, and a 20-foot fossil bed equivalent to the *Pecten coalingaensis* zone of the Kreyenhagen and Kettleman hills appears at the edge of the valley about 650 feet above the base of the formation as mapped (fossil locality 4714). As the uppermost beds that belong above the *Pecten coalingaensis* zone are hidden by the surface deposits of the valley, the whole formation here may have a thickness of 900 or 1,000 feet. Probably the formation is overlain beneath the valley by the Tulare.

ETCHEGOIN IN THE WHITE CREEK BASIN.

A detached area of Etchegoin beds is preserved in the syncline near the head of White Creek, as before mentioned. At one time these beds were doubtless continuous with those of the same formation around Pleasant Valley. The lowest 100 feet of beds, immediately overlying the Cretaceous, are composed of coarse and pebbly, compact but soft yellowish-gray sandstone hardly distinguishable from the underlying Cretaceous sandstone. These beds do not contain very many fossils, but grade upward into beds largely composed of fossils, with a matrix of yellowish-gray sand. This basal fossil zone contains a fauna closely resembling that of the *Glycymeris* zone on Anticline Ridge and is correlated with it. (See fossil localities 4662, 4663, and 4664.) The bulk of the formation in its middle portion consists of similar sand and sandstone resembling the massive upper Cretaceous sandstone and containing occasional fossil beds. Numerous layers of very hard sandstone and some concretions are present. The beds for a few hundred feet below the top of the formation are more variable, a thick zone of coarse pebbles being followed above by alternating beds of sandy shale, calcareous shale, and coarse and fine sand and sandstone, with a hard and prominent thin bed of dark-brownish sandstone full of small white fossils near the top. The total thickness of the beds here preserved is about 1,100 feet.

The basal beds of the Etchegoin are apparently conformable in dip with the Cretaceous in the White Creek syncline, although of course the break between the two periods was profound. The beds at the base dip at angles as high as 60° or more along parts of the syncline, but the dip decreases gradually to only a few degrees in the axis of the fold. The character of the sand forming the Etchegoin beds indicates that it was derived largely from the Upper Cretaceous sandstone beds.

ETCHEGOIN IN WALTHAM VALLEY.

The continuation of this basin deposit of Etchegoin forms a filling in the region of open hills toward the head of Los Gatos Creek, where it overlies both Cretaceous and Franciscan, and in the synclinal trough of Waltham Valley, which extends for many miles along the western side of Juniper Ridge outside of the area mapped.

ETCHEGOIN IN THE KREYENHAGEN HILLS.

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

The zone of blue-sand beds at the base of the formation is constant throughout the Kreyenhagen Hills. Its thickness varies from place to place and its position is of little value except for rough correlations. The thickness of the blue-sand zone within the Etchegoin near Zapato Creek is over 2,500 feet, whereas at points south of Big Tar Canyon the beds characterized by this blue color have not been observed to extend as much as 800 feet above the base of the formation. The lower part of the formation is composed chiefly of sandy beds of all degrees of coarseness up to pebble beds, and of many varieties of blue, gray, and drab color, with minor amounts of clay. The upper part of the formation is composed of alternating thick zones of sand and clay, the clay being somewhat more in evidence than in the lower portion.

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

The following sections of the formation in different parts of the Kreyenhagen Hills, together with the section in figure 4, give a tabulated description of the formation as it occurs typically and convey an idea of the variety of the beds.

Section of Etchegoin formation on Canoas Creek.

	Feet.
Fine gray sand and clay, with occasional hard layers, upper *Mya* zone (fossil localities 4744 and 4782); overlain by gravel of Tulare	450
Gray sand and clay in alternating beds of variable thickness	1,700
Top of blue sandstone; massive gray sand, both coarse and fine, interbedded with clay in lesser amounts and occasional heavy beds of blue sand; contains numerous sand dollars (locality 4707) and a zone at the base with many fossils; the upper *Mulinia* zone	550
Similar beds to the base of the zone of blue sand. Beds at base containing many fossils (locality 4769), probable equivalent of the *Glycymeris* zone and of lower *Mulinia* zone of Kettleman Hills	900
	3,600

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

	Feet.
Thinly bedded hard white porcelaneous shale, with whitish-gray fine sand, pebbly sand, and sandy clay, containing lenticular layers and nodules of porcelaneous shale and many bone fragments; summit of Etchegoin not definitely determinable, but this zone so mapped	250
Alternating thick zones of whitish-gray sand and clay	1,080
Solid zone of thin-bedded pebbly sandstone	45
Whitish-gray sand and clay with a 15-foot bed of coarse pebbly sand in middle	660
Prominent beds of compact gray sand with softer sand and sandy clay between; whitish-gray sand with black pebbles at base	210
Compact fine gray sand streaked with layers of fine whitish sand and sandy clay	420
Compact, slightly gritty white shale somewhat similar to Santa Margarita (?)	10
Solid zone of gray sandstone, coarse pebbly sandstone, and hard calcareous shale	40
Fine gray sand	50
Highest bed of blue sand, with a 10-foot layer of pebbles at base and a 3-foot layer full of sand dollars, barnacles, Arcas, etc., 20 feet above base; probably upper *Mulinia* zone	80
Interbedded blue sand and sandy clay with a prominent 20-foot bed of blue sand at base	120
Minor beds of blue sand, with a thick zone of hard calcareous shale in middle	90
Prominent blue-sand bed, pebbly toward the base and containing many sand dollars	90
Soft gray sand	70
Very prominent blue sand	40
A prominent 30-foot bed of blue sand at base overlain by bluish and gray sand and three less prominent beds of blue sand	250
	3,500

ETCHEGOIN IN M'LURE VALLEY.

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

ETCHEGOIN IN THE KETTLEMAN HILLS.

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

Different horizons in the Etchegoin of the Kettleman Hills afford good datum lines that may be recognized by means of the characteristic faunas and the constancy of the beds containing them, and it is convenient to designate these briefly, beginning with the summit of the formation as a constant datum line and going down. In addition to the main zones that will be here mentioned there occur other fossil beds which may assume local importance, but which were not found so constant. Complete lists of the fossils contained in these zones at different localities are given below. In this connection reference should be made to the section in figure 5 and the tabulated section on page 123. The summit of the formation is marked, as it is in portions of the Kreyenhagen Hills, by a constant fossiliferous zone of sand and sandstone interbedded with dark clay, which may be called here, like the same zone in the Kreyenhagen Hills, the upper *Mya* zone, because of the great abundance of Myas. It also contains many other fossils, especially common being small yellow Littorinas and small oysters. This zone has a thickness varying between 200 and 300 feet and is prominent in the topography because it usually forms a line of hills. In the southern part of the Kettleman Hills it forms the main ridge. This zone and the transition between it and the overlying fresh-water beds is further discussed in connection with the Tulare formation. Below it comes a zone of unequal thickness, but usually about 700 feet thick, which in some portions of the hills is composed almost entirely of fine inky-blue clay, and in others of clay and sand interbedded in varying proportions. Toward the base of this zone, usually between 700 and 900 feet below the top of the formation, there is a zone of fossiliferous sandstone beds that is the equivalent of the zone of *Pecten coalingaensis* in the Kreyenhagen Hills. These beds likewise show a tendency to form hills or knobs, but they are not as prominent as those of the upper *Mya* zone. Below the *Pecten coalingaensis* zone the formation is largely sand and clay, chiefly sand, down to the base, the lower portion being composed as elsewhere of alternating beds of ordinary sand and blue sand. The next prominent fossil bed to be mentioned is another one containing a great many Myas, and it will be referred to as the lower *Mya* bed. It occurs between very prominent beds of blue sand on the summits of hills, and in the north-central portion of the Kettleman Hills forms the main ridge. Owing to the fact that the formation is thicker in the southern than in the northern portion of the hills and apparently thicker on the western than on the eastern flank of the anticline, the distance below

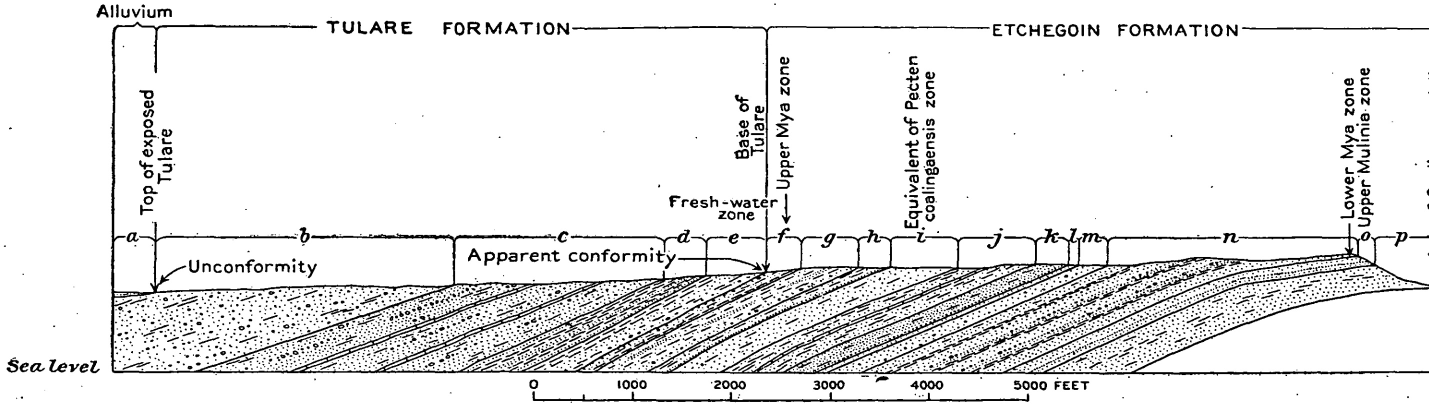


FIGURE 5.—Section of Tulare and Etchegoin formations along road 6 miles from northwest end of Kettleman Hills on southwest flank of Coalinga anticline, along line N-N′ on geologic map (Pl. I).

	Feet.
a. Alluvium.	
Tulare.	
b. No good outcrops but probably alternating sand, coarse gravel, and clay; highest Tulare exposed	700+
c. Chiefly light-gray sand affording a light sandy soil, interbedded with straw-colored earthy clay, and with occasional beds of gravel and thin layers of hard sandstone	700
d. Gypsiferous dark clay, with thin beds of sand	160
e. Incoherent gray sand and clay, with fresh-water fossils in lower portion; base of Tulare	260
	1,820+
Etchegoin.	
f. Yellowish-gray sand and clay, with some dark clay; many fragments of porcelain shale on surface, small oysters in sand at top, and yellow calcareous shale lenses in bluish-black clay at base; upper *Mya* zone, top of Etchegoin	125
g. Alternating beds of gypsiferous fine drab sand, sandy clay, and drab to bluish clay, with occasional sandstone layers, and with bed at base containing delicate fossils, *Nucula*, etc	250
h. Similar beds, with layers of iron-stained sandstone at base	115
i. Similar gypsiferous beds, with light-colored sand predominating; the *Pecten coalingaensis* zone should be here somewhere but was not found	250
j. Inky-blue clay with minor beds of sand and with a hard 1-foot bed of yellow limestone in middle	290
k. Fine sand and some light and dark clay, with hard, very gypsiferous yellow and variegated sandstone at the top and interspersed hard layers below; sandstone with *Solen*, etc., near base	135
l. Highest blue-sand bed	45
m. Grayish-blue massive sand and pebbly sand, with fossils	130
n. Thinly and massively bedded drab and light-gray sand, with occasional beds of blue sand and layers of inky-blue clay, white clay, and pebbles; the sand at base is the lower *Mya* bed (fossil locality 4676)	550
o. Massive beds of blue and gray sand, with *Mulinia*, etc., at base; upper *Mulinia* zone	150
p. Less prominent beds of blue and gray sand and dark clay, with *Echinarachnius*, *Ostrea*, *Cardium*, etc., toward base (fossil locality 4678)	350
	2,390
Total Tulare and Etchegoin	4,310+

The base of the Etchegoin is probably several hundred feet lower.

the summit of the formation at which this and other beds occur can not be stated as a constant. The variation of this zone is between about 1,900 and 2,400 feet below the summit. One of the fossils most in evidence in the Kettleman Hills is the large *Mulinia*, and a bed containing abundant specimens of this form lies about 100 feet below the lower *Mya* bed. It marks the highest horizon at which the large specimens have been found and is, as far as can be told, the equivalent of the upper *Mulinia* zone in the Kreyenhagen Hills. In the northern portion of the Kettleman Hills it is near the base of the exposed series and is the lowermost easily recognizable zone, whereas in the central portion of the hills beds of considerable thickness are exposed below. Inasmuch as the base of the Etchegoin can not be mapped in these hills the upper *Mulinia* bed is taken as a datum line in the lower portion of the formation and its summit is mapped. It can not be definitely traced at all points along the line mapped, but its horizon has been approximated as nearly as possible where its fossils and those of the overlying lower *Mya* bed have not been found. Another zone in the Kettleman Hills in which *Mulinia* is very abundant is between 500 and 700 feet below the upper one, and may be referred to as the lower *Mulinia* zone. It is approximately the equivalent of the *Glycymeris* zone in the Coalinga field. It is about the lowest bed exposed and is approximately the base of the Etchegoin formation.

The following tabulated section and the section in figure 5 represent the lithologic character and variations of the Etchegoin in the Kettleman Hills. Variation is the rule and it would be difficult to find any two sections in which the same beds are exposed and the characteristics are constant. On the northeast flank of the anticline the beds are repeated with approximately the same thickness, but the sections measured made it appear that there was possibly a slight thinning on that side.

The following section is on the southwest flank of the anticline in the south-central portion of the hills, beginning at the 1,030-foot hill on the main ridge 5 miles northwest of the Dudley-Lemoore road (in the center of sec. 3, T. 23 S., R. 18 E.), and extending northeastward across the strike of the beds to the anticlinal axis.

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

	Feet.
Inky-blue clay below fresh-water bed	50
Yellow and gray sand full of fossils and of fragments or nodules of porcelain shale; the upper *Mya* zone (fossil locality 4730)	200
Inky-blue clay zone; sandy beds at top containing innumerable small oysters; occasional layers of yellow calcareous shale; a thin bed, 15 feet above base, of coarse purple and yellow, iron-stained, and exceedingly gypsiferous sandstone with many fossils (locality 4693), probably the *Pecten coalingaensis* zone.	725

	Feet.
Mostly light-gray and drab sand, with beds of dark clay in minor amount; a pebbly sand layer 200 feet below top; pebbly sand and iron-hardened sandstone layers near base	1,400
Blue-sand zone, several massive beds of blue sand and pebbly sand interbedded with fine light-gray and drab sand, sandy shale, and pebbly sand and occasional iron-hardened beds; at top is probably the upper *Mulinia* zone; the basal sand is full of fossils and is the lower *Mulinia* zone (locality 4689)	675
	3,050

The upper *Mulinia* zone occurs 2,000 feet below the summit of the Etchegoin in the section in figure 5, whereas the bed that has been correlated with it in the above tabulated section occurs over 300 feet lower. It seems probable from this and similar instances in the case of other sections that there is a thickening of the formation toward the south between the top and this bed, similar to the thickening that takes place between the oil field north of Coalinga and the Kreyenhagen Hills. It may reasonably be assumed that a thickening takes place below the upper *Mulinia* zone as well, and that the base of the formation is not as far below this zone in the northern portion of the hills as farther south.

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

FOSSILS, ORIGIN, AND AGE.

FOSSILS.

Fossils are found more or less abundantly and usually in an excellent state of preservation throughout the Etchegoin formation in the Coalinga district. Several recognizable zones, each carrying a more or less distinctive fauna, occur between the base and top of the formation, but these faunas are closely related and have not been deemed worthy of recognition in the mapping. The following species have been found by the writers in and near the district under discussion:

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district.

Name.	3849.	4643.	4648.	4656.	4657.	4658.	4659.	4660.	4661.	4662.	4663.	4664.	4665.	4669.	4670.	4671.	4672.	4673.	4674.	4675.	4676.	4677.	4678.	4679.	4681.	4682.	4683.	4684.	4688.	4690.
ANTHOZOA.																														
Astrangia coalingensis Vaughan																														
ECHINODERMATA.																														
Astrodapsis cf. tumidus Rémond																														
Astrodapsis sp. *a*																														
Echinarachnius gibbsii Rémond	×	×			×				×	×						×		×	×					×					×	×
Scutella perrini Weaver																														
BRACHIOPODA.																														
Terebratalia occidentalis Dall																														
Terebratalia smithi Arnold																														
PELECYPODA.																														
Arca trilineata Conrad			×	×				×		×		×	×		×			×		×			×	×						
Arca sp. *a*																														
Cardium coosense Dall								×												×										
Cardium meekianum Gabb								×					×								×		×	×						
Cardium sp. indet																														
Chama pellucida Broderip																														
Clidiophora punctata Conrad																														
Cryptomya ovalis Conrad																														
Cryptomya quadrata Arnold													×																	
Cumingia californica Conrad				×																										
Diplodonta harfordi F. M. Anderson																														
Diplodonta parilis Conrad																														
Glycymeris coalingensis Arnold				×					×			×					×													
Glycymeris septentrionalis Middendorf					×		×	×		×								×										×		
Glycymeris sp. indet																			×											
Macoma inquinata Deshayes				×												×		×					×	×						
Macoma nasuta Conrad				×									×																	
Macoma secta Conrad																														
Macoma sp. *a*																														
Mactra albaria Conrad													×																	
Mactra coalingensis Arnold													×																	
Metis sp. indet															×															
Modiolus directus Dall																														
Modiolus rectus Conrad				×																										
Mulinia densata Conrad		×		×	×		×																×	×	×	×	×	×		
Mya japonica Jay													×								×	×	×							
Mytilus (Mytiloconcha) coalingensis Arnold				×		×		×				×				×	×							×					×	

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	3849.	4643.	4648.	4656.	4657.	4658.	4659.	4660.	4661.	4662.	4663.	4664.	4665.	4669.	4670.	4671.	4672.	4673.	4674.	4675.	4676.	4677.	4678.	4679.	4681.	4682.	4683.	4684.	4688.	4690.
PELECYPODA—continued.																														
Nucula castrensis Hinds																														
Ostrea atwoodi Gabb		×	×									×											×	×						
Ostrea lurida Carpenter																														
Ostrea vespertina Conrad																														
Ostrea vespertina Conrad var. sequens Arnold																														
Ostrea sp.												×																		
Panopea generosa Gould						×								×																
Paphia staleyi? Gabb		×		×	×	×						×												×						
Paphia tenerrima Carpenter				×				×		×		×	×																	
Paphia truncata? Gabb				×																										
Pecten coalingaensis Arnold																														
Pecten deserti Conrad																														
Pecten nutteri Arnold																														
Pecten oweni Arnold				×			×	×		×	×	×		×																
Pecten wattsi Arnold												×																		
Pecten wattsi Arnold var. etchegoini F. M. Anderson																														
Phacoides acutilineatus Conrad												×																		
Pholadidea ovoidea Gould																														
Placunanomia californica Arnold																														
Saxidomus nuttalli Conrad				×		×										×														
Schizothærus nuttalli Conrad					×	×																		×						
Schizothærus pajaroanus Conrad													×																	
Semele rubropicta Dall																														
Siliqua cf. nuttalli Conrad																								×						
Siliqua sp. indet																														
Solen sicarius Gould		×											×					×			×									
Solen sp. indet																														
Transennella californica Arnold																														
Zirphæa gabbi Tryon																														
GASTEROPODA.																														
Astyris richthofeni Gabb																														
Bathytoma carpenteriana Gabb var. fernandoana Arnold																														
Calliostoma coalingensis Arnold																														
Calliostoma kerri Arnold																														
Cancellaria tritonidea Gabb																			×											
Chrysodomus imperialis Dall																														
Chrysodomus portolaensis Arnold													×	×																
Crepidula princeps Conrad													×	×																

Goniobasis kettlemanensis Arnold																														
Littorina mariana Arnold and var. alta Arnold																														
Lunatia lewisii Gould			×										×										×							
Margarita sp																														
Nassa californiana Conrad													×							×								×		
Nassa californiana Conrad var. coalingensis Arnold					×		×								×			×												
Natica?																				×										
Neverita recluziana Petit																														
Neverita recluziana Petit var. alta Dall																				×										
Olivella biplicata Conrad																														
Olivella pedroana Conrad																														
Opalia sp. indet																														
Pisania fortis Carpenter var. angulata Arnold																	×													
Pleurotoma coalingensis Arnold																														
Sigaretus scopulosus Conrad										×																				
Thais crispatus Chemnitz																														
Thais crispatus Chemnitz, nearly smooth var																														
Thais etchegoinensis Arnold																														
Thais kettlemanensis Arnold																								×						
Trochita filosa Gabb																×		×			×									
Trophon (Forreria) coalingense Arnold																														
Trophon (Forreria) ponderosum Gabb																								×						
Trophon (Boreotrophon) stuarti Smith																														
Turritella vanvlecki Arnold						×				×																				
Xylotrya sp																														
CIRRIPEDIA.																														
Balanus sp				×					×			×				×	×													
Balanus large sp																													×	
Balanus concavus Bronn																														
Tamiosoma gregaria? Conrad					(?)					×																				
CRUSTACEA.																														
Cancer fissus Rathbun																														
Loxorhynchus grandis Stimpson																														
PISCES.																														
Fish bones of various kinds																														
Carcharodon arnoldi Jordan																														
Fish, bulbous growths																														
Fish spines																														
Fish vertebræ																														
CETACEA.																														
Cetaceæ (vert[illegible]e)																														

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	4693.	4695.	4696.	4697.	4698.	4699.	4700.	4701.	4702.	4703.	4704.	4705.	4706.	4707.	4708.	4709.	4710.	4711.	4712.	4713.	4714.	4715.	4716.	4717.	4718.	4720.	4722.	4723.	4724.	4725.
ANTHOZOA.																														
Astrangia coalingensis Vaughan																	×													
ECHINODERMATA.																														
Astrodapsis cf. tumidus Rémond																														
Astrodapsis sp. *a*																×	×		×											
Echinarachnius gibbsii Rémond	×						×						×	×	×		×		×	×	×	×								
Scutella perrini Weaver																			×	×										
BRACHIOPODA.																														
Terebratalia occidentalis Dall																														
Terebratalia smithi Arnold																			×		×									
PELECYPODA.																														
Arca trilineata Conrad	×	×						×							×	×	×		×		×			×	×					×
Arca sp. *a*																														
Cardium coosense Dall																×														
Cardium meekianum Gabb																														
Cardium sp. indet																														
Chama pellucida Broderip																×	×													
Clidiophora punctata Conrad																														
Cryptomya ovalis Conrad	×																													
Cryptomya quadrata Arnold																														
Cumingia californica Conrad																														
Diplodonta harfordi F. M. Anderson																														
Diplodonta parilis Conrad																														
Glycymeris coalingensis Arnold																														
Glycymeris septentrionalis Middendorf																														
Glycymeris sp. indet																														
Macoma inquinata Deshayes																						×			×	×	×	×		×
Macoma nasuta Conrad												×					×					×								
Macoma secta Conrad																														
Macoma sp. *a*																														
Mactra albaria Conrad																														
Mactra coalingensis Arnold																														
Metis sp. indet																														
Modiolus directus Dall																														
Modiolus rectus Conrad					×																									
Mulinia densata Conrad		×		×	×																									
Mya japonica Jay		×																				×			×	×	×	×		×
Mytilus (Mytiloconcha) coalingensis Arnold	×																				×									

Nucula castrensis Hinds															×															
Ostrea atwoodi Gabb																														
Ostrea lurida Carpenter															×	×														
Ostrea vespertina Conrad															×			×	×			×					×			
Ostrea vespertina Conrad var. sequens Arnold									×														×		×			×		×
Ostrea sp								×				×									×									
Panopea generosa Gould																														
Paphia staleyi Gabb																						×								
Paphia tenerrima Carpenter																														
Paphia truncata? Gabb																														
Pecten coalingaensis Arnold																×	×		×		×									
Pecten deserti Conrad																			×			×								
Pecten nutteri Arnold																			×		×									
Pecten oweni Arnold				×																										
Pecten wattsi Arnold																			×											
Pecten wattsi Arnold var. etchegoini F. M. Anderson																			×											
Phacoides acutilineatus Conrad																														
Pholadidea ovoidea Gould																														
Placunanomia californica Arnold																						×								
Saxidomus nuttalli Conrad																														
Schizothærus nuttalli Conrad																														
Schizothærus pajaroanus Conrad																														
Semele rubropicta Dall																														
Siliqua cf. nuttalli Conrad																														
Siliqua sp. indet																														
Solen sicarius Gould												×			×											×				×
Solen sp. indet																														
Transennella californica Arnold																						×								
Zirphæa gabbi Tyron																	×													
GASTEROPODA.																														
Astyris richthofeni Gabb																														
Bathytoma carpenteriana Gabb var. fernandoana Arnold								×																						
Calliostoma coalingensis Arnold																	×													
Calliostoma kerri Arnold	×																		×											
Cancellaria tritonidea Gabb								×																						
Chrysodomus imperialis Dall																														
Chrysodomus portolaensis Arnold																														
Crepidula princeps Conrad															×				×											
Goniobasis kettlemanensis Arnold			×																			×								
Littorina mariana Arnold and var. alta Arnold								×														×			×	×	×	×	×	
Lunatia lewisii Gould				×															×											
Margarita sp																														
Nassa californiana Conrad																	×													
Nassa californiana Conrad var. coalingensis Arnold																			×											
Natica?																														

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	4693.	4695.	4696.	4697.	4698.	4699.	4700.	4701.	4702.	4703.	4704.	4705.	4706.	4707.	4708.	4709.	4710.	4711.	4712.	4713.	4714.	4715.	4716.	4717.	4718.	4720.	4722.	4723.	4724.	4725.
GASTEROPODA—continued.																														
Neverita recluziana Petit	×			×				×	×	×	×	×				×	×		×											
Neverita recluziana Petit var. alta Dall																×														
Olivella biplicata Conrad																														
Olivella pedroana Conrad																	×													
Opalia sp. indet																			×											
Pisania fortis Carpenter var. angulata Arnold																														
Pleurotoma coalingensis Arnold																														
Sigaretus scopulosus Conrad																														
Thais crispatus Chemnitz				×											×															
Thais crispatus Chemnitz, nearly smooth var																														
Thais etchegoinensis Arnold		×		×															×											
Thais kettlemanensis Arnold																														
Trochita filosa Gabb	×														×										×		×			
Trophon (Forreria) coalingense Arnold																														
Trophon (Forreria) ponderosum Gabb																														
Trophon (Boreotrophon) stuarti Smith																			×											
Turritella vanvlecki Arnold																														
Xylotrya sp																						×								
CIRRIPEDIA.																														
Balanus sp																														
Balanus large sp																			×											
Balanus concavus Bronn																	×													
Taniosoma gregaria? Conrad																														
CRUSTACEA.																														
Cancer fissus Rathbun																														
Loxorhynchus grandis Stimpson																														
PISCES.																														
Fish bones of various kinds						×										×												×	×	
Carcharodon arnoldi Jordan																×				×										
Fish, bulbous growths		×	×	×		×																×								
Fish spines			×																											
Fish vertebræ																														
CETACEA.																														
Cetaceæ (vertebræ)				×																										

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	4728.	4729.	4730.	4736.	4741.	4744.	4749.	4750.	4751.	4752.	4753.	4754.	4755.	4756.	4757.	4758.	4759.	4760.	4761.	4762.	4763.	4769.	4778.	4780.	4781.	4782.	4783.	4799.	4806.	4857.
ANTHOZOA.																														
Astrangia coalingensis Vaughan																×														
ECHINODERMATA.																														
Astrodapsis cf. tumidus Rémond																	×													
Astrodapsis sp. *a*																														
Echinarachnius gibbsii Rémond							×	×	×		×		×	×	×	×	×		×									×	×	
Scutella perrini Weaver																														
BRACHIOPODA.																														
Terebratalia occidentalis Dall			×																											
Terebratalia smithi Arnold																×														
PELECYPODA.																														
Arca trilineata Conrad				×			×	×							×	×	×	×		×	×	×		×	×				×	×
Arca sp. *a*																												×		
Cardium coosense Dall																					×									
Cardium meekianum Gabb								×							×				×										×	
Cardium sp. indet																						×								
Chama pellucida Broderip																														
Clidiophora punctata Conrad																													×	
Cryptomya ovalis Conrad			×													×														
Cryptomya quadrata Arnold																														
Cumingia californica Conrad																×														
Diplodonta harfordi F. M. Anderson																													×	
Diplodonta parilis Conrad														×		×					×								×	
Glycymeris coalingensis Arnold								×						×		×					×								×	
Glycymeris septentrionalis Middendorf																													×	
Glycymeris sp. indet																														
Macoma inquinata Deshayes				×		×	×	×		×				×		×										×				
Macoma nasuta Conrad														×		×														
Macoma secta Conrad																													×	
Macoma sp. *a*														×						×										
Mactra albaria Conrad																														
Mactra coalingensis Arnold																				×									×	
Metis sp. indet																						×								
Modiolus directus Dall																		×												
Modiolus rectus Conrad						×										×								×						
Mulinia densata Conrad							×	×				×		×		×						×						×		
Mya japonica Jay		×		×		×				×		×														×				
Mytilus (Mytiloconcha) coalingensis Arnold				?			×	×								×													×	

Fossils from the Etchegoin formation (uppermost Miocene), Coalinga district—Continued.

Name.	4728.	4729.	4730.	4736.	4741.	4744.	4749.	4750.	4751.	4752.	4753.	4754.	4755.	4756.	4757.	4758.	4759.	4760.	4761.	4762.	4763.	4769.	4778.	4780.	4781.	4782.	4783.	4799.	4806.	4857.
PELECYPODA—continued.																														
Nucula castrensis Hinds																														
Ostrea atwoodi Gabb																						×								
Ostrea lurida Carpenter																							×							
Ostrea vespertina Conrad	×															×							×							
Ostrea vespertina Conrad var. sequens Arnold	×																													
Ostrea sp.																														
Panopea generosa Gould														×	×															
Paphia staleyi Gabb														×							×									
Paphia tenerrima Carpenter																														
Paphia truncata? Gabb							×																							
Pecten coalingaensis Arnold																×														
Pecten deserti Conrad																														
Pecten nutteri Arnold																														
Pecten oweni Arnold							×																					×	×	×
Pecten wattsi Arnold																×							×							
Pecten wattsi Arnold var. etchegoini F. M. Anderson																														
Phacoides acutilineatus Conrad																														
Pholadidea ovoidea Gould								×																						
Placunanomia californica Arnold																														
Saxidomus nuttalli Conrad							×	×						×	×						×									
Schizothærus nuttalli Conrad																														
Schizothærus pajaroanus Conrad																														
Semele rubropicta Dall																×														
Siliqua cf. nuttalli Conrad								×																						
Siliqua sp. indet.																×														
Solen sicarius Gould				×		×								×	×							×								
Solen sp. indet.							×																							
Transennella californica Arnold																														
Zirphæa gabbi Tryon																×														
GASTEROPODA.																														
Astyris richthofeni Gabb																×													×	
Bathytoma carpenteriana Gabb var. fernandoana Arnold																×														
Calliostoma coalingensis Arnold																×														
Calliostoma kerri Arnold																×														
Cancellaria tritonidea Gabb																×														
Chrysodomus imperialis Dall								×																						
Chrysodomus portolaensis Arnold																														×
Crepidula princeps Conrad								×								×														×

Goniobasis kettlemanensis Arnold																														
Littorina mariana Arnold and var. alta Arnold			×																											
Lunatia lewisii Gould								×						×					×					×					×	×
Margarita sp.																													×	
Nassa californiana Conrad							×							×		×						×							×	×
Nassa californiana Conrad var. coalingensis Arnold																×														
Natica?																														
Neverita recluziana Petit					×							×				×		×												
Neverita recluziana Petit var. alta Dall																														
Olivella biplicata Conrad																×														
Olivella pedroana Conrad																						×								
Opalia sp. indet																														
Pisania fortis Carpenter var. angulata Arnold																	×													
Pleurotoma coalingensis Arnold																													×	
Sigaretus scopulosus Conrad																														
Thais crispatus Chemnitz																														
Thais crispatus Chemnitz, nearly smooth var.							×																							
Thais etchegoinensis Arnold														×																
Thais kettlemanensis Arnold																														
Trochita filosa Gabb															×	×	×							×						
Trophon (Forreria) coalingense Arnold							×																							×
Trophon (Forreria) ponderosum Gabb																												×	×	
Trophon (Boreotrophon) stuarti Smith																														
Turritella vanvlecki Arnold																														
Xylotrya sp.																														
CIRRIPEDIA.																														
Balanus sp																														×
Balanus large sp.														×																
Balanus concavus Bronn																														
Tamiosoma gregaria? Conrad																														×
CRUSTACEA.																														
Cancer fissus Rathbun														×																
Loxorhynchus grandis Stimpson																											×			
PISCES.																														
Fish bones of various kinds																														
Carcharodon arnoldi Jordan																														
Fish, bulbous growths					×																									
Fish spines																														
Fish vertebræ																														
CETACEA.																														
Cetaceæ (vertebræ)																														

3849. Point where road from Coalinga to Stone Canyon crosses the Waltham Creek sheep property. Spur of sandstone. Middle beds.
4643. Upper *Mulinia* zone on main ridge of Kettleman Hills 1 mile southeast of 1,370-foot hill, in the SE. ¼ sec. 20, T. 22 S., R. 18 E. Lower middle beds.
4648. Seventy-five feet below summit on south side of 1,375-foot hill just west of Mr. Orr's house in Big Tar Canyon, in the NE. ¼ NW. ¼ sec. 8, T. 23 S., R. 17 E. Basal beds.
4656. At northwest end of Anticline Ridge, 6 miles north-northeast of Coalinga, SW. ¼ sec. 34, T. 19 S., R. 15 E. Lowest Etchegoin bed or *Glycymeris* zone, just below bed of 4657.
4657. At northwest end of Anticline Ridge, 6 miles north-northeast of Coalinga; bed just above 4656; near south side of SW. ¼ sec. 34, T. 19 S., R. 15 E. Basal beds.
4658. Near northwest end of Anticline Ridge, at southeast end of long 1,200-foot hill, in NE. ¼ sec. 3, T. 20 S., R. 15 E. Near base of Etchegoin.
4659. At northwest end of Anticline Ridge on 1,200-foot hill and for 1 mile northwest of that hill along *Glycymeris* zone. Basal beds. See 4656.
4660. About 2½ miles southwest of Coalinga, northeast of West Coalinga well. *Glycymeris* zone or basal beds. See locality 4674.
4661. Eight miles north of Coalinga, in the NW. ¼ sec. 29, T. 19 S., R. 15 E. *Glycymeris* zone or basal beds.
4662. At north edge of Etchegoin area in White Creek basin, one-half mile east of road up White Creek and three-fourths mile southeast of Michigan well, center of NW. ¼ sec. 16, T. 19 S., R. 13 E. *Glycymeris* zone, 100 feet above base of Etchegoin.
4663. At north edge of Etchegoin area in White Creek basin, on summit of ridge one-half mile west of road up White Creek and three-fourths mile southwest of Michigan well, about 1 mile northwest of 4662. In basal sandstone of the Etchegoin.
4664. On north side of White Creek about 5 miles northwest of junction with Los Gatos Creek. In basal Etchegoin beds on south side of synclinal basin.
4665. On south side of White Creek about 6 miles northwest of junction with Los Gatos Creek. Basal beds.
4669. At south end of Kettleman Hills, on summit of 540-foot hill in the very southwest corner of area mapped, in center of sec. 2, T. 25 S., R. 19 E., and for 1 mile S. 15° E. of that hill. Probably about the lowest Etchegoin beds exposed south of Avenal Gap.
4670. At southernmost end of Kettleman Hills, 5¼ miles south-southeast of Light's house in Avenal Gap, on knob of vertical angle B. M. (elevation 505 feet), in center of sec. 10, T. 25 S., R. 19 E. Prominent bed of yellowish limestone in uppermost portion of Etchegoin.
4671. On northeast flank of Anticline Ridge, about 6½ miles northeast of Coalinga and about 2 miles north-northeast of B. M. 947 feet. Several hundred feet above base of Etchegoin, in the lower middle beds.
4672. South of Waltham Creek, 3½ miles southwest of Coalinga, on northeast nose of 1,200-foot ridge four-fifths mile north-northwest of 1,900-foot hill, center of SE. ¼ sec. 13, T. 21 S., R. 14 E. Basal beds.
4673. One mile southeast of Alcalde, at elevation of 1,600 feet on ridge west of 1,900-foot hill, center of NE. ¼ sec. 24, T. 21 S., R. 14 E. Basal beds.
4674. Halfway between West Coalinga and Commercial Petroleum wells, about 3 miles southwest of Coalinga. *Glycymeris* zone or basal beds. See locality 4660.
4675. About 2½ miles due west of Coalinga, at elevation of about 1,200 feet on road, north line of sec. 1, T. 21 S., R. 14 E. Lower middle beds.
4676. Six miles southeast of northwest end of Kettleman Hills, where old road crosses main ridge one-half mile east of 1,332-foot hill. Lower *Mya* zone, or lower middle beds.
4677. Ten miles southeast of northwest end of Kettleman Hills, on northeast side of summit of 1,370-foot hill, west side of NW. ¼ sec. 20, T. 22 S., R. 18 E. Lower *Mya* zone, or lower middle beds.
4678. On road north of locality 4676, one-half mile east-northeast of 1,332-foot hill. Lower middle beds.
4679. Area about 10 to 12 miles southeast of northwest end of Kettleman Hills; *Mulinia* beds on both sides of anticline, between 1,370-foot and 1,277-foot hills on main ridge and within 1 mile northeast of those hills on opposite side of anticline. Lower middle and basal beds.
4681. On east side of Kettleman Hills 3 miles northeast of Light's place in Avenal Gap, on southwest side of long, low ridge near axis of anticline, middle of west side of NE. ¼ sec. 4, T. 24 S., R. 19 E. Upper (?) *Mulinia* zone, or lower middle beds.
4682. One-third mile west of locality 4681, north-central part of NW. ¼ sec. 4, T. 24 S., R. 19 E. Upper *Mulinia* zone, or lower middle beds.
4683. South of Avenal Gap in Kettleman Hills; extremely fossiliferous sand on summit of 500-foot knob just north of old house, 2½ miles S. 45° E. of Light's place; northern part of NW. ¼ sec. 27, T. 24 S., R. 19 E. Upper *Mulinia* zone, or lower middle beds.
4684. South-central part of Kettleman Hills, about 5 miles northwest of Dudley-Lemoore road, in second main canyon 1¼ miles N. 45° E. of 1,030-foot hill, center of SW. ¼ sec. 35, T. 22 S., R. 18 E. Lower *Mulinia* zone, about 3,000 feet below top of Etchegoin; lower middle or basal beds.
4688. On Anticline Ridge, southwest of Turner well No. 2, middle of S. ½ sec. 2, T. 20 S., R. 15 E. Several hundred feet above base of Etchegoin, in the lower middle beds.
4690. Two miles southwest of Coalinga, south of Lucile well, SW. ¼ sec. 6. Lower middle beds.
4693. South-central part of Kettleman Hills, about 9 miles northwest of Avenal Gap, 1,000 feet northeast of 1,030-foot hill, SW. ¼ NE. ¼ sec. 3, T. 23 S., R. 18 E.; 950 feet stratigraphically below summit of Etchegoin. About the same as *Pecten coalingaensis* zone, or upper middle beds.
4695. East side of Kettleman Hills south of Avenal Gap, from gravelly surface of ground, NE. ¼ SE. ¼ sec. 27, T. 24 S., R. 19 E. Lower middle beds.
4696. About 2,000 feet east of main ridge of Kettleman Hills, 1 mile southeast of Light's place, SW. ¼ NW. ¼ sec. 21, T. 24 S., R. 19 E. In dark gypsiferous sand and clay about 750 feet stratigraphically below top of Etchegoin; probably the equivalent of the *Pecten coalingaensis* zone, or upper middle beds.
4697. Near south end of Kettleman Hills, along summit of ridge (elevation 592 feet) 4 miles S. about 20° E. of Light's place in Avenal Gap, on west side of sec. 3, T. 25 S., R. 19 E. Prominent pebble bed 1,600 to 2,000 feet below summit of Etchegoin. Probably same horizon as 4695, in lower middle beds.
4698. North of White Creek syncline, about three-fourths mile north of White Creek and 3½ miles northwest of junction with Los Gatos Creek, in center of sec. 23, T. 19 S., R. 13 E. Upper middle beds.
4699. Eastern border of southernmost group of Kettleman Hills, in gray and blue sand on northeastern side of knoll in western part of sec. 26, T. 24 S., R. 19 E. About same horizon as 4695 and 4697, in lower middle beds.
4700. Kettleman Hills. Float. Undifferentiated lower or middle beds.
4701. East side of Kettleman Hills, at base of upper *Mya* zone or uppermost beds on Dudley-Lemoore road, in east-central part of sec. 17, T. 23 S., R. 19 E.
4702. South-central part of Kettleman Hills, on northwest side of 813-foot hill 4½ miles northwest of Avenal Gap, 400 feet east of main ridge where old road crosses, NW. ¼ NW ¼ sec. 25, T. 23 S., R. 18 E. Gypsiferous sand and pebble bed about 900 feet stratigraphically below summit of Etchegoin. Probably equivalent to *Pecten coalingaensis* zone, or upper middle beds.

4703. Central part of Kettleman Hills, 10 miles northwest of Avenal Gap, three-fourths mile N. 30° W. of 1,030-foot hill, SW. ¼ SW ¼ sec. 34, T. 22 S., R. 18 E. About 900 feet stratigraphically below summit of Etchegoin. Probably equivalent of *Pecten coalingaensis* zone, or upper middle beds.
4704. Central part of Kettleman Hills, 11 miles northwest of Avenal Gap, on south base of 1,145-foot hill, in the very southeast corner of sec. 28, T. 22 S., R. 18 E. Just above upper *Mulinia* zone, in lower middle beds.
4705. One-third mile south of B. M. 923 feet on Zapato Creek, from hard layers in sand forming a ridge that runs along 1 mile from there on south side of road to Canoas Creek, on west side of NW. ¼ sec. 17, T. 22 S., R. 16 E. About 450 feet below summit of Etchegoin. *Pecten coalingaensis* zone, or upper middle beds.
4706. Just across the gully east of the Call well, 7 miles north-northwest from Coalinga, in the northwest corner of sec. 32, T. 19 S., R. 15 E. Lower middle beds (?).
4707. About one-fourth mile northeast of Hugo Kreyenhagen's house, between two roads that run east from Canoas Creek, center of sec. 27, T. 22 S., R. 16 E. Sea-urchin bed immediately above upper *Mulinia* zone, about 900 feet stratigraphically above base of Etchegoin, in lower middle beds.
4708. 1,245-foot hill 4 miles southeast of northwest end of Kettleman Hills, east side of sec. 32, T. 21 S., R. 17 E. *Arca* bed in upper *Mya* zone, or uppermost beds.
4709. East side of Kettleman Hills, on summit of ridge in center of SE. ¼ sec. 6, T. 22 S., R. 18 E. Drab sand with hard sandstone layers, 750 to 800 feet stratigraphically below summit of Etchegoin. *Pecten coalingaensis* zone, or upper middle beds.
4710. Three-fourths of a mile northwest of Zapato Creek B. M. 806 feet, on north side of ravine, west-central part of NE. ¼ sec. 5, T. 22 S., R. 16 E. *Pecten coalingaensis* zone, or upper middle beds.
4711. West side of 1,245-foot hill 4 miles southeast of northwest end of Kettleman Hills, central part of sec. 32, T. 21 S., R. 17 E. Oyster bed 50 feet above *Arca* bed of locality 4708. Upper *Mya* zone, or uppermost beds.
4712. East of Zapato Creek, one-half mile south of Adolph Kreyenhagen's house, SW. ¼ SE. ¼ sec. 8, T. 22 S., R. 16 E. Variable pebbly sand, with many fossils. *Pecten coalingaensis* zone, or upper middle beds.
4713. About 5½ miles southeast of northwest end of Kettleman Hills, on top of 1,332-foot hill in south-central part of sec. 3, T. 22 S., R. 17 E. Sand-dollar bed of drab sand overlying blue and gray sand of lower *Mya* zone, both being in the lower middle beds.
4714. Two miles southwest of Coalinga, at elevation of 900 feet, near edge of Alcalde Hills, on ridge descending east from prominent hill (elevation 1,410 feet), just east of center of SW. ¼ sec. 6, T. 21 S., R. 15 E. Coarse sand and pebble conglomerate about 650 feet stratigraphically above base of Etchegoin. *Pecten coalingaensis* zone, or upper middle beds.
4715. South end of Kettleman Hills, sec. 10, T. 25 S., R. 19 E. Upper middle and uppermost Etchegoin beds.
4716. Near northwest end of Kettleman Hills, 2 miles north-northwest of 1,245-foot hill, east of center of SW. ¼ sec. 20, T. 21 S., R. 17 E. In sand just below flinty white shale bed that marks top of Etchegoin. Just below 4740. Upper *Mya* zone, or uppermost beds.
4717. Near northwest end of Kettleman Hills, 1¾ miles northwest of 1,245-foot hill, just east of old house, northwest corner of sec. 29, T. 21 S., R. 17 E. *Arca* sand below white shale at top of Etchegoin, upper *Mya* zone, or uppermost beds.
4718. Main ridge of Kettleman Hills, 4 miles north of Dudley-Lemoore road, on summit of 1,020-foot hill, east side of sec. 11, T. 23 S., R. 18 E. Upper *Mya* zone, or uppermost beds.
4720. One mile due north of Light's place in Avenal Gap, on south side of hill (elevation 555 feet) in center of SW. ¼ sec. 8, T. 24 S., R. 19 E. Very gypsiferous sand at base of upper *Mya* zone, or uppermost beds.
4722. Three-fourths mile southeast of Adolph Kreyenhagen's on Zapato Creek, northwest corner of sec. 16, T. 22 S., R. 16 E. Upper *Mya* zone, or uppermost beds.
4723. South group of Kettleman Hills, on point of main ridge facing Avenal Gap one-half mile east-southeast of Light's place, south side of SE. ¼ sec. 17, T. 24 S., R. 19 E. Upper *Mya* zone, or uppermost beds.
4724. Main ridge of south group of Kettleman Hills, 1 mile south of Avenal Gap, NW. ¼ SE. ¼ sec. 20, T. 24 S., R. 19 E. Upper *Mya* zone, or uppermost beds.
4725. East side of Kettleman Hills, on 500-foot ridge at contact of Etchegoin and Tulare north of sharp turn in Dudley-Lemoore road, southwest corner of sec. 8, T. 23 S., R. 19 E. Upper *Mya* zone, or uppermost beds.
4728. On northeast border of Kettleman Hills, on southwest flank of 900-foot hill just east of old road, in north part of sec. 35, T. 21 S., R. 17 E. Upper *Mya* zone at top of Etchegoin immediately underlying Tulare fresh-water beds of 4731.
4729. About 1½ miles east of Garza Creek, just north of road, at west foot of hill (elevation 1,174 feet), southeast corner of NE. ¼ sec. 36, T. 22 S., R. 16 E. Upper *Mya* zone, or uppermost beds.
4730. Central part of Kettleman Hills, on summit of 1,030-foot hill on main ridge 9¾ miles northwest of Light's place in Avenal Gap, center of sec. 3, T. 23 S., R. 18 E. Upper *Mya* zone, or uppermost beds.
4736. East side of Kettleman Hills, east of Dudley-Lemoore road, NE. ¼ SW. ¼ sec. 17, T. 23 S., R. 19 E. Upper *Mya* zone just below fresh-water bed (Tulare) of locality 4737, uppermost beds.
4741. In Kettleman Hills, 3½ miles north of Dudley-Lemoore road on little hill (elevation 600+ feet), northeast corner of sec. 12, T. 23 S., R. 18 E. In lower middle beds just above lower *Mya* zone.
4744. West of Canoas Creek, north of road leading to Zapato Creek, SW. ¼ NW. ¼ sec. 22, T. 22 S., R. 16 E. Upper *Mya* zone, uppermost beds.
4749. On ridge east of Garza Creek, in NE. ¼ sec. 1, T. 23 S., R. 16 E. Lower *Mulinia* zone, basal beds of Etchegoin.
4750. On ridge east of Garza Creek, about 1,200 feet stratigraphically above 4749, SW. ¼ sec. 36, T. 22 S., R. 16 E. Lower middle beds.
4751. On ridge east of Garza Creek and immediately west of road from Garza Creek to Big Tar Canyon, NW. ¼ sec. 36, T. 22 S., R. 16 E. About 1,000 feet stratigraphically above 4750, or in upper middle beds.
4752. On ridge east of Garza Creek and immediately northeast of road connecting Garza Creek and Big Tar Canyon, NE. ¼ sec. 36, T. 22 S., R. 16 E. Upper *Mya* zone, about 1,000 feet stratigraphically above 4751, uppermost beds.
4753. On Waltham Creek 13 miles southwest of Coalinga, 200 yards north of Elmer Frame's house. In gray sandstone well up in Etchegoin formation, probably in middle beds.
4754. Waltham Creek, 13 miles southwest of Coalinga, three-fourths mile east of Elmer Frame's place. Gray sandstone 200 feet stratigraphically below 3849; probably in middle beds.
4755. About 4 miles south of Coalinga in Jacalitos Hills, SW. ¼ sec. 21, T. 21 S., R. 15 E. Undifferentiated lower or middle beds.
4756. Vicinity of Henry Spring, 4 miles south-southwest of Coalinga, on east side of 1,900-foot hill, SW. ¼ sec. 18, T. 21 S., R. 15 E. Lower middle or basal beds.
4757. Same locality, but 150 feet stratigraphically above 4756. Lower middle or basal beds.
4758. Same locality, but 490 feet stratigraphically above 4756. Upper middle beds.
4759. Same locality, but 500 to 900 feet stratigraphically above 4756. Upper middle beds.

4760. On old road crossing north end of Kettleman Hills, three-fourths mile northeast of 1,332-foot hill, SE. ¼ NW. ¼ sec. 2, T. 22 S., R. 17 E. In lower middle beds 1,900 feet stratigraphically below summit of Etchegoin. About equivalent of lower *Mya* zone.
4761. On ridge one-half mile south of junction of Jacalitos and Salt creeks, southeast corner sec. 31, T. 21 S., R. 15 E. *Cardium* bed at base of Etchegoin; about equivalent of *Glycymeris* zone; basal beds.
4762. Southwest of Coalinga district, in Waltham Valley, three-fourths mile east of Elmer Frame's house. *Arca* and *Mactra* bed, probably basal beds.
4763. Southwest of Coalinga district, on Stone Canyon-Waltham Creek road just west of Waltham Valley. Probably middle beds.
4769. On east side of Canoas Creek just south of Hugo Kreyenhagen's home, northwest corner of SW. ¼ sec. 27, T. 22 S., R. 16 E. Probable equivalent of the *Glycymeris* zone, or lower *Mulinia* zone, at contact between Etchegoin and Jacalitos.
4778. About three-fourths mile east of Adolph Kreyenhagen's house on Zapato Creek, west side of sec. 9, T. 22 S., R. 16 E. Small *Ostrea* bed, about 100 feet stratigraphically below *Mya* bed at top of Etchegoin formation in upper *Mya* zone.
4780. One-fourth mile west of locality 4778. *Arca* bed about 350 feet below summit of Etchegoin, in upper beds.
4781. Arcas from north-central part of Kettleman Hills. Basal *Mulinia* beds.
4782. On southwest flank of high hill (elevation 1,458 feet) east of lower part of Canoas Creek, at elevation of 1,200 feet, SW. ¼ SW. ¼ sec. 23, T. 22 S., R. 16 E. Upper *Mya* zone, or uppermost beds.
4783. On the northwest bank of Canoas Creek, three-fourths mile below H. Kreyenhagen's, 16 miles southeast of Coalinga, northeast corner of SW. ¼ sec. 22, T. 22 S., R. 16 E. In *Ostrea* bed 125 feet stratigraphically below the top of the Etchegoin formation, in uppermost beds.
4799. Coalinga district; exact locality unknown.
4806. Two miles southeast of Coalinga, on north side of Alcalde Canyon, center of SW. ¼ sec. 7, T. 21 S., R. 15 E. *Glycymeris* zone, near base of Etchegoin.
4857. Extreme southeast end of Kettleman Hills, in secs. 11 and 12, T. 25 S., R. 19 E. *Pecten oweni* bed, probably lowest Etchegoin.

FAUNAL ZONES.

The lowest fossiliferous bed in the Etchegoin is in a zone in which *Glycymeris coalingensis* Arnold and *G. septentrionalis* Middendorf are exceedingly abundant; this zone is called the *Glycymeris* zone. Above this are beds in which *Mulinia densata* Conrad is very abundant; this is the upper *Mulinia* zone. Still higher in certain parts of the field *Echinarachnius gibbsii* Rémond is very common, but other fossils rare, and this is sometimes called the *Echinarachnius* zone. A few hundred feet below the top of the Etchegoin is an exceedingly fossiliferous zone in which *Pecten coalingaensis* Arnold is a common species, and this is called the *Pecten coalingaensis* zone; above it and practically at the top of the Etchegoin is the upper *Mya* zone, characterized by numerous *Mya japonica* Jay. In the Kettleman Hills is another zone between the *Mulinia* and *Pecten coalingaensis* zones, in which *Mya japonica* Jay is practically the only fossil; this is called the lower *Mya* zone.

The *Glycymeris* zone, or zone of the basal beds, is characterized by the two species of this genus previously mentioned, *Diplodonta harfordi* F. M. Anderson, *D. parilis* Conrad, *Cardium meekianum* Gabb, and *Pecten oweni* Arnold. Locality 4806 is typical of this zone. The localities representative of this zone are Nos. 4648, 4656, 4657, 4658, 4659, 4660, 4661, 4662, 4663, 4664, 4665, 4669, 4672, 4673, 4674, 4679 (in part), 4684, 4749, 4756, 4757, 4761, 4762, 4769, 4781, 4806, and 4857.

The upper *Mulinia* zone, or zone of the lower middle beds, contains numerous *Mulinia densata* Conrad, *Ostrea atwoodi* Gabb, and *Arca trilineata* Conrad. It is represented by the following localities: Nos. 4643, 4671, 4675, 4676, 4677, 4678, 4679 (in part), 4681, 4682, 4683, 4688, 4690 (?), 4695, 4697, 4699, 4704, 4706 (?), 4707, 4713, 4741, 4750, and 4760.

The *Pecten coalingaensis* zone, or zone of the upper middle beds, is characterized by *Pecten coalingaensis* Arnold, *P. wattsi* Arnold and its variety *etchegoini* F. M. Anderson, *Terebratalia smithi* Arnold, and *Ostrea vespertina* Conrad. Locality 4712 yields a fauna typical of this horizon. It is also represented by the following localities: Nos. 4693, 4696, 4698, 4702, 4703, 4705, 4709, 4710, 4712, 4714, 4715 (in part), 4751, 4758, and 4759.

The upper *Mya* zone, or zone of the uppermost Etchegoin beds, carries *Mya japonica* Jay, *Littorina mariana* Arnold and its variety *alta* Arnold, *Trochita filosa* Gabb, and *Solen sicarius* Gould. Just above the upper *Mya* zone is usually found a bed in which are numerous *Ostrea vespertina* Conrad var. *sequens* Arnold. This zone is represented at the following fossiliferous localities: Nos. 4670, 4701, 4708, 4711, 4715 (in part), 4716, 4717, 4718, 4720, 4722, 4723, 4724, 4725, 4728, 4729, 4730, 4736, 4744, 4752, 4778, 4780, 4782, and 4783.

The following localities are undifferentiated: Nos. 3849, 4700, 4753, 4754, 4755, 4763, and 4799.

ORIGIN OF THE ETCHEGOIN.

A study of the faunas of the various zones of the Etchegoin leads to some interesting conclusions concerning the physical conditions under which the strata were deposited at various times throughout the Etchegoin epoch, and also to some important correlations, not only with formations in other parts of the Coast Range but with horizons of the Tertiary of the Eastern States.

The abundance of *Arca* in the *Glycymeris* and *Mulinia* zones leads to the conclusion that the water in which the lower part of the Etchegoin was laid down was somewhat warmer than that now prevalent on the Pacific coast at the latitude of Coalinga.

Following the deposition of the two lower zones came a period in which estuarine conditions prevailed over at least a part of the Coalinga shore line, for in the Kettleman Hills is a bed in which are to be found large numbers of *Mya japonica* Jay, a noted cold-water species preferring mud flats. This *Mya* bed in turn is followed by strata in which is a fauna having many characteristics in common with the fauna of the Gulf of California province, a province that has been subject to tropical conditions at least since the beginning of Miocene time. It is therefore reasonable to suppose that a subsidence and change of conditions to those favoring the immigration of warmer-water species took place some time after the deposition of the middle Etchegoin. These conditions were suddenly altered near the close of the Etchegoin epoch, as is indicated by the fauna of the upper *Mya* zone, which contains *Mya japonica*, *Macoma inquinata*, and *Littorina mariana* (closely allied to the northern *L. grandis* Midd.), species supposed to have been best suited to cold-water and possibly estuarine conditions. It is a noteworthy fact in connection with this late Etchegoin cold-water invasion that it exterminated most of the species found in the subjacent beds, at least for the local Coalinga province, and that *Ostrea vespertina* Conrad, the only important species of the preceding fauna which persisted into the last part of the Etchegoin, was so adversely influenced by the new conditions that it became a dwarf of its former self and took up new characteristics at least of varietal importance. The uppermost Etchegoin representative of the beautiful well-developed *Ostrea vespertina* is the dwarfed, thin variety *sequens*.

Other evidence showing the varying conditions which prevailed during the latter half of the Etchegoin is to be found in the occurrence within the formation of curious bulbous growths of fishes, such as are later mentioned as occurring associated with the fresh-water fossils in the basal Tulare. The lowest horizon at which they were found is at locality 4697, from 1,600 to 2,000 feet below the summit of the formation. These occur alone, with marine fossils, or with fresh-water fossils. At one horizon about 900 feet below the summit of the Etchegoin, along the eastern foot of the main ridge in the southern portion of the Kettleman Hills, abundant specimens of *Goniobasis*, a fresh-water genus, were found in gypsiferous beds associated with the curious fish bones. This horizon is represented by locality 4696, and is about equivalent to that of *Pecten coalingaensis*. These bones and shells indicate that a close connection existed between areas of salt water and nearly if not entirely fresh water during much of the Etchegoin period, and that, especially in the later portion of the period, conditions were on the verge of becoming such as existed during early Tulare time. The great thickness of inky-blue fine clay in the upper portion of the Etchegoin of the Kettleman Hills below the sands of the upper *Mya* zone is believed to have originated as fine delta deposits, possibly subaerially and above the reach of the tide.

The presence of enormous quantities of *Echinarachnius*, accompanied by no other fossils, in some of the middle or upper middle Etchegoin sands and of somewhat similar deposits in the upper Jacalitos indicates that at various periods throughout the upper Miocene extensive shallow sand flats prevailed along the edge of the San Joaquin sea.

CORRELATION AND AGE.

F. M. Anderson[a] correlates the typical San Pablo beds of the Mount Diablo province with the lower portion of the Etchegoin, and this correlation agrees in general with that made by the writers. To be more exact, it is believed that the upper Jacalitos and lower Etchegoin are probably the equivalent of the typical San Pablo, and that

[a] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, p. 180.

the upper Etchegoin is possibly younger than the latest San Pablo and agrees in age more nearly with the lower part of the fossiliferous Purisima formation on the southwestern flanks of the Santa Cruz Mountains.[a]

The similarity of the fauna of the upper Etchegoin to the fauna of the latest marine formation in the Carrizo Creek district of eastern San Diego County and similar beds at Santa Rosalia and other points in Lower California has led the writers to correlate the latter with the Etchegoin, and on the basis of this correlation to suppose that the upper Miocene sea occupied the upper end of the Gulf of California depression. This last correlation is in agreement with that of Gabb and Cooper, who considered the bed of Carrizo Creek to be Pliocene (some of their Pliocene now being recognized as upper Miocene by the writers). The number of species common to the two faunas is not large, but the abundance of the individuals and the uniqueness of the forms compensate for this. Among the forms common to the two faunas are *Ostrea vespertina* Conrad, *Pecten deserti* Conrad, and *Neverita recluziana* Petit.

The similarity of *Ostrea vespertina* Conrad, *Mytilus* (*Mytiloconcha*) *coalingensis* Arnold, and *Pecten deserti* Conrad, of the Etchegoin fauna, to *Ostrea sculpturata* Conrad, *Mytilus* (*Mytiloconcha*) *incurvus* Conrad, and *Pecten gibbus* Linnæus var. *concentricus* Say, of the Miocene and Pliocene of the Atlantic States, points strongly to a direct connection between the Atlantic and Pacific provinces during the Miocene. If such a connection existed it was possibly through southern Arizona and New Mexico and thence along the course of the Rio Grande to the Gulf of Mexico, although it might have been farther south.

The age of the Etchegoin in terms of the standard time scale is now, and probably will be for some time to come, a question on which opinions differ. F. M. Anderson and the writers agree on the general correlation of the San Pablo and Etchegoin; about this there can be very little doubt. But when it comes to assigning the San Pablo and Etchegoin to the Pliocene, the writers differ with Anderson[b] and also with Weaver.[c]

According to the list found in this paper the Etchegoin is represented by 84 recognizable species. Of these, 55 species or varieties, or 65 per cent, are extinct, while but 29 species, or 35 per cent, are still living in the Pacific Ocean. According to Lyell's classification this would place the formation decidedly in the Miocene. Furthermore, of the fauna of 18 recognizable species at locality 4712, a fauna typical of the upper part of the Etchegoin, 16 species and varieties,

[a] Arnold, Ralph, Proc. U. S. Nat. Mus., vol. 34, 1908, p. 353.

[b] Proc. California Acad. Sci., 3d ser., Geology, vol. 2, pp. 180 et seq.; idem, 4th ser., vol. 3, pp. 28 et seq.

[c] Bull. Dept. Geology Univ. California, vol. 5, p. 269.

or 89 per cent, are extinct and only 2 species, or 11 per cent, are now living.

In addition to the evidence presented above, which at best is largely dependent upon the personal interpretation of the meaning of species, there is the evidence of the position of the Etchegoin in the geologic series of California. An examination of its fauna indicates that its upper portion is equivalent to the lowest Purisima of the western side of the Santa Cruz Mountains, and there is no question that in places at least 4,000 or 5,000 feet[a] of strata separate this lower Purisima fauna from the lower Merced fauna, and that between 3,000 and 5,000 feet of Merced (both Pliocene and Pleistocene) overlie the lower Merced fauna. Therefore it is evident that since the deposition of the Etchegoin enough time has elapsed for the deposition of between 7,000 and 10,000 feet of strata on the California coast. Taking 25,000 feet as a conservative estimate of the total maximum thickness of the Tertiary on the west coast, the 7,000 to 10,000 feet of strata above the Etchegoin would place the top of the Etchegoin at least a third of the way down toward the base of the Tertiary. Hence, by this line of reasoning also, it seems more consistent to place the Etchegoin in the Miocene than in the Pliocene.

IMPORTANCE WITH RELATION TO PETROLEUM.

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

TULARE FORMATION (UPPER PLIOCENE-LOWER PLEISTOCENE).[b]

DEFINITION AND GENERAL DESCRIPTION.

The Etchegoin is overlain along the border of the valley by the Tulare formation, a thick terrane of bedded but little-consolidated gravel, sand, and clay, with occasional indurated layers throughout and with associated beds of fresh-water shells, marl, and limestone at the base. This terrane is the uppermost member of the series

[a] See Santa Cruz folio (No. 163), Geol. Atlas U. S., U. S. Geol. Survey, 1909.

[b] Described in the preliminary report on this district, Bull. U. S. Geol. Survey No. 357, under the name Paso Robles formation.

of upturned formations exposed in the monocline on the eastern flank of the Diablo Range. It differs materially from the formations so far described in that the origin of its greater portion is doubtful, being in part fresh water, in part marine, and in part probably subaerial. In the Kettleman Hills, where these beds are best exposed, the basal sand, which appears to lie conformably upon the marine bed at the top of the Etchegoin, contains many fresh-water fossils. The beds above this have a thickness of several thousand feet, and as far as observed are nonfossiliferous except at one horizon near the summit, at which a few marine fossils have been found. (See fossil locality 4743.) Along the foothills west and northwest of the Kettleman Hills the basal fresh-water beds have not been recognized and may be lacking. There gravel and sand beds belonging to the same series overlie the Etchegoin with local appearances of unconformity.

This whole series of tilted beds overlying the Etchegoin is here referred to and mapped as one formation for the reason that it appears to be a continuous succession and can not be consistently subdivided. It was formed under varying conditions of deposition, but the indications are that it represents a nearly continuous if not wholly uninterrupted period. Its accumulation began in the Pliocene epoch, probably in the earlier portion, and is thought to have continued into the Pleistocene. Its summit may be considered as the highest bed markedly displaced from its original attitude by the uplift which threw the formation into folds. It is unconformably overlain by the more recent horizontal terrace deposits and alluvium.

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

PREVIOUS DESCRIPTIONS.

This formation was named Tulare by Frank M. Anderson in his paper entitled "A stratigraphic study in the Mount Diablo Range of California."[a] He stated that it is a fresh-water formation fully

[a] Proc. California Acad. Sci., Geology, vol. 2, 1905, No. 2.

1,000 feet thick lying conformably upon the Etchegoin formation in the Kettleman Hills. It was originally mentioned by W. L. Watts,[a] who gave a section of the beds and included a list of the fresh-water shells collected from them by him and identified by J. G. Cooper. He described the occurrence of similar fresh-water deposits in the region of McKittrick farther south, which are possibly to be correlated with these. In the same year Cooper described the fossils collected by Watts in these deposits and gave notes on their occurrence.[b]

The formation here described as the Tulare was referred to in the preliminary report on the Coalinga district[c] as the "Paso Robles," owing to its supposed equivalence to that formation, which had been named[d] earlier than the Tulare. The correlation was based upon the similarity in stratigraphic position and lithology of the beds in the Coalinga district to those spreading over the summit region of the Temblor Range, between the Polonio and Palo Prieto passes, about 15 miles southwest of the southernmost exposures in the Kettleman Hills. These beds in the Temblor Range seemed to be continuous with and to answer the description given by Fairbanks of the Paso Robles formation in the Salinas Valley. The formation there was originally named from the town of Paso Robles, and described as a probably fresh-water Pliocene formation of unconsolidated beds at least 1,000 feet thick, spreading widely over the Salinas drainage area and extending nearly or quite to the divide (the Temblor Range) between Estrella River and the San Joaquin Valley. It was stated by Fairbanks to lie unconformably upon the San Pablo formation, by which was meant the Santa Margarita.

Subsequent study of the Salinas Valley deposits, carried on by the junior author during the autumn of 1908, has shown that at least the lower portion of the beds there to which the name Paso Robles was applied are of marine origin and equivalent to a part of the upper Miocene succession in the Coalinga district described in the present paper as Jacalitos and Etchegoin. As yet no fossils have been found in the upper portion of the Paso Robles formation, and this portion may prove to be of fresh-water origin, as stated in Fairbanks's original description, but in view of the fact that no stratigraphic break in the succession of Paso Robles beds has been found, the discovery of the marine origin and the approximately San Pablo age of the lower portion tends to cast doubt upon the propriety of the adoption of the name Paso Robles in the Coalinga field. It is not certain that the upper portion of the Paso Robles

[a] The gas and petroleum yielding formations of the central valley of California: Bull. California State Min. Bur. No. 3, 1894, pp. 55, 67.

[b] Proc. California Acad. Sci., 2d ser., vol. 4, 1894, pp. 167-169.

[c] Bull. U. S. Geol. Survey No. 357, 1908.

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

formation farther west is equivalent to any part of the post-Etchegoin formation in the Coalinga district; and at any rate this portion has a thickness of but a few hundred feet at most, so that it could hardly represent a great part of the important formation in the Coalinga district. Hence the designation of this formation as the Tulare is appropriate.

DISTRIBUTION AND LOCAL CHARACTER.

TULARE IN THE KETTLEMAN HILLS.

The area covered by the Kettleman Hills is the only one in which the Tulare is at all completely exposed. This area therefore forms the basis for most of the discussion of the formation given here and may be considered as the type locality. As shown on the map, the Tulare occupies an almost complete fringe around the hills, dipping steeply away on the flanks of the anticline which exposes the Etchegoin beneath. Throughout the Kettleman Hills the Etchegoin and Tulare formations are apparently conformable, and in places there are indications that a gradual change took place toward the end of the deposition of the former, that shallow-water marine conditions gave way to brackish water, and these in turn to fresh-water conditions. In some places, at least, the estuarine upper *Mya* beds which are constant at the summit of the Etchegoin appear to grade into the fresh-water beds above.

As an example, a characteristic occurrence at the northern corner of the hills (at fossil localities 4716 and 4740) may be described. There a thickness of about 75 feet at the summit of the Etchegoin consists of unconsolidated fine gypsiferous sand containing at the base a great many Arcas, etc., and at the top an abundance of delicate little oysters in fine grayish-white, ashlike sand and earthy, sandy clay full of gypsum. The oyster sand is overlain by and seems almost to grade into a bed a few feet thick of brittle, porcelaneous and opaline, black, brown, gray, and variously colored siliceous shale that weathers to a bluish-white tint and is locally soft and chalklike. It bears some resemblance to the "indicator" bed in the Vaqueros north of Coalinga and to the various other occurrences of diatomaceous and porcelaneous shale already cited, but it is not certain that it had a similar origin. This bed is overlain by a zone of sand and pebbles about 20 feet thick that is full of strangely shaped flinty fossil bones of purplish and black color. Three varieties of these are shown in Plate LII. Some of these bones have been recognized, with the aid of Mr. J. W. Gidley, of the United States National Museum, Dr. D. S. Jordan, of Stanford University, and Dr. J. C. Merriam, of the University of California, as being the bulbous growth from the anterior portion of the back or the anterior end of the ventral fin, and others as spines of some fish or different fishes. Not even the order to which these belong is determinable and they may be either marine or fresh-water fishes. Some associated petrified fragments resemble copralites, and there are likewise fragments closely resembling the teeth of mammals. Bones of the same character have been mentioned as associated with both marine and fresh-water fossils in the Etchegoin (fossil localities 4695, 4696, 4697, 4699, and 4741). Associated with the bones in the locality that is being described are minute fresh-water gasteropods, and one small oyster similar to those in the beds below was found on the surface together with the other fossils. If oysters are in place in this bed they indicate an alternation of brackish and fresh water conditions. Just above the bed with bones and other fossils comes a zone of fine gray sand with scattered pebbles and some clay full of fresh-water shells, such as *Anodonta*, etc., and containing likewise specimens of the strange bones in smaller numbers than the bed below. Above this fresh-water zone, which is here altogether about 100 feet thick, the formation is not fossiliferous.

The preceding paragraph describes the contact zone between the Etchegoin and Tulare formations as it occurs at one place in the northern part of the Kettleman Hills, and although minor variations are to be found at every other locality the essential points are the same. As this description shows, the division is no sharp one and it is possible that a gradual change to fresh-water conditions took place and that the formations intergrade. The line of contact between the two formations is drawn at the top of the porcelaneous shale bed because that bed appears to be represented farther southeast by a bed of soft white sand containing oyster shells. In the central and southeastern portions of the Kettleman Hills this contact bed of shale has not been recognized definitely, but the upper *Mya* beds are at many places characterized by the inclusion of layers of white siliceous shale that may represent a similar process of deposition. The succession of fossils in the *Mya* beds is not everywhere as given in the paragraph above, the oysters in some localities, notably farther south in the Kettleman Hills, being absent at the top and more abundant below the beds with *Mya*, *Arca*, *Littorina*, etc. It is also true that a fossil bed does not everywhere come within a few feet below the fresh-water beds, as for instance in the central and south-central part of the hills, where a zone of inky-blue clay over 50 feet in thickness intervenes between the beds with *Mya*, etc., and those with fresh-water shells. Nor does the bed full of strange bones generally come below the *Anodonta* bed. The latter is more commonly found immediately overlying the *Mya* and oyster beds, and the pebble beds with bones, in turn, lie above this. The contact zone is locally marked by thin hard beds of limestone and hardened sandstone formed of the fresh-water fossils, and an earthy rock with oolitic structure due to the small gasteropods that make up more than half its bulk. Beds of this character at the contact form the high ridge or line of hills that parallels the valley for much of the way along the northeast flank of the Kettleman Hills (fossil localities 4721 and 4731).

The thickness of the basal fossiliferous zone of the Tulare is usually no more than 60 to 100 feet, although it is as much as 300 feet on the southeast side of the Kettleman Hills a few miles northeast of Avenal Gap. These variations from place to place indicate the variable shallow-water conditions of deposition that prevailed at the beginning of Tulare time; yet the constancy over at least the whole area occupied by the Kettleman Hills of the estuarine and perhaps brackish-water fauna at the top of the Etchegoin and of the fresh-water fauna just above it shows over what extent the continuous deposition of the material of each of these zones took place.

The only fossils found in the Tulare at a higher horizon than the basal zone are of marine origin and occur in the upper portion of the formation (fossil locality 4743). Their stratigraphic position is shown in the tabulated section given below (p. 147).

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

A marked feature of the gravel is the predominance in it of subangular fragments of hard white siliceous shale derived presumably from the shale either of the Tejon or of the Santa Margarita (?) formation. This shale is very resistant and lends itself remarkably to preservation in younger deposits of gravel and débris.

The gravel deposits southwest of the Coalinga district, along the Temblor Range south and west of Antelope Valley, which are believed to be equivalent in age to the Tulare, are likewise characterized by the predominance of inclusions of similar shale. On the Temblor Range this shale comes from the formation that is continuous with the Santa Margarita (?) described along Reef Ridge, and it is therefore probable that the Tulare in the Coalinga district derives at least a large part of the shale pebbles from that formation. These pebbles have in general been subjected to only a moderate amount of erosion and resemble in this respect the similar fragments derived from the Santa Margarita (?) that are abundant in the recent alluvial deposits and are scattered over the surface of the country both near and far away from their source.

The other pebbles and bowlders in the gravel beds of the Tulare are of many different types of rock and were probably derived chiefly from the Coast Ranges. Many of them are angular and have been subjected to little wear before being deposited. Rocks of a granitic type are very common, and also serpentine, porphyries of different kinds, several varieties of basic igneous rocks, both fresh and considerably altered, jasper, sandstone, conglomerate, quartz, schist, etc.

On the summit of the most southwesterly ridge of the Kettleman Hills bowld rs full of fossils characteristic of the Vaqueros beds on Reef Ridge, particularly *Pecten andersoni*, were found in the Tulare formation. Bowlders of exactly the same type are common in the upper *Mya* zone at the top of the Etchegoin, and this may be taken as a further indication of the close relationship between the summit beds of the Etchegoin and the Tulare, inasmuch as the materials were derived from the same source and, to judge by these bowlders, from almost exactly the same locality. These bowlders give a good illustration of the profound unconformity existing between the Vaqueros and these later Tertiary formations. The siliceous-shale fragments are likewise common in the upper Etchegoin, although not present, as far as observation has gone, in the earlier beds, which proves that the original shale formation, probably the Santa Margarita (?), was exposed to erosion during at least the later Etchegoin and the Tulare periods.

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

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

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

Section of Tulare formation 9 miles northwest of Avenal Gap.

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

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

Section of Tulare formation along Dudley-Lemoore road.

	Feet.
Massive 1 to 3 foot beds of well-compacted but not indurated fine sand, clayey sand, clay, coarse sand, and gravelly sand, with several beds, many feet thick, of coarse gravels and bowlders in the middle and at the base. Much gypsum occurs in fine particles and as a filling in cracks, causing hardening in individual beds and in spots. Some sand and gravel beds are lenticular. One hundred feet below the top are two coarse sand beds 15 feet apart containing a few specimens of *Ostrea* and *Littorina*, marine fossils (locality 4743)	400

	Feet.
Yellowish-gray earthy sand, sandy clay, and clay in well-defined massive beds, with some pebbly sand	650
Dark clay	75
Thick zone of pebbly sand	150
Chiefly dark clay	150
Yellowish-gray fine sand yielding whitish surface sand	75
Pebbly sand	70
Sandy clay	80
Chiefly fine gray sand, alternating with pebbly sand, sandy clay, and clay; a thick zone of pebbles and bowlders occurs about 350 feet below the top	1,100
Chiefly fine gypsiferous ashlike light-gray sand, with dark clay layers and many large pebbles scattered through, but no prominent gravel beds; lower portion is the fresh-water zone, but no fossils were here found; it overlies dark clay and *Mya* beds at the top of the Etchegoin	350
	3,100

The beds near the base of the Tulare are tilted as high as 40° and 45° in the south-central part of the hills on the southwest flank of the anticline, but toward the edge of the hills the dip gradually decreases. On the northeast flank of the anticline and in the northern and southern parts of the hills the dip is not as steep as this. Furthermore, the belt of exposed beds is not as wide elsewhere as in the part of the hills where the above sections were made and therefore no approach to the total thickness can be measured elsewhere. In the section in the northern part of the hills given in figure 5 the thickness is much less, the upper portion of the formation being presumably buried beneath the plain. Thence southward toward Avenal Gap the exposed section grows constantly thicker. This fact may be due in part to a thickening of the formation southward in the same manner as the Etchegoin thickens, but no proof of such a change can as yet be offered.

TULARE IN THE KREYENHAGEN AND JACALITOS HILLS.

The Tulare beds dip under the Kettleman Plain and reappear on the western arm of the syncline along the border of the Kreyenhagen and Jacalitos hills. As in the Kettleman Hills, the formation dips more steeply and exposes a much greater thickness toward the south, but here this difference is even more pronounced. The beds have a dip of only a few degrees northwest of Zapato Creek, and form a comparatively narrow belt to the point where they are overlapped by the alluvial deposits of Pleasant Valley. South of Canoas Creek they rise to extremely steep dips, appearing almost overturned in places, and cover a wide belt. They are, however, very poorly exposed. The formation here consists of deposits similar to those in the Kettleman Hills, but the basal fossiliferous beds have not been found. The formation is chiefly characterized by its heavy gravel deposits, which, contrary to the rule in the Kettleman Hills, in places rest directly upon the Etchegoin, forming high hills fronting the valley. This occurrence of heavy bowlder deposits near the base has led to the theory that possibly the fresh-water basal zone is lacking and that a higher portion of the Tulare has overlapped upon the Etchegoin. North of Zapato Creek an unconformity between the Tulare and the Etchegoin is shown to exist by the fact that the gravel beds of the former overlap upon the Etchegoin and locally cover up some of the higher beds of that formation. Southeast of Big Tar Canyon the basal portion of the Tulare is sand and clay and is not strongly characterized. Its basal line is assumed to be at the top of a zone of white nodular shale beds interbedded with sand containing the strange bones mentioned before as occurring both in the Etchegoin and Tulare in the Kettleman Hills. This zone may be the equivalent of the white shale at the contact of the two formations in the northern part of the Kettleman Hills. The flinty nodules contained in this zone, which are similar in appearance to nodules and laminæ occurring at about if not exactly the same horizon elsewhere in the Kreyenhagen and Kettleman hills, are made up of 88 to 89 per cent of silica, according to an analysis by R. C. Wells, of the United States Geological Survey. They contain only a trace of lime. The Etchegoin and Tulare appear conformable in the southern part of the Kreyenhagen Hills. The latter formation has a thickness of at least 2,000 feet and probably much more.

TULARE IN THE GUIJARRAL HILLS.

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

ORIGIN OF THE FORMATION.

The transition from salt to fresh water conditions that took place at the beginning of the Tulare period has been discussed, but it is uncertain what conditions prevailed during the subsequent period during which the great bulk of the formation was deposited. After the deposition of the fossiliferous fresh-water beds the process of change continued further and culminated in a fairly constant set of conditions that were prevalent during the greater part of Tulare time. The change may have brought about a deepening of the body of fresh water, or a return of the sea over the same area in which this formation was laid down, or, most probable of all, the transition may have simply reached its natural conclusion in the establishment of land conditions.

Lithologically, the Tulare is somewhat similar to the marine Tertiary formations in which unconsolidated strata are common, but the absence of fossils, which are so abundant in those marine formations, makes it doubtful whether any great part of it is of marine origin. Its constituent materials show that it was formed at no great distance from their source and that, if marine, it must have been littoral. It is hardly supposable that near-shore marine or lacustrine deposition could have continued throughout the long period represented by this formation, either of marine or fresh-water character, without fossil remains being left, as they were in the case of the earlier formations and of the basal fresh-water zone. The presence of the marine fossils noted in the second section above proves that the sea gained access to the basin in which the formation was laid down for a short time, at least, in the later portion of the period. It is not improbable that similar temporary incursions of the sea occurred at other times.

The Tulare beds exhibit still greater resemblance to the more recent horizontally stratified deposits of stream wash, wind-blown dust and sand, etc., forming the surface of the floor of the Great Valley and the various small valleys along the border of the Diablo Range. These deposits consist of earthy clay, sand, gravel, and fragmentary matter and find their counterpart in the beds of the Tulare. On the basis of this analogy and the general absence of fossils in the main part of the Tulare, it may be assumed that a large part of the formation was subaerial in origin, being the accumulation in the basin between the Sierra Nevada and Diablo ranges of the material worn from them during a long period of time.

The Great Valley of California is structurally a geosynclinal trough that must have been undergoing a process of filling during much of Tertiary and Quaternary time. A large part of all the material washed from the eastern flanks of the Coast Ranges and the broad western face of the Sierra Nevada during this period must have found lodgment in it. During the late Tertiary and the Pleistocene the valley was probably similar to that of to-day and the deposits were forming in it as now. When the movements took place during the Pleistocene the valley deposits were uplifted in places along the border and exposed as the formation here described under the name Tulare. During the period since that time aggradation in the large and small valleys of this region has continued, and if the border of the Great Valley and the filled synclinal basins along the present eastern side of the Diablo Range should now be subjected to uplift a thick subsequent formation resembling the Tulare would be brought to light. Such a formation would be in part made up of material derived from the Tulare and in some places would be decidedly unconformable, though in others perfectly conformable and continuous with it.

The occurrence of the mollusks and fish bones in such various associations and their final disappearance lend probability to the view that the later Etchegoin and early Tulare period was one of varying and possibly alternating estuarine, tide-marsh, and lake conditions, changing gradually to those of dry land. Such a change would be brought about by aggradation alone or by gradual uplift, whereas a theory of any other change would involve the assumption of complicated movements.

The body of fresh water occupying the area of the present Kettleman Hills at the beginning of Tulare time, as indicated by the fossils, must have been shallow and must have extended over an almost level surface. It may have been very much such a lake as the present Tulare Lake, in which mollusks similar to those that inhabited the Pliocene lake are now living. W. L. Watts[a] gives a list of fresh-water shells obtained from beds at McKittrick, in Kern County, about 40 miles south of the south end of the Kettleman Hills. If these represent the same horizon as the basal beds of the Tulare they prove a great extent for the lake of that period. The absence of fresh-water fossils higher in the formation in the Coalinga district proves that this shallow lake did not persist as such. It either deepened or vanished. If it deepened to such a depth as to preclude the existence of organisms such as would be preserved in the sediments at its bottom, it is strange that the deposits should have been so coarse, and it would be expected that fossils would be found somewhere along the belt that must have been nearer the shore, as for instance in the deposits that lap up over the Etchegoin west of the Kettleman Plain. And if such a great thickness of beds is considered as having been deposited in a deep lake it is necessary to postulate the existence of an unbroken barrier between it and the open ocean. The marine fossils noted in the second section above, in the upper part of the formation, represent an incursion of the sea that was probably brief. The beds above and below the zone of these fossils are similar and probably originated under the same conditions. If those below are supposed to be of deep-lake origin, it must be supposed, to be consistent, that the opposition to the entrance of the sea was temporarily overcome and then reestablished.

---

[a] Bull. California State Min. Bur. No. 3, 1894, p. 49.

The most natural conclusion regarding the Tulare period in the central valley is that it was for the most part one of land conditions somewhat similar to those prevailing to-day, and that the strata were formed subaerially as widespreading deposits of the streams descending the mountains on either side of the valley. There were probably various secondary transporting and sorting agencies, such as gravity, winds, floods, and temporary lakes.

Fairly constant subsidence probably went on, keeping the surface of the filling basin near the level of the sea, and at times allowing the sea to enter, as a result of a slight disturbance of the equilibrium maintained between aggradation and subsidence. There is no known reason for believing that at any time a structural barrier across the Great Valley determined a sharp line where land, lake, river, or tide-marsh conditions ended and sea began.

In the collection of Stanford University there are some marine fossils that were obtained at a depth of 1,058 feet in an artesian well at the east edge of Tulare Lake (in sec. 12, T. 22 S., R. 22 E.).[a] Among them are many good specimens of *Ostrea lurida* Carpenter, together with fragmentary shells, one a small shell resembling *Mactra* or *Venus* and another a piece of a coarse hinge resembling that of *Mulinia*. The matrix is medium-grained, clay-colored, fairly well cemented sand, containing subangular fragments of white siliceous shale. W. L. Watts[b] cites a well boring near Tulare Lake in which fresh-water fossils were found at a depth of 1,058 feet. It would appear to be the same instance, but his reference to the shells as fresh-water was probably not based on his own observation. F. L. Ransome[c] cites an instance at Stockton of fresh-water shells found at a depth of 600 feet. Such occurrences are more in keeping with the theory of occasional encroachment of salt water, and of local fresh-water deposits formed in marshes or in temporary shallow lakes, like the present lakes in the southern end of San Joaquin Valley, than with the theory of the long-continued occupation of the basin by the sea or by a large, deep lake. It is not known whether the wells cited had reached the Tulare formation at these depths, for where the deposits forming the valley floor are undisturbed it would be impossible to distinguish between the beds limited by the arbitrary boundaries of the Tulare and the later sediments into which they must grade. But the question of origin is believed to be the same for the Tulare as for the subsequent deposits.

According to the theory of the origin of the Tulare above outlined the formation would grade seaward into an equivalent with more and more abundant estuarine elements and finally into a littoral

---

[a] They were sent in 1892 by Mr. Harvey G. Anderson through Mr. S. A. Blythe, and have been obtained for examination through the kindness of Prof. J. Perrin Smith.

[b] Bull. California State Min. Bur. No. 3, 1894, p. 20.

[c] Bull. Dept. Geology Univ. California, vol. 1, 1896, p. 381.

marine formation. It is believed that the latter is represented in the Merced formation on San Francisco Peninsula.

FOSSILS AND AGE.

FOSSILS.

The only important fossiliferous zone in the Tulare is that at the base, which may be called the *Anodonta* zone, because of the abundance in it of fresh-water mussels of this genus. The following species have been found in the Tulare formation in the Coalinga district:

Tulare (Pliocene-lower Pleistocene) fossils from the Coalinga district.

Name.	4715.	4721.	4731.	4732.	4735.	4737.	4738.	4739.	4740.	4743.
PELECYPODA.										
Anodonta kettlemanensis Arnold	....	X	X	X	X	X	....	....	....	....
Gonidea coalingensis Arnold and var. cooperi Arnold	....	X	X	....	....	....	....	X	....	....
Ostrea lurida Carpenter	....	....	....	....	....	....	....	....	....	X
Sphærium cooperi Arnold	....	....	X	X	....	....	....	....	....	....
Sphærium kettlemanensis Arnold	....	....	X	X	....	....	....	....	....	....
GASTEROPODA.										
Amnicola andersoni Arnold	....	....	....	X	....	....	....	....	....	....
Amnicola sp	X	....	....	....	....	....	....	....	....	....
Carinifex marshalli Arnold	....	....	....	X	....	....	....	....	....	....
Goniobasis kettlemanensis Arnold	X	....	....	....	X	....	....	....	....	....
Goniobasis nigrina? Lea	....	....	....	X	....	....	....	....	....	....
Littorina cf. mariana Arnold	....	....	....	....	....	....	....	....	....	X
Physa humerosa Gould	....	....	....	X	....	....	....	....	....	....
Physa wattsi Arnold	....	....	....	X	....	....	....	....	....	....
Planorbis vanvlecki Arnold	X	....	X	X	....	....	....	....	....	....
PISCES.										
Fish, bulbous growths	....	....	X	....	....	....	X	X	X	....
Fish spines	....	....	....	....	....	....	....	....	....	....

4715. South end of Kettleman Hills, sec. 10, T. 25 S., R. 19 E. The marine and fresh-water fossils at this locality are more or less mixed owing to their scattered occurrence over the surface of the eroded upturned beds.

4721. Northeast border of Kettleman Hills, 4 miles west of Tulare Lake, on summit of 758-foot hill, NE. ¼ sec. 15, T. 22 S., R. 18 E. Fresh-water zone at base of Tulare.

4731. Northeast border of Kettleman Hills, near northwest end, on top of hill (elevation 905 feet) just east of old road and cabin, NW. ¼ NE. ¼ sec. 35, T. 21 S., R. 17 E. Fresh-water zone just above oyster bed of locality 4728.

4732. About 2 miles from northwest end of Kettleman Hills, on south side of main ridge, 1½ miles northwest of 1,245-foot hill, SW. ¼ NE. ¼ sec. 30, T. 21 S., R. 17 E. Fresh-water zone at base of Tulare.

4735. Central part of Kettleman Hills, on southwest side, 1 mile southwest of 1,370-foot hill and one-third mile northwest of oil derrick, in center of south line of SW. ¼ sec. 19, T. 22 S., R. 18 E. Fresh-water zone at base of Tulare.

4737. East side of Kettleman Hills, east of Dudley-Lemoore road, NE. ¼ SW. ¼ sec. 17, T. 23 S., R. 19 E. Fresh-water zone overlying upper Etchegoin bed of locality 4736.

4738. In Kreyenhagen Hills, 20 miles southeast of Coalinga, one-fourth mile east of B. M. 872 feet just south of El Cerrito well, SE. ¼ NW. ¼ sec. 14, T. 23 S., R. 17 E. In white shale zone at base of Tulare, as mapped.

4739. Same general locality as 4738, on point of 900-foot hill, nearly 1 mile northwest of B. M. 872 feet, SE. ¼ sec. 10, T. 23 S., R. 17 E. At contact of Etchegoin and Tulare.

4740. Near northwest end of Kettleman Hills, 2 miles north-northwest of 1,245-foot hill, east of center of SW. ¼ sec. 20, T. 21 S., R. 17 E. Fresh-water zone just above Etchegoin oyster beds and white shale of locality 4716.

4743. On west side of Kettleman Hills, along Dudley-Lemoore road, in steeply dipping beds of pebbly sand exposed in bed of arroyo, 1,000 feet up gully from edge of plain, in north part of SW. ¼ sec. 35, T. 23 S., R. 18 E. About 2,500 feet above fresh-water zone at base of formation.

FAUNAL RELATIONS AND AGE.

A comparison of the above list with the lists of species from the same locality prepared by J. G. Cooper[a] shows a marked discrepancy between the two. This is caused by the different identifications of

[a] Proc. California Acad. Sci., 2d ser., vol. 4, May 26, 1894, p. 167; Bull. California State Min. Bur. No. 3, 1894, p. 55; Proc. California Acad. Sci., 3d ser., Geology, vol. 2, 1905, p. 180.

Doctor Cooper and the senior author of this report. Cooper identified the Kettleman Hill species, with the exception of two forms, as species now living, while Arnold, after a careful comparison of the fossils with the series of recent fresh-water mollusks in the United States National Museum, decided that with three exceptions the fossils were new, although in most cases allied to recent forms. A comparison of the two lists discloses the following relations:

Cooper's identification.	*Arnold's identification.*
Anodonta decurtata Conrad	Anodonta kettlemanensis Arnold.
Anodonta nuttalliana Lea	Probably same as above.
Amnicola turbiniformis Tryon	Amnicola andersoni Arnold.
Carinifex newberryi Lea	Carinifex marshalli Arnold.
Goniobasis occata Hinds	Goniobasis kettlemanensis Arnold. Goniobasis nigrina (?) Lea.
Margaritana subangulata Cooper	Gonidea coalingensis Arnold. Gonidea coalingensis var. cooperi Arnold.
Physa costata Newcomb	Physa wattsi Arnold. Physa humerosa Gould.
Planorbis tumens Carpenter	Planorbis vanvlecki Arnold.
Sphærium dentatum Haldeman	Sphærium cooperi Arnold. Sphærium kettlemanensis Arnold.

This fauna indicates that the basal Tulare in the Coalinga district is possibly older than the lowest known fossiliferous beds in the Santa Clara formation of the Santa Cruz region and certainly very much older than the fresh-water fossils from the Colorado Desert of southern California. In fact, the basal Tulare is believed to be the fresh-water equivalent of the San Diego formation and lower Pliocene in age. About 2,500 feet above the base of the Tulare *Ostrea lurida* Carpenter, a species so far known only from Pleistocene and Recent faunas, has been found. This fact is interpreted as indicating a recurrence of marine or estuarine conditions during late Tulare time and the extension of the formation into the Pleistocene.

IMPORTANCE WITH RELATION TO PETROLEUM.

The Tulare formation does not come into contact with the oil-bearing formations and contains no traces of oil. Over most of the area in which it occurs it is separated by so great a thickness of deposits from the productive zones that its mere presence is usually sufficient to indicate the inaccessibility of the oil.

TERRACE DEPOSITS AND ALLUVIUM (QUATERNARY).

CHARACTER AND EXTENT.

The later Pleistocene and Recent periods are represented by a mantle of alluvium and terrace deposits covering the floor of the Great Valley and the large side valleys, extending over the bottoms of the smaller valleys and over the lower slopes of the foothills. The larger areas of these deposits are shown on the map (Pl. I), but the minor ones where the deposits form only a thin film over the earlier formations have not been shown. In fact, they would be very difficult to distinguish in many places. In the large valleys it is probable that these deposits have a thickness of several hundred feet at least, as the late period has been largely one of aggradation over these basins. Elsewhere the deposits are merely superficial and the smaller valleys and canyons are characterized rather by the absence than by the presence of recent fillings. The smaller valleys show evidences of several terraces along their sides, some of these being much better preserved than others. Along portions of Zapato Creek, as shown in Plate IV, *A*, six or seven terraces may be counted, including one at the summit of the foothills that is of widespread importance. These terraces are frequently covered with stream gravel and sand, and such materials are widely scattered over the lower portions of the foothill belt, their presence tending to confuse the geology where it is not determinable whether they are of fluviatile origin or are derived from weathering of the underlying rocks. The greater portion of the whole region under discussion is covered by surface soil and residual sand derived from the soft formations. All of these comparatively recent deposits are similar in materials and appearance to the underlying formations and are not easily distinguishable from them. They have the effect of obscuring the main facts of the geology over large areas.

A small sand ridge, appearing to be the relic of an old beach line of Tulare Lake, has already been mentioned under the subject of topography. It owes its present position in part to the decrease in area and depth of the lake and in part to the relative uplift of the area of the Kettleman Hills.

VALLEY ALLUVIUM.

The nature of the deposits covering the valley floors has been referred to in connection with the Tulare formation, to which they are similar. The exposures of these deposits afforded by the shallow channels of the streams flowing across the plain are limited to the uppermost layers, but it is probable that these give a fair representation of the character of all of the post-Tulare beds. A typical exposure is pictured in Plate XII, *A*. A feature of the Quaternary deposits is that they are not predominantly coarse, but on the contrary are composed largely of fairly even grained sand and clay, often of an earthy appearance, horizontally stratified in intergrading zones rather than beds. Lenses of gravel and gravelly sand are intercalated. Even near the hills in the gradually sloping alluvial fans the deposits are largely of fine materials, being in great part derived from soft formations. But masses of coarse débris containing bowlders, fragments, and concretions from the older formations are also common.

LOOSE SOIL.

The soft surface sand and clay, whether originating through residual weathering or brought from a distance, or even where in place as a part of the underlying formation, is characteristically porous and crumbly. It is in many places and over large areas so soft that a horse can not step on it without sinking in over his hoofs or considerably deeper. This looseness of the soil is due to the complete desiccation to which it is subjected during most of the year. In the Kettleman Hills and Plain the difficulties of travel due to this cause are aggravated by the myriads of rodent burrows with which the surface is riddled. The ground caves in under a horse every little way.

STREAM CONGLOMERATE ON WHITE CREEK.[a]

During late Quaternary time deposits of hard conglomerate have been in process of formation along the bed of White Creek and are still being formed. The creek flows from an area of serpentine and other metamorphic rocks and carries much mineral matter, which it deposits as the water evaporates, forming a white coating on the gravel of the stream bed and cementing it into a solid pavement. Through the pavement thus formed in a previous period the stream has carved a channel, leaving the conglomerate as a terrace deposit along the sides of the valley. The gravel is made up of pebbles and bowlders of many kinds of metamorphic and sedimentary rocks, but the cementing material is so hard that the stream in cutting the conglomerate forms clean cross sections through all the constituent materials.

At least three terraces appear along the sides of the valley of White Creek. It is on the middle one of these terraces, which is usually 20 to 40 feet above the stream, and on the lower one, which forms the present valley floor and stream pavement and which is in most places a few feet above the channel of the stream, that the conglomerate occurs. The conglomerate extends for about 5 miles along White Creek, beginning at a point some 2 miles below the edge of the serpentine area and terminating about a mile above the confluence of White Creek with Los Gatos Creek. The ledge forming the terrace capping or stream-bed pavement is in places 15 feet or more thick. The Cretaceous sandstone which underlies the capping is less indurated than the conglomerate and gives way more readily to weathering and erosion. As a result, the capping is undercut and large blocks of it break off. Thus erosion removes the deposit more rapidly than it would a formation of such hardness laid upon a more resistant foundation.

[a] This subject was more fully treated in a paper by the present writers entitled "Conglomerate formed by a mineral-laden stream in California" (Bull. Geol. Soc. America, vol. 19, 1908, pp. 147-154).

An analysis by Dr. E. C. Sullivan shows that the cement deposited on White Creek is made up principally of calcium and magnesium carbonates, with minor amounts of silica and ferric oxide. There is little doubt that the source of this cement is in the area of serpentine and associated metamorphic rocks on Joaquin Ridge. Magnesium carbonate and silica are only slightly soluble in water under surface conditions, so that when once deposited with the associated minerals as a hard cementing matrix between the pebbles and bowlders along the stream bed the resulting conglomerate is necessarily very resistant to erosion and permits cutting of the constituent bowlders rather than removal of these rocks from the matrix when attacked by running water.

IGNEOUS ROCKS.

The only igneous rocks occurring within the Coalinga district are associated with the Franciscan formation. The Cretaceous, Tertiary, and Quaternary formations were not affected by igneous intrusions, and there is no evidence that there was volcanic activity in this or the adjacent regions during these periods.

SERPENTINE.

The serpentine that has already been described in connection with the Franciscan as covering such a wide region in the heart of the Diablo Range originated as an intrusion of basic igneous rock into the sedimentary Franciscan formation before the beginning of the period in which the Knoxville-Chico beds were laid down. There are many different varieties of the rock, varying from hard, little-altered dark-green and bronze-green peridotite, in which the constituent crystals are well displayed, to much metamorphosed and surficially altered serpentine, soft, smooth, green, white, and variously colored, and to related minerals. The varieties resemble those that are associated with the Franciscan formation throughout the Coast Ranges.

The hard streaks of rock form irregular outcrops and the softer portions weather over large areas into bare, soft heaps of comminuted serpentine in the shape of dust, sand, flakes, and nodules of many colors. The material has gathered much more rapidly than erosion could carry it away, and covers up the rocks to a depth of several feet in places. The streams flowing from the serpentine area, notably White Creek, carry much of the serpentine powder, and deposit it as a dustlike coating on the rocks along their course. It is made up chiefly of small flakes of an olive-gray color and resembles bran in texture and consistency. Outcrops and weathering deposits of similar character were the source of the serpentinous shale of the Big Blue, described with the Santa Margarita (?) formation (middle Miocene).

SODA SYENITE FROM WHITE CREEK.

Toward the head of White Creek is a hill formed of a hard hornblende-bearing igneous rock that seems to have been formed as a boss intrusive in the serpentine. It is a beautiful soda-bearing syenite, mottled black and white and varying from an extremely fine grained facies to a porphyritic one, in which there are large, perfect needles and lath-shaped crystals of hornblende. The area of this rock as shown on the map is slightly exaggerated.

Several somewhat weathered specimens of this syenite showing variations in coarseness from the fine to the porphyritic texture were secured. One of these specimens was chemically analyzed by Dr. W. F. Hillebrand, of the United States Geological Survey, and they have been microscopically examined by Mr. E. S. Larsen, jr., of the Survey, who has kindly furnished the following description.

The specimens are all granitoid rocks of light-gray color composed chiefly of dull white feldspar and its decomposition products, but with numerous long prisms of a black lustrous hornblende. In addition, most specimens show secondary calcite, analcite, and green ægirite. Drusy cavities are common containing crystals of feldspar, prisms of hornblende, and secondary ægirite, calcite, zeolite, and analcite. One specimen of the rock shows both the fine and the coarse-grained types, separated by a sharp but irregular boundary.

A microscopic study shows that the specimens are very similar and that they are made up largely of plagioclase with considerable brown hornblende, a little biotite, accessory apatite, zircon, and black iron ore, and secondary calcite, analcite, ægirite, and white mica. No nephelite or orthoclase were found, though a few very fine intergrowths that were observed were thought to be possibly orthoclase and albite. The texture is granulitic. The feldspars generally show very fine, irregular albite twin lamellæ which give a maximum extinction angle of 16°; the index of refraction is less than 1.540, and the extinction angle measured on cleavage pieces after 010 is 18° and after 001 is 5°. They are therefore albite. In one of the specimens there are numerous feldspar phenocrysts which show a core of andesine or andesine-labradorite grading into a broad band of albite. Alteration is always well advanced and gives rise to natrolite and white mica.

The hornblende occurs in long, well-developed prisms without terminal planes. It is often twinned. Pleochroism is very marked in dark brown and yellow, the birefringence is moderate, and the extinction angle ($Z \wedge c$) is 14°. It is probably barkevikite. Many of the ends and borders are altered to a very dark greenish blue amphibole, but otherwise they are very fresh even where the associated feldspar is completely decomposed.

Ægirite is rather abundant in rough prisms or dendritic growths, which are usually collected in patches. It is strongly pleochroic in greens and yellows, is highly birefracting, and has X parallel to the length of the prisms. Analcite is not common in the fresher rock, but in one specimen it has almost completely replaced the feldspar. Megascopically the latter specimen is not very different from the fresher rock, but the thin section consists mainly of isotropic analcite with scattered grains of calcite, zeolite, ægirite, and white mica, all inclosing fresh crystals of barkevikite. In places a few feldspar crystals can be seen, but they are almost completely altered to natrolite, white mica, etc.

The following analysis was made by Dr. W. F. Hillebrand. The rock was of the fine-grained type and was fairly fresh. It consisted of albite, hornblende, some biotite, accessory apatite, zircon, and iron ore, and secondary ægirite, calcite, zeolite, analcite, and white mica. The analysis was made on powder of 100-mesh size and hence the results for H_2O and FeO are probably very nearly right.

Analysis of soda syenite from the head of White Creek.

[By W. F. Hillebrand.]

SiO_2	60.00	MgO	1.40
TiO_2	.42	K_2O	.94
ZrO_2	.03	Na_2O	9.31
Al_2O_3	16.88	Li_2O	Tr.
Cr_2O_3	None.	H_2O-	.43
Fe_2O_3	1.83	H_2O+	1.53
FeO	3.02	P_2O_5	.14
MnO	.12	CO_2	.59
CaO	3.16	S	Tr.
SrO	.02		
BaO	.06		99.88

The norm computed from this analysis according to the method of the quantitative classification follows:

Norm computed for soda syenite from the head of White Creek.

Orthoclase	5.56	Diopside	11.04
Albite	69.04	Olivine	1.28
Anorthite	1.67	H_2O	1.96
Nephelite	5.40	CO_2	.59
Ilmenite	.76		
Apatite	.34		100.19
Magnetite	2.55		

This places the rock in Class II, order 5, rang 1, subrang 5. It appears to be the first rock of this division to be described. It closely resembles the umptekite described by W. Ramsey.

To sum up, the rock has a granulitic texture and consists, when fresh, of albite and barkevikite with a little biotite, accessory zircon, apatite, and iron ore. Alteration of the feldspar has produced zeolites, white mica, calcite, analcite, and ægirite. The chemical analysis is noteworthy on account of the high soda and low potash. The orthoclase and nephelite indicated by the analysis are probably not present.

STRUCTURE.

Some of the broad features of the structure of the Coalinga district have been briefly touched on in the preceding discussions of the topography and geology, and these as well as many of the minor features will be further treated in connection with the occurrence of petroleum in the description of the developed territory. The structural axes and the general attitude and succession of the strata are represented on the maps (Pls. I, XV, and XXII) and in the various profile sections (figs. 6, 7, 8; Pls. XVI, XIX, XX, XXI), and therefore merely a general review of the structural phenomena and the discussion of certain particular points are necessary here.

CROSS STRUCTURES AND THEIR TOPOGRAPHIC INFLUENCE.

The structure of the Diablo Range is, broadly speaking, anticlinal, and its eastern flank is composed of a great monocline of sedimentary strata dipping toward the San Joaquin Valley. But the regularity of this monocline is broken by a series of waves and offsets into which it was thrown by various important as well as minor plunging anticlinal and synclinal folds, and by faults that run in various directions both parallel with and oblique to the main structural trend of the mountains. This main trend parallels the general course of the Sierra Nevada, the Coast Range, and the coast in this portion of California, and is approximately N. 35° to 40° W. The general orientation of the secondary structural axes is considerably more to the west of north than this. These show their influence prominently in the topography by producing the oblique spurs and valleys discussed under the subject of topography. The same features, both topographic and structural, may be observed south of the Coalinga district and also in the mountainous tracts west of it. It is owing to such structures that the Gabilan Range converges with and joins the Diablo Range in the latitude of the Coalinga district; and the various discontinuous spurs of the high and complex portion of the Diablo Range, which are arranged in positions en échelon with one another, may be explained on the same basis. It would appear therefore that the region has been subjected to two main sets of compressional forces, the one set acting on a line running roughly N. 50° E. (and S. 50° W.), and the other set along a line running N. 20° to 30° E., making a counter-clockwise angle of about 20° to 30° with the former set.

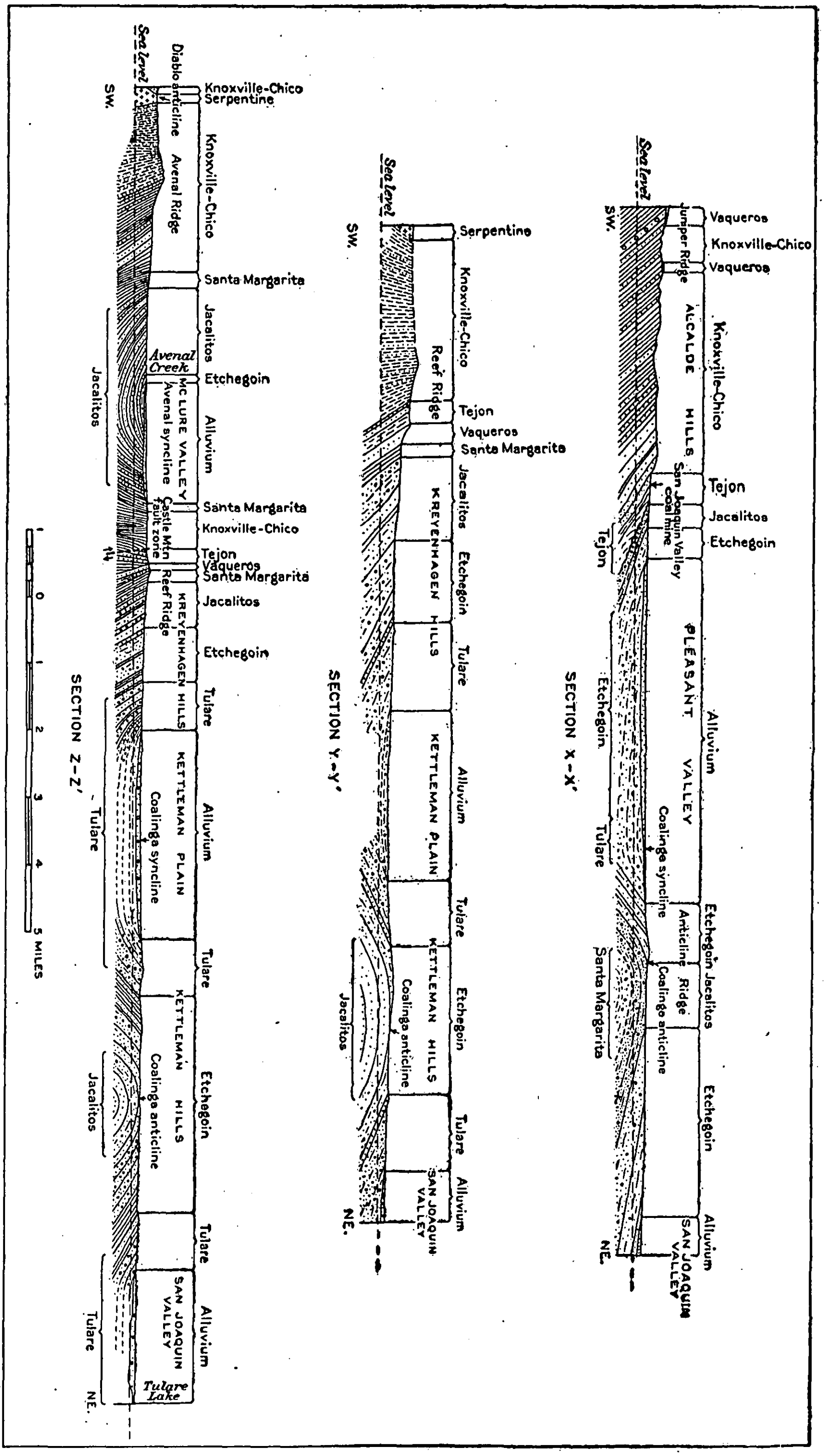
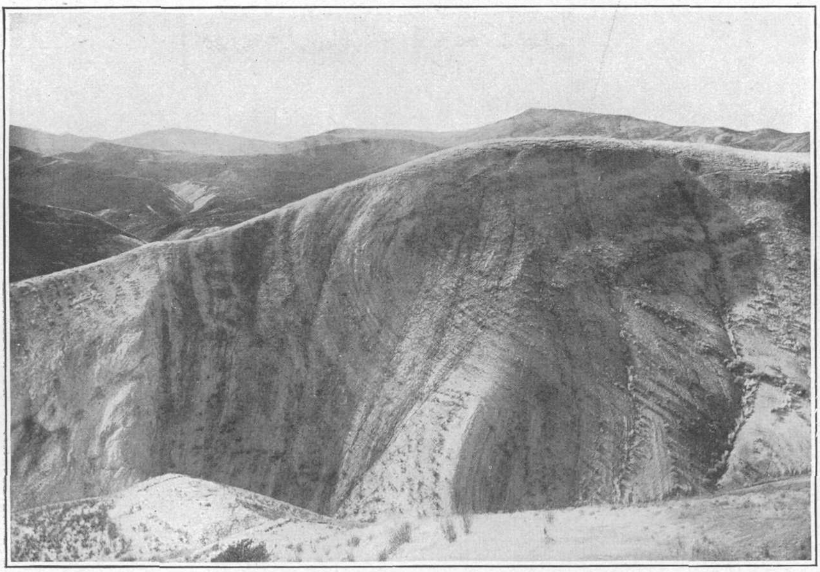


FIGURE 6.—Geologic sections across Coalinga district. (See Pl. I.)

PERIODS OF MOVEMENT AND THE EFFECTS ON FORMATIONS OF DIFFERENT AGE.

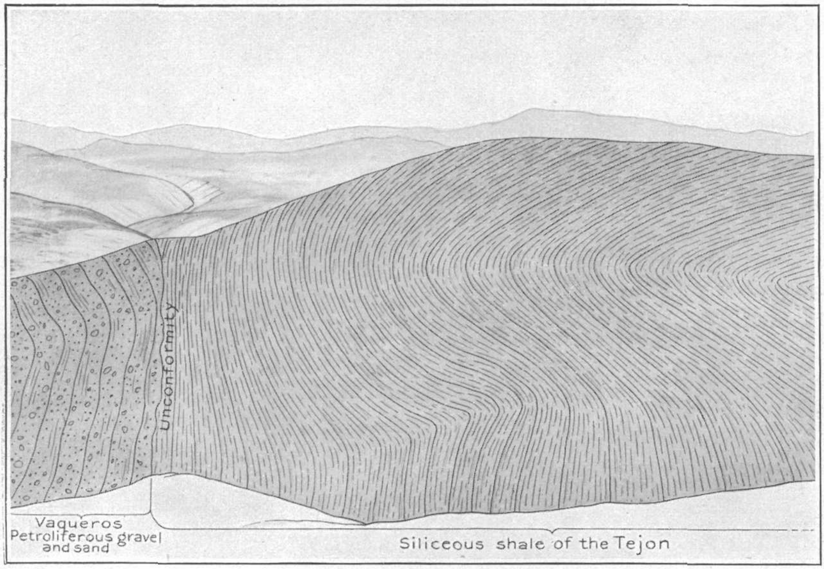
A large part if not the major part of the movement that has resulted in the disturbance of the Tertiary beds in this region, and possibly of the Cretaceous beds over considerable areas in which they were not previously greatly disturbed, took place in Pleistocene time after the deposition of the Tulare (Pliocene-Pleistocene) formation. This is indicated by the fact that the later Tertiary and early Pleistocene formations have been disturbed almost as much as the older ones, and in some places as much as or even more than the Cretaceous beds. An example of this is found in the beds exposed in the Coalinga anticline, where the Cretaceous strata dip gently and appear to have been folded hardly at all before the Eocene and Miocene beds were tilted on the same anticline to the vertical position. One reason, however, for this comparatively little disturbed condition of the Cretaceous formations is their compactness and relative homogeneity, by which they resist stresses that would severely disturb the later, more loosely consolidated beds. Relative immunity from disturbing forces is characteristic of the Cretaceous formations in many parts of California. But in most parts of the Coalinga district the Cretaceous strata have been closely folded in spite of their resistance and intricately faulted partly as a result of it, showing that the disturbances that brought about these results were very severe. These disturbances are thought to have occurred for the most part before the Tertiary, or at least before the Miocene, for reasons stated in the discussion of the geologic history. It is certain that important movements took place during Cretaceous and Tertiary time, notably at the close of the Tejon (Eocene) period of deposition, when the beds of that age were uplifted and greatly disturbed before the subsidence that allowed the deposition of the Vaqueros (lower Miocene) sandstone on their eroded surface, and also at the close of the Vaqueros period. As regards the still later movements, the facts that all the formations from the Cretaceous to the lower Pleistocene are in places approximately conformable in dip, and that at least the Miocene, the Pliocene, and the later portion of the series almost invariably appear so, indicate that the whole series was affected as one during the Pleistocene epoch by extraordinarily severe disturbances.

In the Tertiary formations the land movements have resulted chiefly in folding rather than in faulting. The strata of these formations are everywhere tilted, at angles ranging from a few degrees to the vertical, and are locally overturned, but evidences of faulting are by no means as common. The only fault of importance that is definitely known to affect the Tertiary formations in this district is one shown on the maps (Pls. I and XV) in the Alcalde Hills southwest of

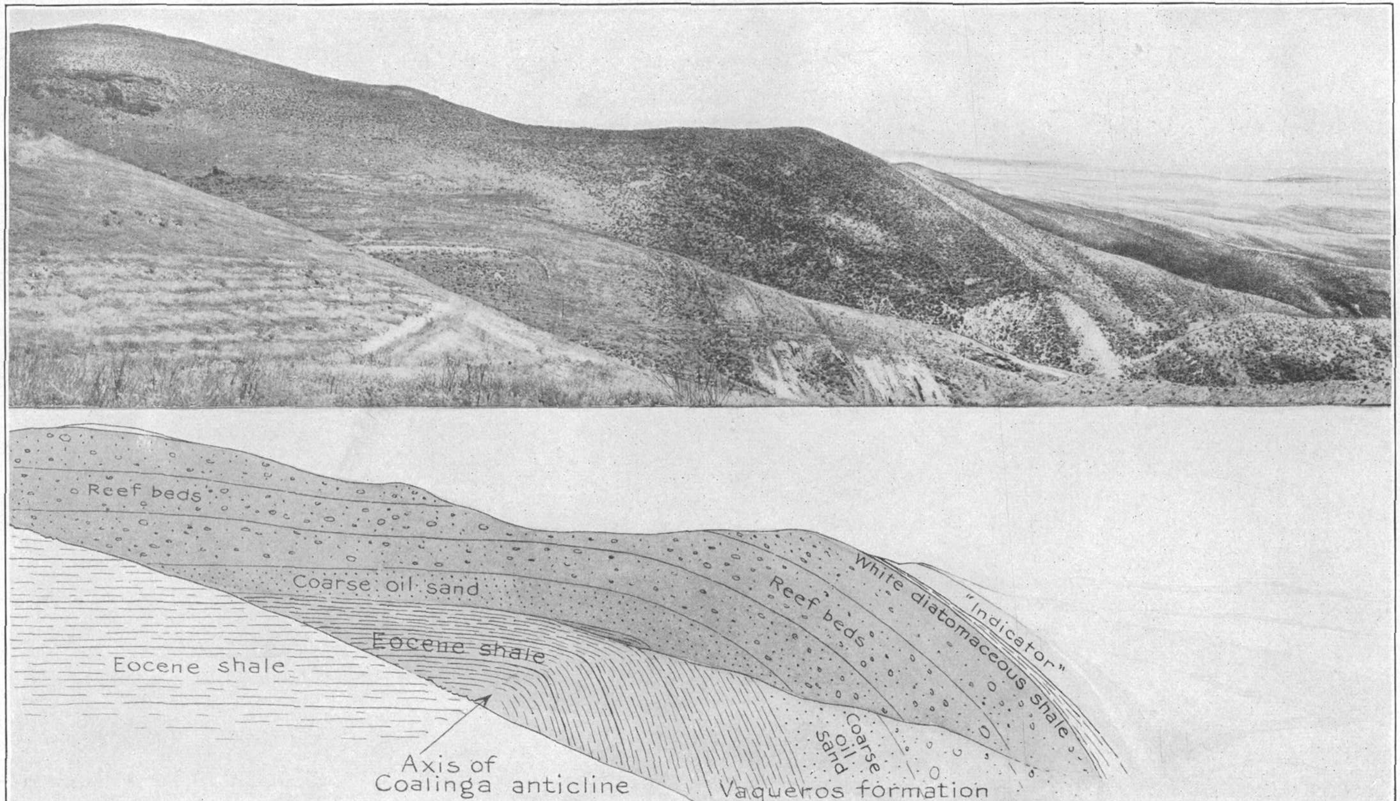


A. OVERTURNED SHALES OF TEJON FORMATION IN AXIS OF COALINGA ANTICLINE.

Looking northwest across foothills, 8 miles north of Coalinga. Note base of overlying Vaqueros on left; the vegetation following lines of bedding in the fold; Joaquin Ridge in the distance. Taken from Tejon-Vaqueros contact on ridge shown in Plate VII. Photograph by Ralph Arnold.



B. DIAGRAM OF PLATE XIII, *A.*



BASAL VAQUEROS OIL SANDS ON AXIS OF COALINGA ANTICLINE.

Looking southeast along plunging axis, showing petroliferous beds dipping gently southeastward on the left, the overturned axis in the center, the steeply dipping beds on the right, the shales of the Tejon formation in the foreground, and Pleasant Valley in the distance. Taken from Tejon-Vaqueros contact on ridge shown in Plate VII. Photograph by Ralph Arnold.

Coalinga. This fault has a downthrow of at least 200 feet on the northeast. It is discussed in the description of the geology of the Westside field (p. 222). A few small local faults, such as are shown in Plates VI, *B*, and X, have been noted. The displacement shown on the left in Plate X is due to collapse of the soft beds of the Big Blue, which is mapped with the Santa Margarita (?) formation (middle Miocene).

The older formations, on the other hand, are much faulted as well as folded, and many faults in them have not been mapped. The Knoxville-Chico (Cretaceous) beds exposed along Los Gatos Creek afford an excellent example of the great number of large and small faults that occur along a fault zone such as that which determines the position of this old valley.

THICKNESS OF THE SEDIMENTARY STRATA.

The great thickness of the sedimentary strata along the flank of the Diablo Range is proof of the greatness and comparative continuity of the movements to which the land has been subjected during the recorded geologic history. The total maximum thickness of the different formations, as given in the columnar section (fig. 2), is not measurable in any one locality, but the total is found in many sections to be as much as 12,000 to 15,000 feet or more.

Possibly a slight exaggeration of thickness may result from the spreading of the beds at the surface, where they are relieved from pressure, and from the related tendency on the part of tilted strata to assume steeper dips at the surface than the true dip at depths. The steeply dipping and locally almost overturned beds of loose, dry sand, gravel, and clay toward the south end of the Kreyenhagen Hills suggest the probability of their having expanded at the surface and thus augmented their apparent thickness. Superficial spreading, uptilting, and disturbance occur likewise in the more compact older rocks, especially in the shales of the Knoxville-Chico (Cretaceous), Tejon (Eocene), and Santa Margarita (?) (upper middle Miocene). The tendency toward steepening of the dip at the surface is aided by gravitational movement of the soil. A local overturn at the surface in the shales of the Santa Margarita (?) formation is shown in Plate XI, *B*. The exaggeration of thickness due to such surficial phenomena, however, is hardly appreciable in some portions of the district, as, for instance, in the developed oil field, where the thicknesses of formations as revealed in the oil wells agree closely with those measured on the surface; and it is not thought that it results anywhere in a large proportional increase over the true thickness. The measurements of formations given in this paper are intended to represent fairly the thicknesses apparent in the surface outcrops, except in the discussion of the developed territory, in which many figures are given that are based on the measurements obtained in wells.

It has been pointed out in the description of the formations how they vary in thickness within short distances. This variation is characteristic of the region. In the post-Eocene formations it may be partly explained by the theory that the gradual subsidence which took place during the different periods progressed more rapidly toward the south than it did in the northern part of the Coalinga district, where the shore line must have been near, and that the periods of land conditions interrupting the progress of sedimentation were more prolonged in the northern region. A large part of the irregularity of thickness is doubtless due to the removal of portions during intervals of erosion. Furthermore, much irregularity is due to the local variations in the nature of the deposits and to the original manner and amount of their deposition.

UNCONFORMITIES.

The number of unconformities between formations in the Coalinga district gives further proof that the region underwent almost continuous movements, and that these were of various kinds. The unconformities are rarely clearly apparent at the contacts between the formations, and the unconformable relations are usually to be made out only from a detailed study of (1) the areal distribution of the formations, which gives a clue to the presence of overlap, and of (2) the fossils, which indicate time breaks. The evident angular unconformities that have been discovered are between the Vaqueros (lower Miocene) and Tejon (Eocene) at various localities north of Coalinga; between the Tejon and older Cretaceous shales at points on Reef Ridge; between the Vaqueros and Cretaceous in the Alcalde Hills and on Juniper Ridge; between the Santa Margarita (?) (upper middle Miocene) and Vaqueros where the Castle Mountain fault zone crosses Reef Ridge; between the Santa Margarita (?) and Tejon at the same point and also at the San Joaquin Valley coal mine; and between the Santa Margarita (?) and Cretaceous along the north and east sides of McLure Valley.

The unconformity between the Tulare (Pliocene-Pleistocene) and Etchegoin (upper Pliocene) north of Zapato Creek is less definitely to be made out. Elsewhere the formations, even those profoundly distinct in age, generally appear conformable in dip, and it is not improbable that overlaps and unconformities that have not been made out occur within the formations that are treated in this report as stratigraphic units. That little reliance is to be placed on an appearance of angular conformity is made clear at several points north of Coalinga, where an appearance of such a relation between the Tejon (Eocene) and Vaqueros (lower Miocene) is to be found only a short distance from points where the contact displays pronounced discordance in dip. Overlaps of all the Tertiary formations, except the Tulare, upon the Knoxville-Chico (Cretaceous) occur within the Coalinga district, thus proving their mutual unconformity. Except the overlap of the Etchegoin on White Creek, and that of the Vaqueros in the Alcalde Hills, over the sandstone of the Chico (Upper Cretaceous) these overlaps take place over the lower portion of the Knoxville-Chico. The variation of the formations in original areal extent and in thickness, lithologic character, and structure within small areas gives an indication of the local activity of the disturbing forces which have continued to act within this region.

MAIN LINES OF STRUCTURE.

Coalinga anticline and syncline.—Among the individual features of the structure in the Coalinga district the Coalinga anticline is next in importance to the general monocline on the eastern face of the Diablo Range. This anticline is one of the principal oblique structures of the range. It forms Joaquin Ridge and plunges toward the valley, exposing in turn the Franciscan rocks at the head of Joaquin Ridge and all the subsequent formations. The synclinal axis of its plunge is at Polvadero Gap, beyond which it is undoubtedly continued by the anticline plunging in the opposite direction, which causes the beds to dome up into the Kettleman Hills. At the south end of these hills, about a mile south of the mapped area, the anticline does not plunge beneath the surface of the valley again, as might be expected by analogy. On the contrary, it exposes a fairly low portion of the Etchegoin formation, beds several thousand feet stratigraphically lower than those exposed at the north end, and the hills are left incomplete, their termination being due to erosion rather than to structure as at the north end. The Lost Hills, which are within 10 miles south of the area shown on the map, are due to a continuation of the Coalinga anticline. The length of this fold within the district is 60 miles. Its principal features are its alternating plunges in different directions, its curving course indicating a complexity in the forces which have acted upon it, its asymmetry, and its broad summit and steep flanks. The plunges and arches of the anticline are indicated by symbols on the geologic map (Pl. I). The steep dips on its southwestern flank north of Coalinga as compared with the gently dipping summit and northeastern flank are very pronounced, these features being illustrated in Plates III, XIV, and XVIII and on the map of the Coalinga field (Pl. XV). Similar asymmetry is observable in the northern part of the Kettleman Hills, although the divergence in dip on the two flanks is not so great, the usual maximum dip being 35° to 45° on the southwest and 25° to 31° on the northeast. The Coalinga syncline is the parallel supplementary feature and forms the topographic depression of Pleasant Valley and Kettleman Plain. Like the anticline, it plunges southwestward from Joaquin Ridge and rises again opposite the Kettleman Hills. West of Oil City it dies out in low dips on the flank of the anticline.

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

Structure in the basin of Los Gatos and White creeks.—The structure in the basin of Los Gatos and White creeks between Joaquin and Juniper ridges is peculiar and complicated. A broadly folded anticline of Cretaceous beds with a locally sharp axis plunges southwest and northeast off the flanks of these two ridges toward the lower part of Los Gatos Creek, where it is crossed by a broad syncline plunging both northwestward into the axis of the White Creek basin and southeastward into Pleasant Valley. The syncline becomes sharply defined and regular along White Creek, where it incloses a remnant of Etchegoin (upper Miocene). Toward Pleasant Valley it broadens out to form part of the general monocline dipping toward the axis of the Coalinga syncline. A complicated set of faults occurs along Los Gatos Creek, as illustrated on the map (Pl. I). On the south side of the main line shown as the Los Gatos Creek fault zone the rocks are the thinly bedded dark shale and sandstone of the middle division of the Knoxville-Chico (Cretaceous). On the north side the massive sandstone beds of the upper division are faulted down into contact with them. The movement has been in the nature of a flattening out of the axis of the White Creek syncline toward its head, resulting in the formation of the main fault and of branch faults on the downthrow side, with greater and greater throw in the successive blocks toward the southeast. A great number of small faults are not of sufficient size to show on the map. Many of these may be seen in the exposures along the sides of Los Gatos Creek. Faulting of a somewhat similar character to that described has taken place likewise on the northeast arm of the syncline, but time did not allow a detailed study of the system. The basin of Los Gatos and White creeks has probably been an axis of movement along which successive disturbances have taken place during a long period. The southeastward continuation of this same line of disturbance probably accounts for the depression of the Coalinga anticline in the region of Polvadero Gap.

Zone of Alcalde Canyon.—Another old zone of movement is represented by the southeast face of Curry Mountain and the lower part of Alcalde Canyon from Alcalde toward Pleasant Valley. Profound faulting probably took place along the zone at different times. The sharp northern face of the 1,900-foot hill southeast of Alcalde suggests faulting, but no evidence of displacement in the later Tertiary formations has been obtained. The region north of Waltham Creek has had in some respects a different history from that to the south, and it is difficult to correlate the features of the geology in the regions so separated. To the south the formations have a far greater thickness, the sandstone portion or upper division of the Knoxville-Chico (Cretaceous) is lacking, the siliceous shales of the Santa Margarita (?) formation (upper middle Miocene) appear and gradually thicken and are only doubtfully to be correlated with the Santa Margarita (?) formation to the north, and a great thickness of the Tulare (Pliocene-Pleistocene) formation is steeply tilted and well exposed.

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

Castle Mountain fault zone.—The main structural features of the southwestern part of the territory mapped are the Castle Mountain fault zone and the Pyramid Hills anticline, the Avenal syncline, and the Diablo anticline. The first named is a very important and complicated zone of faulting that affected the Vaqueros and older formations. The downthrown side is on the northeast. Faulting along the same zone is the cause of the prominent scarp of Castle Mountain farther west. The fault is not exposed east of Reef Ridge because covered over by the later formations. The lowest of these, the Santa Margarita (?) formation, is only very slightly wrinkled at this point, showing that practically all movement along this part of the Castle Mountain fault ceased before the upper middle Miocene.

Pyramid Hills anticline.—The Castle Mountain fault zone is the locus of an important anticlinal fold that was formed long after the cessation of fault movement along the eastern portion of the zone. The shale of the Santa Margarita (?) formation and the younger formations have been worn off over the summit of the fold, and the rocks exposed along this uncovered axis belong chiefly to the Knoxville-Chico. The disturbance of the pre-Miocene rocks has been so great that the axis of the anticline is not easily traceable within the faulted zone. To the southeast the general zone of faulting gives place along a divergent axis to an overturned anticline in the Knoxville-Chico beds, and this is traceable into a regular, sharp fold covered by the shale of the Santa Margarita(?). This is the anticline forming the prominent ridge of the Pyramid Hills and the northeastward-tilted monocline of the southern end of Reef Ridge and the Kreyenhagen Hills.

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

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

CHARACTER OF THE FOLDS AND FAULTS.

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

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

GEOLOGIC HISTORY.[a]

GENERAL FEATURES.

The portion of geologic time of which the rocks of this part of the Diablo Range afford a record is comparatively late. The oldest rocks that appear in the axis of the mountains and that form a basement on which the later ones rest probably go no further back than Jurassic time, but even in them the record is obscure. Traces of preexistent rocks are to be found as inclusions in the younger formations, but they tell nothing of the age and give only suggestions as to the character of the terranes that must have formed land surfaces somewhere within this region during pre-Jurassic time. The history of the later periods, however, is preserved in considerable detail in a great series of strata that represent probably the greater portion of the time from the beginning of the Cretaceous to the present. These have been periods of great activity during which earth movements affecting broad areas, but at the same time causing various effects locally, have resulted in continually changing conditions and produced a complicated record.

JURASSIC (?) PERIOD.

The earliest period of which there is definite record is that of the Franciscan formation, of which the age or extent in time is not known, but which is doubtfully referred to the Jurassic. The conditions that prevailed during this period were probably those of widespread marine deposition, although the absence of remains of organisms in the rocks leaves this origin in doubt. The Franciscan sediments were laid down to a great depth over a very extensive area covering much of the present Coast Range region, and are generally similar, fairly fine grained materials, consisting largely of fine sandstone, dark clay shale, and jasper. The natural conclusion to be drawn is that the open ocean occupied much of this region in the Franciscan period. The source of the materials is unknown.

At the close of or perhaps in part during the period when the sediments of the Franciscan were being laid in beds at the bottom of the basin of deposition, they were intruded by immense bodies of molten rock of a basic variety that has since been changed into the serpentine so abundant over the areas in which the rocks of this formation occur, and other igneous intrusions probably took place

[a] A brief discussion of the geologic history of the Diablo and Temblor ranges is given by F. M. Anderson in his "Further stratigraphic study in the Mount Diablo Range of California" (Proc. California Acad. Sci., 4th ser., vol. 3, 1908, p. 6).

some time during the same general period. It is not possible to state the character of the further events or the length of time before the arrival of the period represented by the Cretaceous beds. There is no incontrovertible evidence that any of the intrusive or metamorphic activity took place after the latter period commenced.

CRETACEOUS PERIOD.

The oldest Knoxville-Chico beds probably represent an early part of Cretaceous time. The strata that began forming in this period were similar to those of the Franciscan formation, and the prevailing conditions were probably not greatly different in the two periods. The sea spread widely over the Coast Range region, probably covering much of it to a considerable depth, and coarse and fine sediments derived from a land area whose position and character are doubtful were alternatingly laid down to form the present interbedded shale and sandstone of the lower two-thirds of the group. Remains of organisms are rare in these beds, but where found indicate their marine origin and Cretaceous age. The general scarcity of fossils may indicate a fairly deep water origin for the beds. There is no evidence that many fossils once present have been obliterated by crushing or leaching. The beds contain little calcareous material and in many places remain without sign of great disturbance. In the higher portion of the Cretaceous coarser and probably more littoral beds predominate and fossils are somewhat more abundant.

The amount of information that has been obtained from the Cretaceous deposits of the Coalinga district does not warrant the formulation of a definite outline of the history of that period. One or more epochs of uplift of the strata above the sea and prevalence of land conditions probably intervened between long epochs during which the great depth of sediments was accumulated, but the length of these different epochs has not been determined. During the early portion of the Cretaceous fine materials were by far the most abundant, fine silt alternating rapidly with fairly fine sand. During the later portion sand was more abundant. The later portion of Cretaceous time is not everywhere represented in the district at the present day, owing either to the land having been above water or to the subsequent removal of the deposits. The conditions during those periods in which deposits were being formed were equable and resulted in the formation of homogeneous masses of strata of great thickness. The great zone of conglomerate that has been described as lying in the middle of the lower or predominantly fine-grained portion of the group represents a remarkable change of conditions. It means that a land area, of rocks in part dissimilar to those now outcropping in the Diablo Range, was in close proximity, and it probably indicates a considerable break in time between its age and that of the beds below it.

The total thickness of the beds formed during the Cretaceous that are still within the district is at least 12,800 feet. They have become compacted since their deposition, and perhaps the original beds are not all present in the sections measured, so that this thickness is probably less than the amount of vertical subsidence that the land must have undergone to allow their deposition. The homogeneity of the successions of strata through great thicknesses shows that the source of the material and the general conditions did not greatly vary. The basin of deposition must have been subsiding gradually with reference to a fairly constant or rising area of land.

EARLY TERTIARY PERIOD.

The greatest diversity of movements and conditions that is recorded for a period in the Coast Ranges is that which throughout characterizes the Tertiary. In some places the era opened under conditions continuing those of the late Cretaceous, and in the very northern part of the Coalinga district the beds belonging to the period close to the line between these two great time divisions are as yet only with doubt referable to either the one or the other. There is, however, a great faunal hiatus between the uppermost Cretaceous fossiliferous bed (Chico) and the lowermost Eocene fossiliferous stratum (Tejon), which must represent a long period of time. In contrast to the seeming intergradation of the Chico and Tejon in the region north of Alcalde Canyon is a profound unconformity between the Eocene and older Cretaceous beds farther south; and this overlap occurred within a small central portion of the Coalinga district. Either the interval of time that probably intervened throughout this region between the portions of Cretaceous and Eocene time here represented was occupied by the erosion of the upper portion of the Knoxville-Chico in the southern part of the field, or else the southern area of Cretaceous was continuously above water during the time occupied by the deposition of the Upper Cretaceous beds in the northern part of the district. Evidence was not gathered sufficient to decide which of these conditions was the more likely. Whereas the source of the sediments during Jurassic and at least earlier Cretaceous time is doubtful, the great land area and most important source of detritus having possibly been toward the east, the Coast Range belt of relief is known to have dominated the later formations, and the present Great Valley region, at least in later Tertiary time, is known to have played an active part as a basin of depression.

During the Eocene the region of the Coalinga district occupied a littoral belt east of the Coast Ranges and at least for a portion of the time shore-line and estuarine conditions prevailed in the vicinity of Coalinga. At the coal mines in the Alcalde Hills the beds that give evidence of such conditions are especially well exposed. They are roughly bedded, of varying coarseness, full of gypsum and alkaline salts, and interbedded with lignite, showing that the materials accumulated roughly not far distant from the shore in shallow, brackish water. Elsewhere, as along Reef Ridge, the shallow-water character of these beds is less pronounced. The fossil remains in the lower portion of the Tejon (Eocene) formation show that mollusks lived abundantly in the sea and that other forms, such as echinoderms, corals, and bryozoans, were likewise present.

It is possible that the marine conditions were exchanged during a long or short period for land conditions before the deposition of the shale beds in a later period of the Eocene, but little evidence on this point has been obtained. In that later period the land probably sank and the shore receded, the source of supply of coarse materials being removed partly by this recession and partly by the base-leveling of the land. The deposits on the sea bottom were formed jointly by fine sediments and minute organisms such as diatoms and foraminifers that lived in the sea and dropped in great numbers to the bottom after death. In the mud that was thus formed on the sea floor the organic matter inside the shells of these little plants and animals must have become buried and been preserved. From this source the petroleum that seems to have originated in the Eocene shale is thought to have been derived. Other forms of life that inhabited the sea were delicate little mollusks, which probably lived in the mud at the bottom, and fishes, the scales of which are preserved.

The whole of the formation that was deposited during the Eocene is not preserved in the Coalinga district, owing to a great uplift of the land that brought the marine conditions to an end and subjected the formation to erosion. It is therefore impossible to state what length of time or how large a portion of the Eocene was occupied with deposition. There is no direct evidence whether or not the formation extended beyond the limit of the Eocene into the Oligocene. The greatest thickness of the beds belonging to the Tejon (Eocene) formation that has been preserved within the district is exposed on Joaquin Ridge north of Coalinga, where it amounts to at least 1,850 feet.

The land movement that caused the emergence of the area over which the Tejon formation was laid down during Eocene time was not merely of a local nature but is known to have affected a large portion of the coastal province. As a result of it the Eocene strata were upheaved and in places, notably near the axis of the Coalinga anticline south of Oil City and along the western border of what is now Pleasant Valley, were steeply tilted. Movements probably took place at that time along some of the lines of structure which have been the loci of more recent disturbances, and at that time also some of the features of the present Diablo Range were determined. During most and probably all of the Oligocene period the region of the Coalinga district, as well as a much greater portion of the southern Coast Ranges, was land and the Eocene and older beds were exposed to erosion. As a result large parts of the pre-Miocene formations were worn away and parts of the surface planed off.

MIDDLE TERTIARY PERIOD.

Early in the Miocene the area of the eastern flank of the present Diablo Range became pretty generally submerged to a slight depth below the sea, and the worn surface of the older formations became the floor upon which the marine deposits of sand, pebbles, clay, and shells were formed that have been described as the Vaqueros formation (lower Miocene). During this period land areas probably remained in the northwestern and southwestern portions of the region that is now the Coalinga district. In the northern part of the district coarse shore deposits were formed at the beginning of the period. In the southern part the deposits were littoral but less markedly so, the basal beds being in places more fine grained than those above them. The greater part of the period was taken up by deposition of medium-grained sand materials within a littoral belt. Among the living organisms that flourished in this belt we know from the abundant remains that mollusks and echinoderms existed in great numbers. They were of species characteristic of the early portion of Miocene time throughout the coastal region of California. Remains of trees were abundantly preserved in the gravel and sand deposits, supposedly of lower Miocene age, that form a capping on the flanks of Juniper Ridge. These deposits were laid down upon a level surface that had been worn in the Cretaceous rocks and may have originated in part on a land area adjoining the shallow sea waters. At one stage in the middle portion of the period a peculiar change of conditions that is not easily explainable took place in the northern part of the district. Coarse materials ceased to be deposited, and practically the only materials that were laid down were the remains of diatoms and foraminifers mixed with extremely fine silt. As a result the 15 to 20 foot "indicator" bed was formed. In the succeeding stage in the same area fairly coarse sand somewhat resembling beach sand was the chief material deposited, and the remains of a near-shore marine fauna, consisting chiefly of mollusks, were preserved. A rough measure of the Vaqueros (lower Miocene) period is afforded by the thickness of the strata laid down. The compact beds of Reef Ridge have a maximum known thickness of about 900 feet.

The relation of the formations on the two sides of the Castle Mountain fault has an important bearing on the questions involved in the history of the early Miocene as well as other periods. The Eocene and lower Miocene formations stop near the south end of Reef Ridge at this fault zone, and first appear again on the southwest side of this fault 7 miles south of Little Tar Canyon on the southwestern edge of McLure Valley.

The hypothesis that seems best to fit the conditions outlined above postulates that the region west of the fault must have been thrown up as a great block or series of faulted blocks during the period of movements following the lower Miocene, and that the Eocene and lower Miocene beds that had been formed over it were almost completely eroded away and the fault block completely reduced during the early middle Miocene land period.

No faulting has taken place along this portion of the fault line since the early middle Miocene, as is proved by the fact that the later beds are unaffected. The prominent fault scarp of Castle Mountain a few miles northwest may be due to more recent movement along the fault there while it has been stationary near Reef Ridge. Unless such a movement has taken place the prominence of this topographic and structural feature would tend to favor the latest possible date for movement along the fault zone as a whole, namely, the early middle Miocene.

The deposition of beds in the Vaqueros (lower Miocene) period was brought to an end by movements which, it is thought, left the land in this portion of California not far above the sea, so that in the succeeding middle Miocene period no great amount of sediment was removed from this region to the wide expanse of sea farther west, in the region now west of the Salinas Valley, in which the fine, largely nonterrigenous ooze of the Monterey shale was laid down. As a consequence, the Vaqueros beds were locally well preserved, and when the time came for later sediments to be laid down upon them there were preserved at the contact no striking evidences of the time that had elapsed. Good structural evidence, in addition to that of paleontology, that a time interval and erosion did occur, however, is afforded by the varying thickness and locally complete absence of the Vaqueros, the deposits of the upper middle Miocene (Santa Margarita (?) formation) overlapping upon different horizons and in places directly upon the pre-Miocene rocks. In the region of the Stone Canyon coal mine, near the summit of the Diablo Range, west of the Coalinga district, the shale of the Santa Margarita (?), which is supposed to be the equivalent of the shale referred to the same formation in Reef Ridge, lies with distinct unconformity upon the tilted and eroded lower Miocene beds, showing that there, too, a land period came between.

In the northern portion of the Coalinga district it is not impossible that there have been preserved in the Big Blue, in its sands and coarse gravel and strange serpentine detritus, accumulations that took place during a portion of this interval between the marine invasions of the lower Miocene and later middle Miocene.

It will be a matter of considerable interest to determine to just what age the Big Blue belongs, both on account of its bearing on the history of the Monterey period and because it is the earliest zone giving indubitable evidence of the occurrence in it of fragments of the rocks associated with the Franciscan formation. On the northern flank of Joaquin Ridge this zone is composed almost entirely of serpentine fragments of all sizes derived from a near-by area in which the Franciscan was exposed. It is very probable that this area was in the same position as the present serpentine area on Joaquin Ridge and was brought to the surface by post-Eocene folding along the line determining the axis of the present Coalinga anticline and by erosion over the area thus uplifted. There is no proof that the Franciscan formation or its metamorphic associates appeared at the surface in this district in any preceding period.

After the early portion of the middle Miocene period had elapsed a great subsidence took place and brought the whole southern part of the district below a deep sea. The subsidence there was probably progressive from south to north. In the region of the present Temblor Range south of the Coalinga district the Monterey (early middle Miocene) period is represented, and the subsidence there may have continued through most of middle Miocene time, allowing a very great thickness of shale beds to be formed. If such is the case, the area of subsidence widened toward the north until it affected the southern part of the Coalinga district in the latter portion of the middle Miocene period and caused the deposition of deep-water shale beds as a continuation of the upper portion of the series farther south.

The conditions that prevailed during the period of deposition of the shale of the Santa Margarita (?) formation must have been similar to those of the later part of the Tejon (Eocene) period already discussed and to those prevailing during Monterey (middle Miocene) time over a considerable portion of the Coast Ranges.[a] Organic remains are not well preserved in the shale of the Santa Margarita (?) formation of the Coalinga district, but it is almost certainly largely composed of siliceous and in lesser amount calcareous remains, of diatoms and foraminifers, respectively.

In the northern portion of the district the subsidence during the Santa Margarita (?) period was not so great and coarse shallow-water sediments were laid down. For a portion of the time there thrived here a fauna of strong-shelled mollusks, barnacles, and echinoderms

[a] For an outline of the history of this period elsewhere see Fairbanks, San Luis folio (No. 101), Geol. Atlas U. S., U. S. Geol. Survey, 1904, p. 9; and Arnold and Anderson, Geology and oil resources of the Santa Maria oil district, California: Bull. U. S. Geol. Survey No. 322, 1907, p. 67.

(sand dollars), fitted to survive in troubled waters along shore. This subsidence may have immediately preceded or been contemporaneous with that in the area of the Kreyenhagen field.

The thickness of strata deposited during the Santa Margarita (?) period in the region around the modern Pleasant Valley was about 600 feet (exclusive of the Big Blue). The shale in the southern part of the district was laid down to a thickness of as much as 1,200 feet.

LATE TERTIARY AND EARLY QUATERNARY PERIOD.

The close of the Santa Margarita (?) period witnessed an uplift of the land over the large region that its deposits covered, and the beginning of a long period, occupying most of the rest of Miocene time, during which shallow-water deposits were formed in arms of the sea that were separated from each other by land areas coincident in large measure with the more elevated portions of the present Diablo Range. Probably an interval succeeded the Santa Margarita (?) period during which the area of the Coalinga district was not submerged, but no measure of its length has been obtained and it can not have been as long as the previous interformational periods that have been made out. It is thought to have been longer in the northern than in the southern part of the Coalinga district. The great succession of littoral marine sand, gravel, and clay beds that followed mark a gradual subsidence during the Jacalitos and Etchegoin periods, which are the equivalent of upper Miocene time. This subsidence was probably effected by a gradual process of downfolding in basins of depression that crossed a belt of topographic relief corresponding to the present Diablo Range, and in the large basin of the San Joaquin Valley. The mountainous tracts of the older formations were probably at the same time subject to uplift that caused them to preserve a fairly uniform relation to the sea area and resulted in a comparatively stable position of the shore line. Roughly speaking, the Diablo Range may be said to have existed as a row of islands. The continued presence of these islands preserved the littoral character of the beds which were laid down along their shores and which were later upheaved to form the present fringe along the eastern base of the Diablo Range. The belt of lowland bordering the mountains must have been occupied for part of the time by arms of the sea in which estuarine conditions prevailed and in which large amounts of gypsum and alkaline salts were precipitated. The thickness of the deposits that were laid down under these conditions, in the Jacalitos and Etchegoin periods, amounts to over 7,000 feet, and may be taken as a rough measure of the time that elapsed and of the depth to which the basal platform of the basin or basins sank. The beds of this age are preserved in large part in their original incoherent state and their thickness does not represent as much deposition as a similar thickness would in the consolidated beds of some of the older formations.

The conditions outlined above did not prevail uninterruptedly during the whole of the period represented by the Jacalitos and Etchegoin combined. There probably were many oscillations in the orogenic movements and complex variations in the areas and degrees of movement, in the land areas, and in the conditions of climate and supply of sediments. Such changes are attested by the variety of the beds and zones of deposits that were formed, and by the presence within the series of strata that originated in fresh water or on land, but are far too complicated to be made out in detail. There was at least one period, the close of the Jacalitos, when a marked disturbance took place. In the northern part of the region under discussion the sea spread much farther westward before the beginning of the Etchegoin, causing the beds of that period to overlap beyond the limits of the Jacalitos and to be laid down unconformably upon the Cretaceous and Franciscan. It is possible that an uplift had preceded the subsidence that caused this overlapping and had raised the earlier upper Miocene beds above the sea, allowing them to be eroded; but somewhere within no great distance the marine conditions and sedimentation must have been continuous, and the appearance of conformity between the Jacalitos and Etchegoin formations on Joaquin Ridge and in the Kreyenhagen Hills indicates that at this distance from the axis of the mountain belt to the west deposition went on without interruption. The much greater thickness of the formations south of Waltham Creek than north of it points to episodes in the history of the northern region that have not been made out. Probably the progress of sedimentation was broken at different periods in the northern region when continuous in the southern, the line at present followed by the southern end of Curry Mountain and the lower portion of Alcalde Canyon having been a locus of changes separating areas of different geologic history.

The kinds of organisms that lived in the upper Miocene period and left relics in the rocks were principally mollusks and echinoderms, the latter including both sea urchins and sand dollars. Cirripedia (barnacles), brachiopods, and corals were also common at certain times, and fishes and sea mammals (either cetaceans or sirenians) left a record in their teeth and bones. A great abundance of fossil wood is preserved in the near-shore gravel and sand beds that were formed during the Jacalitos (early upper Miocene) period, and in one place the tooth of an extinct species of horse is associated in the same zone. The conditions throughout most of the period were favorable to marine life and rich faunas were preserved.

The Etchegoin (late upper Miocene) period was brought to a close by a gradual uplift of the land and transition from locally varying open-sea and estuarine conditions to more generally prevalent estuarine and perhaps also brackish-water conditions. The faunas reflected this change and the sediments became thoroughly impregnated with and in places largely made up of salts, especially gypsum. The marine body of water gave place in turn either through a direct transition or after the intervention of a land period to fresh water at the beginning of the Tulare period, which includes most of Pliocene time and probably a part of the early Pleistocene. The origin of the deposits of this period and the conditions prevailing during it have been discussed above in the description of the formation. Suffice it to say here that the character of the period is in doubt, but that the stage with which it opened was not of long duration; that the course of events following that stage probably did not differ greatly from present history; and that the period was probably largely taken up in deposition of sediments subaerially over the topographic basins, gradual subsidence of the basins, and temporary incursions of the sea into them. Deposits of various kinds, fresh-water, subaerial, and marine, were built up into one conformable succession of beds with a thickness of as much as 3,000 feet or more. The period ended in great orogenic movements that caused the greater part of the disturbance now visible in the post-Eocene formations. The Tulare beds and all those below them were warped into folds and tilted at high angles. Similar movement took place widely along the Pacific coast early in the Quaternary, and the disturbances here may be ascribed to the same general epoch of activity. It is partly on the basis of this correlation of movements that the Tulare period is considered as extending into Quaternary time. The previous greatest periods of movement of which record has been obtained in the Coalinga district were at some time in the later half of the Cretaceous and at the close of the Tejon (Eocene). The relative importance of these movements is hard to estimate. It would appear from the fact that all the post-Eocene beds up to the Quaternary have been so violently displaced, the youngest as much as the older ones, while the earliest formations are not everywhere greatly disturbed, that the movements following the Tulare period were the most profound of all. But it must be borne in mind that the compact older formations have acted as a buffer against which the late movements have crushed the little-consolidated and therefore pliant later strata, and that great disturbance in the Tertiary and later beds does not necessarily represent as great a causal force as slighter displacements in the great homogeneous and compacted series of older rocks, such as those belonging to the Cretaceous. This principle being taken into consideration, and the great amount of disturbance in most places in the Cretaceous beds due to forces acting in a period preceding the Miocene being noted, it may be conceded tentatively that the greatest orogenic movements were of pre-Miocene date. The strata on the flanks of Juniper Ridge may be cited as an example of the comparative amount of deformation produced in some places by the different movements. The Cretaceous beds there were steeply tilted before the Miocene, and the Vaqueros (lower Miocene) strata that were laid down over their eroded edges have been uplifted with only gentle tilting in the subsequent periods, whereas only a couple of miles eastward, where not protected by the solid foundation of Cretaceous rocks, the Miocene beds have been sharply folded and faulted. The movements following the Tulare resulted both in broad tectonic uplift and in local warping along the axes of upward movement that determine the present mountain and hill tracts. But these axes had already existed for a long time and the broad features of the mountain regions had been outlined in the previous epochs of movement.

LATE QUATERNARY PERIOD.

The processes that are taking place at the present time are a continuation of those that have been active since the end of Tulare time. During the later Quaternary the great basin of the San Joaquin Valley was continually receiving the wash from the mountains, and approximately horizontal deposits similar to those of the Tulare formation were being laid down over the valley floor. They must have accumulated to a depth of many hundred feet in this and the smaller valleys as well. During this period the mountainous tract was being worn down; but at the same time it underwent a gradual uplift that kept pace partly with the wasting away. It is not known how great a portion of Quaternary time the Tulare period may have occupied, but judging by the amount of movement along the structural axes, erosion of the mountains and hills, and aggradation of the valleys that has taken place since its close we may conclude that most of the Quaternary has been consumed in the subsequent events. Some other features of the geologic history are outlined in the sections dealing with the physiographic development and the faunas.

THE DEVELOPED TERRITORY.

HISTORY OF DEVELOPMENT IN THE COALINGA DISTRICT.[a]

The attention of oil men was early called to what is now known as the Coalinga oil district by a "live" oil seepage on the south line of sec. 17, T. 19 S., R. 15 E. of the Mount Diablo base and meridian, at a point about 1,000 feet east of the southwest corner of this section.

[a] Many of the data concerning the early developments in the Coalinga district have been obtained from written communications of W. W. Orcutt and from accounts given by W. L. Watts in bulletins 3 and 19 of the California State Mining Bureau, published, respectively, in 1894 and 1900. The work of G. H. Eldridge has also brought to light some information which is here included.

At this point a considerable quantity of light oil of a greenish color came up through the shales. It is said that in the early seventies this oil was collected in pits and there refined in a small way.

The early prospectors believed that this seepage had its source in a productive oil sand, but they did not know its extent, its depth below the surface, nor in what direction the sand lay from the seepage, for at this point the strike of the shale swings abruptly from a nearly north and south line to an easterly and westerly direction.

The first successful development work in the Coalinga district took place in the Oil City field about 1890. At this time the Coast Range Oil Company, of Los Angeles, sunk a well 163 feet in the purple shale of the Chico formation in the northern part of sec. 20, T. 19 S., R. 15 E., from which gas and a little greenish oil of light specific gravity is said to have flowed. A windmill pump was attached to this well, and 10 barrels of oil was pumped from it daily for two days, after which the production fell gradually.

In 1891–92 four wells were drilled in the same vicinity by Messrs. Rowland and Lacy, of Los Angeles, but only one of these was successful. It was 400 feet deep and yielded 9 barrels of oil daily.

W. L. Watts visited the district in 1893, gathering material for his report on the San Joaquin Valley oil districts,[a] and reports that at that time he found five wells in the Oil City region, three of which were plugged and in two of which oil or gas was rising. The prospects for a great field were therefore not encouraging at that time.

In 1895 the Producers and Consumers Oil Company, of Selma, organized by J. C. McClurg and others, sank two wells a short distance southeast of the wells of Rowland and Lacy, which yielded 15 and 20 barrels of 34° Baumé oil per day.

In 1896 Chanslor & Canfield drilled three wells in the southern part of sec. 17, T. 19 S., R. 15 E., just north of the sites of the original Oil City wells, and were rewarded with small producers. They then took over the property of the Producers and Consumers Oil Company in the NW. ¼ sec. 20 and drilled a well 300 feet east of the old wells and struck oil sand at 890 feet, which yielded 300 barrels of oil per day. This was the first big well of the district.

The Clear Field Oil Company, a branch of the Union Oil Company of California, drilled a well in the southeast corner of sec. 18, T. 19 S., R. 15 E., in 1897. This well was 1,100 feet deep and showed only a trace of oil.

In 1897 the Home Oil Company, of Selma, entered the field and began drilling still farther east or farther down the dip of the strata, and completed a 1,400-foot well (the famous Blue Goose), which is said to have flowed from 500 to 1,000 barrels of oil per day and to have maintained a production of 250 barrels per day as late as August,

[a] Bull. California State Min. Bur. No. 3, 1894.

1900. Unsuccessful wells were drilled in the Westside field during this year, among them being that of the Sunnyside Oil Company, now the Henshaw water well.

In 1899, after the completion of the Blue Goose well, several other companies commenced operations in the Oil City field, but with indifferent success or failure. The most important event in development during this year was the drilling of water wells by J. A. McClurg in the SW. ¼ sec. 16, T. 20 S., R. 15 E., the water thus obtained being piped to the Oil City field and the region to the west.

The development of the Eastside field began in 1900 with the drilling operations of the Independence, Oil City Petroleum, Twenty-eight, Caribou, and other companies. During the same year several prospect holes were put down in the Kettleman Hills and Kreyenhagen fields. In the latter field several more or less productive wells had been put down a short time previously. Between 1900 and 1907 no developments of consequence took place in the Kettleman Hills and Kreyenhagen fields, but in 1907 and since then up to the present time more or less activity has been displayed in the region south of Waltham Creek, and such wells as the Golden Crest and El Cerrito have attempted to obtain oil in formations overlying the Santa Margarita (?), but so far without success.

Successful development work was begun in the north end of the Westside field in 1901, when the Mercantile Crude, Commercial, Call, Main State, and other companies started drilling. Exploitation was gradually carried southward until the region as far as the Esperanza lease in the SW. ¼ sec. 6, T. 20 S., R. 15 E., was proved. The unsuccessful Blue Diamond hole in the NE. ¼ sec. 26, T. 20 S., R. 14 E., was also put down about this time, and tended to discourage development in the southern part of the western field.

In 1902 the California Oilfields (Limited) entered the Eastside field and soon began active operations in secs. 21 and 27, T. 19 S., R. 15 E. Development work was still carried on in the Westside field, but the decline in the price of oil was at this time beginning to show its effects on the development.

Notwithstanding the low price of oil, which reached as low as 15 cents per barrel in 1905, drilling operations were carried on continuously throughout certain parts of the field from 1902 to 1906. In the fall of 1906 the Lucile well was brought in as a strong producer, thus proving the south end of the present Westside field. Beginning with the impetus that this discovery gave to development and encouraged by the gradually bettering conditions of the oil market, exploitation throughout the Coalinga field went ahead rapidly until in the summer of 1908 about 100 wells were being drilled simultaneously in the district. Mention should be made of the influence of the operations in the northern part of sec. 34, T. 19 S., R. 15 E., which were carried on in 1906 and 1907, by the late Mr. W. P. Kerr and associates. The wells brought in by these men are the most productive in the district. During the latter part of 1906 and the beginning of 1907 these and practically all the other independent wells in the Eastside field, with the exception of those in section 22, were absorbed by the California Oilfields (Limited) or by the Standard Oil Company, which had entered the field as a producer.

An important event in development in 1908 was the completion of the T. C. Oil Company's well in sec. 2, T. 19 S., R. 15 E., which extended the proved territory of the Eastside field 2 miles northward. Among the developments of importance in 1908 and 1909 were the series of exceptionally productive wells of the American Petroleum Company drilled along the eastern edge of the proved Westside field, and the wells of the Nevada Petroleum Company drilled still farther east, which showed zone B to be unproductive in that territory but which encountered productive beds in zone D. In September, 1909, the Silver Tip No. 1, in sec. 6, T. 21 S., R. 15 E., came in as a gusher and produced at the rate of about 20,000 barrels a day for several hours. This well drew the attention of oil operators to the south end of the Westside field, and its completion was followed by renewed activity in sec. 12, T. 21 S., R. 14 E., and sec. 18, T. 21 S., R. 15 E.

AREAS DISCUSSED.

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

OCCURRENCE OF THE PETROLEUM.

The following is a brief summary of the conditions of occurrence of petroleum in the Coalinga district, and is inserted here as introductory to the detailed and necessarily more local discussion concerning each particular field, which follows.

FORMATIONS IN WHICH PETROLEUM OCCURS.

Petroleum occurs in five different formations in this district—the purple-shale member of the Chico (Upper Cretaceous), the Tejon (Eocene), Vaqueros (lower Miocene), Santa Margarita (?) (upper middle Miocene), and Jacalitos (upper Miocene). In the first two the oil is thought to be primary—that is, it is believed to have originated in the formations; in all the others it is secondary—that is, it has come into them from some outside source since their deposition.

OIL ZONES.

General description.—Within each of the formations mentioned are one or more oil-bearing zones consisting either of more or less extensive layers of sand or gravel or of local lenses of the same materials, which can be traced in a general way over large areas. The oil sands in the Chico will be referred to collectively as the Chico oil zone; those in the Tejon as the Tejon oil zone; those in the lower part of the Vaqueros as the lowest Vaqueros zone, or zone D; those in the middle Vaqueros (Eastside field light-oil sands) as the light-oil zone, or zone C; those in the upper Vaqueros (first sand) in the fields northeast of Los Gatos Creek and in the Santa Margarita (?) and the lower Jacalitos in the Westside field south of Los Gatos Creek as zone B; and those in the Jacalitos in the Westside field above the productive basal beds of that formation as zone A. The top of zone B is shown in contour in Plate XV. With the exception of those in the lowest zone in the Vaqueros (zone D) the oil sands are known to consist mostly of more or less local beds or lenses varying in thickness, composition, grain, and hardness from well to well and often showing a puzzling diversity in gravity of product within short distances. Zone D, as would be expected of the basal portion of a widespread formation, partakes of the same general characteristics throughout nearly its entire range within the district—that is, it is generally coarse gravel at the base, with somewhat finer gravel or very coarse sand above this and finally medium-grained sand. The productive beds in the other zones vary from medium fine-grained to coarse pebbly sand or even gravel.

Chico oil zone.—The sandy zones in the lower portion of the purple-shale member contain commercial quantities of oil on the Coalinga anticline in the Oil City field. It was the inducement offered by seepages from this member in the Oil City region that led to the drilling of the test wells from which the present district has been developed. The oil in the Chico oil zone is a paraffin oil, usually of light gravity, about 33° to 34° Baumé, and is greenish in color. The thickness of the productive sands is ordinarily between 15 and 60 feet, and the yields are light, 4 to 75 barrels per well per day being the normal extremes of production, although the initial flow of one of the Oil City wells is said to have been 700 barrels per day.

Tejon oil zone.—The Tejon is known to contain accumulations of oil in commercial quantities only in the southern portion of the district, where the oil has gathered in the porous sandstone of the lower member, below the shales of the upper member, in which it is supposed to have originated. The productive sandstone outcrops in the steeply dipping monocline of Reef Ridge in the Kreyenhagen field. Wells have been put down at a number of places, but have obtained only small quantities of oil from this zone. An amber-colored oil of 45° to 48° Baumé gravity occurs sparingly in the uppermost productive Tejon sands of the Oil City field. This is the lightest oil in the Coalinga district and among the lightest in the State.

Vaqueros oil zones.—The principal oil-bearing formation in the Coalinga district is the Vaqueros or lower Miocene. It yields practically all of the oil in the Eastside field and a considerable part of that in the Westside field and is thought to contain commercially important quantities in the Kreyenhagen field and in the region of the Kettleman Hills. The total distance penetrated through this formation by the wells in the Eastside field is about 700 feet, and in the Westside between 300 and 500 feet. The actual productive sands of course occupy only a relatively small space in this column, usually under 150 feet in the Eastside and under 100 feet in the Westside. Three zones are recognized in this formation, the lowest or zone D, the middle or zone C, productive only in certain parts of the Eastside field where it yields oil up to 31° Baumé in gravity; and zone B, recognized as Vaqueros in the Eastside field and the northern part of the Westside field. The oil from the Vaqueros varies in gravity from 14° to 22° in the Westside and from 14° to 31° in the Eastside. It is black or dark brown and the production averages between 100 and 200 barrels per well per day. One well in the Eastside field is now flowing 3,000 barrels of oil per day and an initial yield of 7,000 barrels in 18 hours was recorded for another well in the same field, but these figures are unusual. The Silver Tip well, in the south end of the Westside field, yielded at the rate of 20,000 barrels a day for a few hours during its initial flow; this is the maximum rate for the district.

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

Jacalitos oil zones, zones A and B.—The Jacalitos (upper Miocene) formation is productive throughout the Westside field except at the extreme south and north ends and in those wells distant over a mile or so from the outcrop of the sands. In other words, the formation is commercially oil bearing wherever it rests upon or is relatively near the Tejon formation—the source of the oil. The line marking the area of productivity of zone B in the Westside field passes somewhere near the east line of the W. ½ sec. 30, T. 20 S., R. 15 E., for in the American Petroleum wells along the west line of this section zone B is unusually productive, whereas half a mile to the east, in the Nevada Petroleum wells, zone B is practically barren; in the latter wells zone D is the productive zone.

Two oil zones are recognized in the Jacalitos formation, the lower or zone B, which is the productive zone over the southwestern part of the Westside field, and zone A, situated some 200 feet above zone B, which carries tar sands or poorly saturated oil sands. The two zones are generally separated by sulphur water, the "big sulphur," although the most persistent sulphur water in the northern end of the Westside field overlies zone A. Northward in the Westside field the productive sands of zone B are found lower and lower in the series of beds, until in the northern end and at least as far south as the M., K. & T. wells the oil is believed to come from beds in the uppermost portion of the Vaqueros.

FACTORS INFLUENCING ACCUMULATION.

The influence of structure upon the accumulation of the petroleum varies somewhat for different parts of the field, the variation being due, it is believed, to the presence or absence of water beneath the oil zones in the various areas. In general the oil in the purple-shale member of the Chico (Upper Cretaceous) is accompanied by water in the underlying beds, and possibly also in the oil sands far down on the dip; under these circumstances the anticlinal theory of accumulation seems to hold good. The anticlinal theory of oil accumulation assumes that the oil, being of less specific gravity, rises above the water in porous rocks and collects at the highest possible points in upward folds, being there confined by impervious strata arching over the folds. The presence of water, according to this theory, is necessary for the accumulation of oil in anticlines.[a] A modified form of the same theory is apparently applicable to certain monoclines, in which water is associated with oil, such as those in the Westside and Kreyenhagen fields, where, instead of impervious beds overlying the porous sands, the residual or heavy hydrocarbons that are left upon

[a] For a fuller discussion of this subject see The geology and oil resources of the Santa Maria oil district, Santa Barbara County, California: Bull. U. S. Geol. Survey No. 322, 1907, pp. 71 et seq.

evaporation of the lighter substances originally in the contained petroleum seal the outcrops and hinder or prevent the escape of the oil from below.

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

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

FACTORS INFLUENCING GRAVITY.

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

RELATIONS OF WATER TO OIL.

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

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

In all of the wells in the Westside field in which the Jacalitos or upper Miocene oil zone (zone B) can be recognized that zone is immediately underlain by a stratum of water. For various reasons it is thought that in this case also the water is secondary and has come into the formation since the passage of the oil from the Tejon (Eocene) into the Miocene. Except in a very small area in the Eastside field no water has so far been reported from below the lowest Vaqueros oil zone (zone D), which indicates almost conclusively that water was not the elevating force for the oil of zone D; it also strengthens the conclusion that the water in the higher zones is surface water that has percolated from the outcrops in the local catchment basin, rather than primary water that has been in the beds since their deposition or water that has come up from below under hydrostatic pressure. Small quantities of water are encountered between the base of the uppermost or fine-grained stratum, bearing light-gravity oil, and the coarser stratum, carrying heavier oil, which underlies it in zone D in the region of section 6, at the south end of the Westside field.

ORIGIN OF THE PETROLEUM.

The oils of the Coalinga district are believed to have been derived from two different sources, namely, the organic shales forming the uppermost member of the Chico (Upper Cretaceous) and those described as the upper portion of the Tejon (Eocene). It is believed that the oil originated from the organic matter, both vegetable and animal, once contained in these beds. The shales are composed in large part of the tests of foraminifers and diatoms, and a smaller number of other organisms, in such abundance as fully to warrant the assumption that the animal and vegetable material that must have been contained in them when deposited was adequate for furnishing a quantity of hydrocarbons and other compounds more than equivalent to the quantity of petroleum found in this field.

The purple-shale member of the Upper Cretaceous is saturated with petroleum, and its interbedded sands have proved to be productive reservoirs. Practically all the free oil of this member seems to have collected in the sandy zones in the lower portion, none passing below them and little or none entering the beds overlying this member. The overlying beds are of dark, compact clay, moist at least surficially and probably throughout, which it is believed would not allow the escape of much oil. Thus, owing to the presence in the shale of zones favorable for the absorption of the oil and of superjacent beds unfavorable to its escape, it has been retained within the purple-shale member where it is thought to have originated. Both for this reason and because the uppermost member of the Cretaceous is limited to a small area in the northern part of the district we must look to some other source for the oil occurring in the Eocene and higher. Furthermore, the petroleum of the purple-shale member of the Cretaceous is of a very different character from that obtained from the later beds, as will be seen upon examination of the analyses made by Irving C. Allen (pp. 267–272). Samples numbered 21, 23, and 24 were obtained from wells of the Coast Range, Coalinga, and Home oil companies of the Oil City area, which get their oil from the purple-shale member of the Upper Cretaceous. All the other samples were from wells that do not penetrate lower than the top of the Tejon (Eocene). The Cretaceous oil is greenish or brownish in color, of light gravity, and contains paraffin, a high percentage of naphtha, and a very low percentage of asphaltum. The other oil of the district is distinctly an asphalt oil and is lacking in paraffin. It is therefore evident that there are two distinct oils in the Coalinga district, to which different ages and origins are to be ascribed.

The asphalt oil affords by far the most abundant supply of the district and is believed to have its source in the shales forming the upper member of the Tejon, which are petroliferous throughout the district. This oil is obtained by the wells from the Miocene beds, which are petroleum-bearing wherever they overlie the shales of the Tejon. Wherever they overlie some older formation, however, their relative productivity varies inversely with the distance from those shales.

If we were to suppose that the oils of this district had some deeper-seated origin and that the shales of the upper Chico and of the Tejon had acted merely as channels of migration for the oil from below we would expect to find the shales of the subjacent Knoxville-Chico (Cretaceous) also acting as channels of migration, for they are apparently of proper consistency (clayey shale) for migration by diffusion. We would also expect to find them charged with oil, their interbedded sandstones productive, and the Miocene formations overlying them containing at least as much oil as, if not more than, the same formations overlying the Tejon. But these postulated conditions concerning the Knoxville-Chico (Cretaceous) do not exist. In all that part of the district in which the purple shale, the uppermost member of the Knoxville-Chico, is not present the Cretaceous shales and sands have been examined carefully in outcrop, and wells have been drilled into them in several places, but no indications of petroleum were found. Beds of Miocene age do not occur in contact with the petroliferous member at the top of the Chico. Where Miocene (Vaqueros, Santa Margarita(?), Jacalitos, and Etchegoin) sands overlie the Cretaceous in a position analogous to that of the Miocene overlying the Tejon (Eocene) these sands yield oil only when situated comparatively near the Cretaceous-Eocene contact. This is most significant, indicating that the Cretacous did not yield the oil, but that, as would be expected, the oil, after passing from the Eocene into the Miocene, has migrated for a short distance along the strata of the Miocene out over Cretaceous beds. Further negative evidence pointing to the origin of the oil in the upper members of the Chico and the Tejon is presented by the fact that there are no faults of consequence within the productive area along which migration from depths could have taken place.

CONTOUR MAP OF THE COALINGA FIELD.

EXPLANATION.

The contour map of the Coalinga field (Pl. XV) shows the topography, geologic structure, boundaries of the more important geologic formations, and certain details of culture, such as towns, section lines, property lines, a few roads, and oil wells. The structure in the productive territory is indicated by contours showing the distance above (marked +) or below (marked −) sea level of the base of the Big Blue or top of zone B in the Eastside field, and of the top of zone B in the Westside field. The contour interval is 100 feet. By means of this map the direction and amount of dip of the strata in the oil-bearing formation may be calculated for any point in the field, and the depth to the various productive sands or zones may be approximated for most parts of the territory. (See also figs. 7, 8; Pls. XVI, XIX, XX, XXI.)

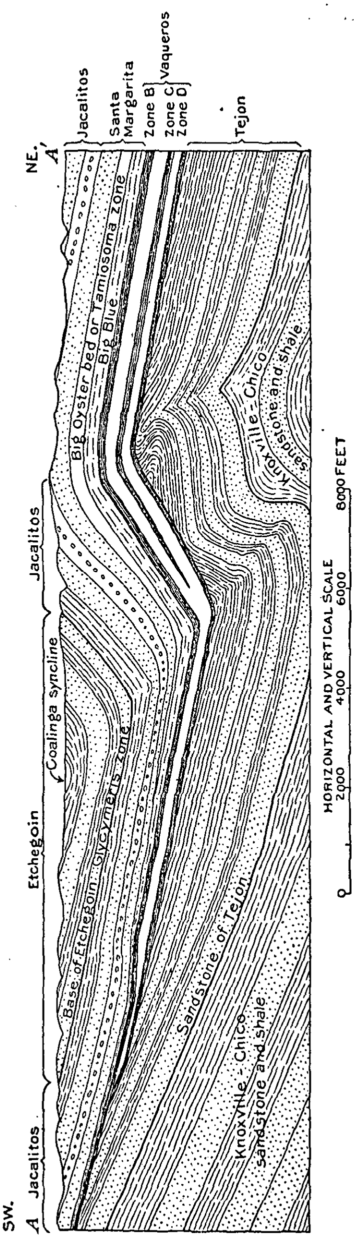


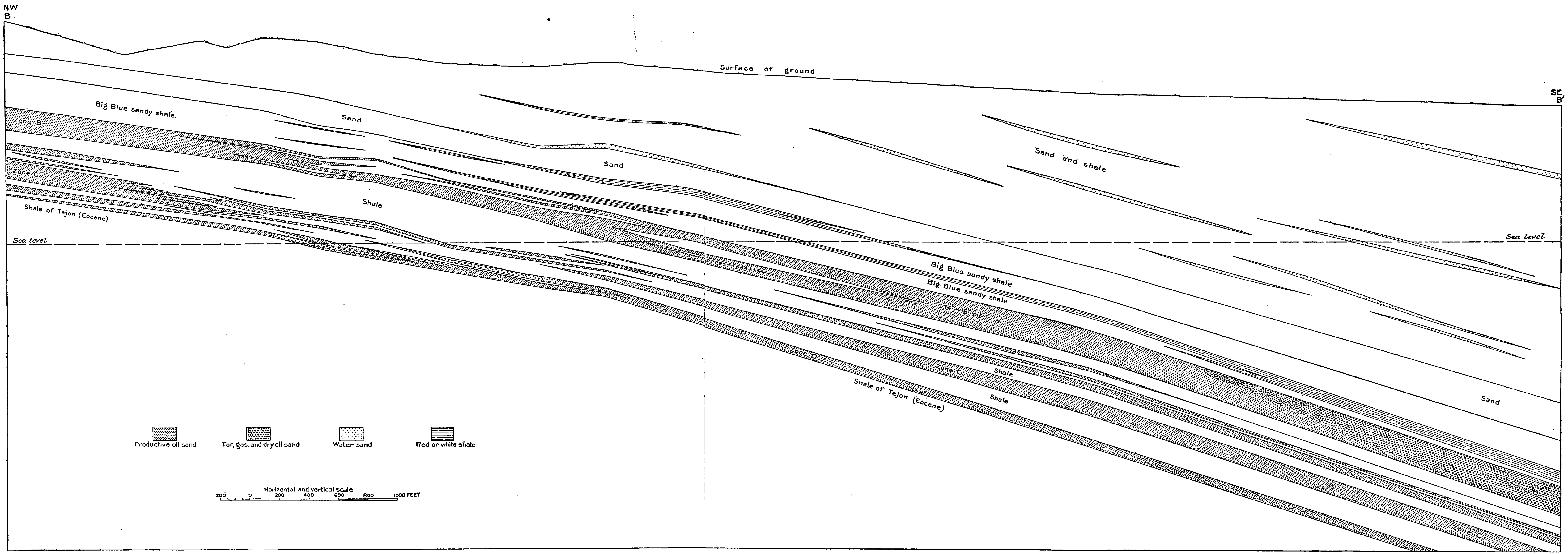
FIGURE 7.—Hypothetical section along line *A–A'*, Plate XV, from the Westside to the Eastside field, showing the relations between the oil zones of the two fields.

USE OF THE MAP.

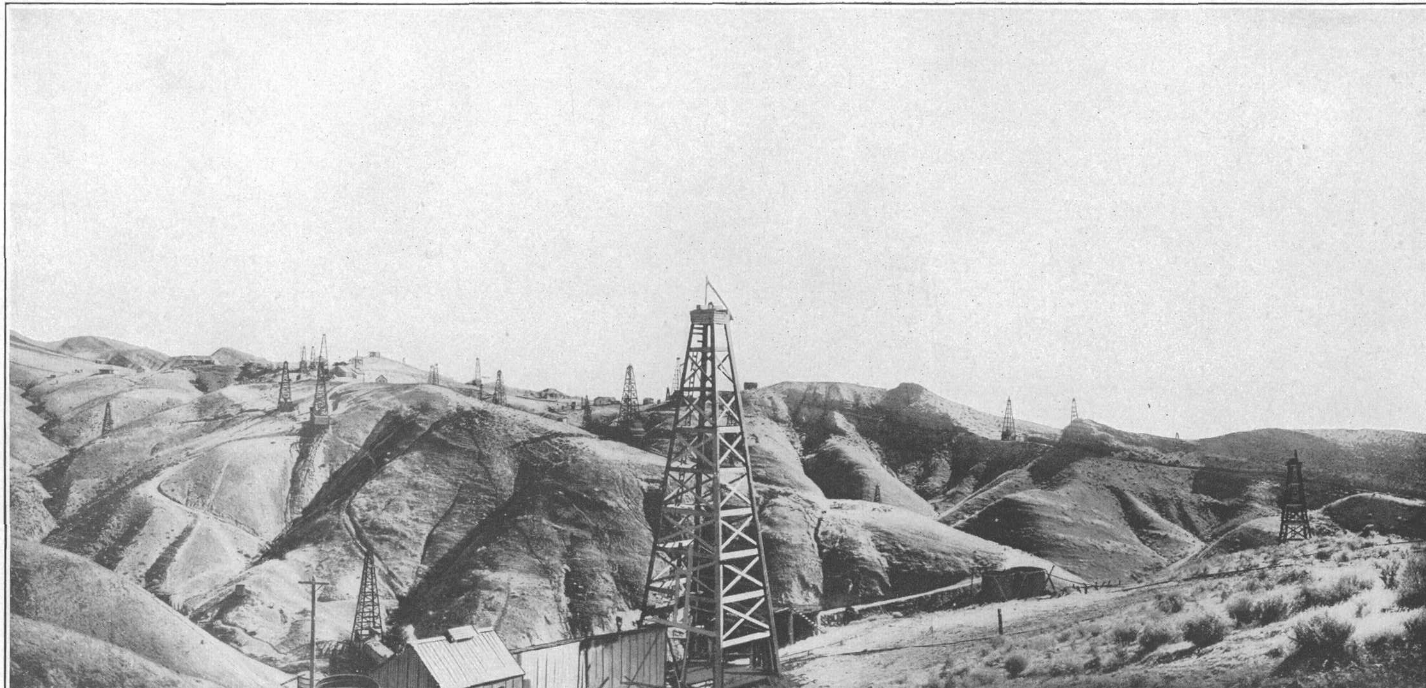
Suppose it is desired to find the probable depth below the surface of the first productive sand at the middle of the north line of the SE. ¼ sec. 24, T. 20 S., R. 14 E. Examination of the map will show that this point lies approximately on the underground contour line marked "−500;" that is, the top of zone B is about 500 feet below sea level here.

A close approximation of the elevation of the point may be had by looking up the elevation for the nearest derrick (see list, p. 248), which happens to be Claremont No. 4, elevation 792 feet, and calculating the difference in elevation, say 22 feet lower, either by the eye or with an aneroid barometer. The distance from the surface to the top of zone B is therefore 500 feet plus 770 feet, or approximately 1,270 feet; and as zone B is the uppermost productive zone for this part of the field that distance is the one desired.

Again, suppose it is desired to find the depth to the main commercially productive zone at the center of sec. 5, T. 20 S., R. 15 E.

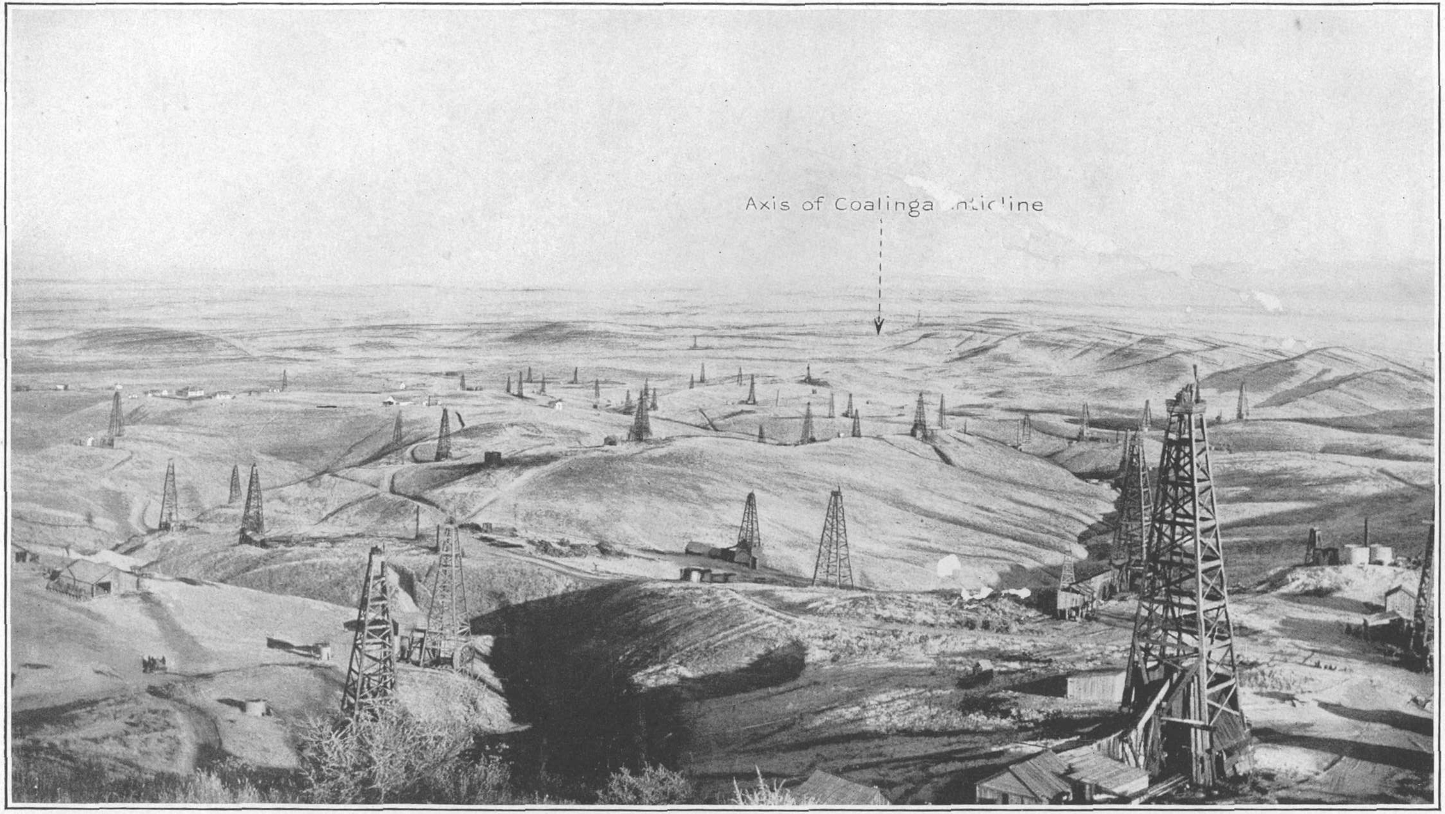


HYPOTHETICAL SECTION ALONG LINE B-B' ON CONTOUR MAP, PLATE XV.



REGULARLY DIPPING BEDS OF SANTA MARGARITA (?) AND JACALITOS FORMATIONS ON NORTHEAST FLANK OF COALINGA ANTICLINE IN EASTSIDE FIELD.

Looking north from ridge on which the Standard Oil Company old camp is situated. Note steep slopes eroded in soft sedimentary beds, the topographic reflection of structure, and difficulties attendant upon operations. Photograph by Ralph Arnold.



VIEW LOOKING SOUTHEAST DOWN PLUNGING AXIS OF COALINGA ANTICLINE IN EASTSIDE FIELD.

Note Pleasant Valley and Reef Ridge in distance on the right, the sky line of Kettleman Hills in the center, and low arch of the anticline forming Anticline Ridge in the middle distance. Photograph by Ralph Arnold.

Proceeding as before, it is found that the depth of the uppermost zone is about 1,460 feet below sea level and that the elevation of the

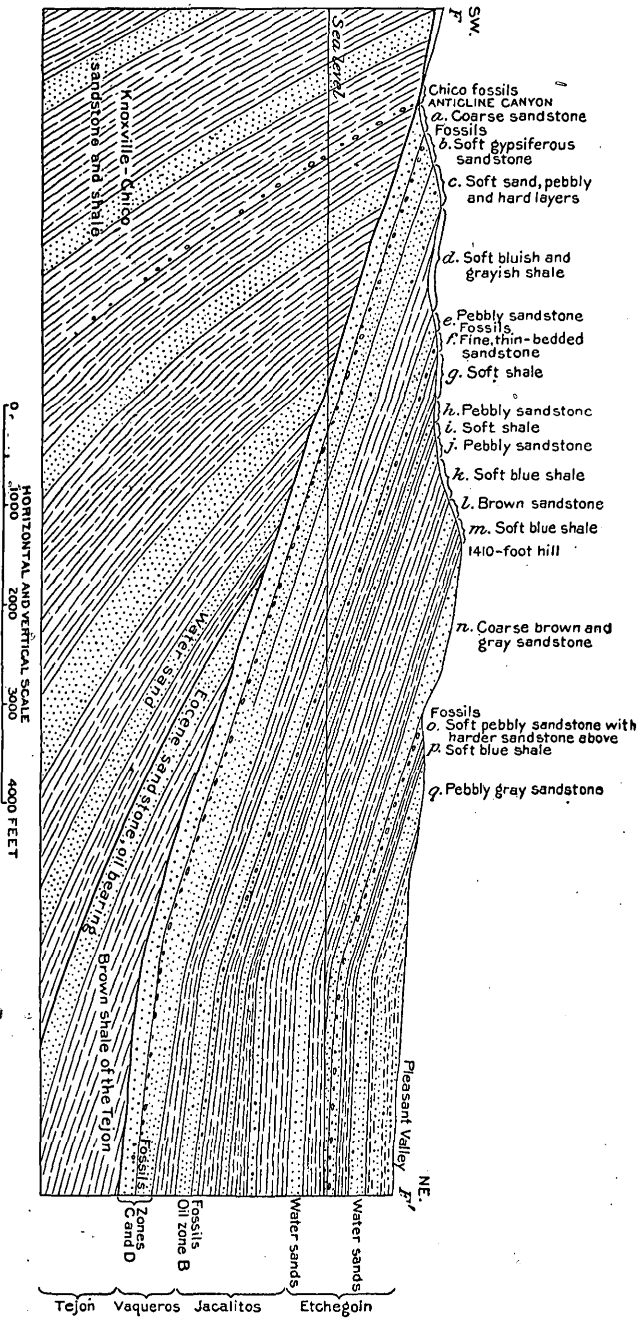


FIGURE 8.—Hypothetical section along line *F-F′*, Plate XV, from Anticline Canyon to California Oil and Gas Company's well No. 1. Based on surface traverse and well logs. (See pp. 219-220 for explanation.)

point is about 950 feet above sea level, or that the top of the uppermost zone is about 2,410 feet below the surface. It will be found, however, by reading over the text referring to this part of the field that the most productive zone is zone D, which lies from 300 to 450 feet below the top of the upper productive zone (zone B) in this region. Therefore the distance to the top of the commercially productive zone will be 2,410 feet plus 300 to 450 feet, or between 2,710 and 2,860 feet.

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

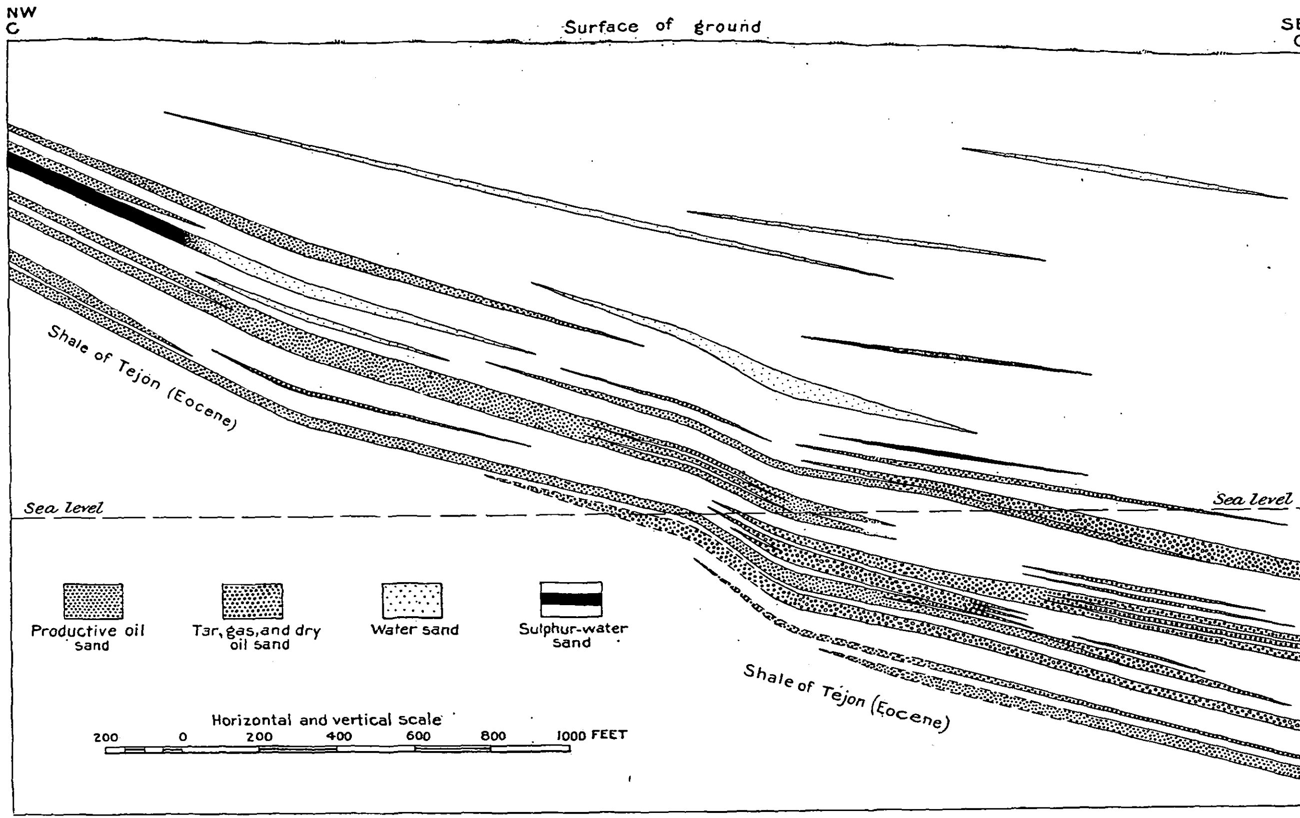
BASIS OF THE CONTOUR MAP.

The section lines and other culture marks were determined by E. P. Davis, of the United States Geological Survey. The log of nearly every well in the field either finished or sunk any considerable distance on October 15, 1909, was used in the determination of the underground structure and the compilation of the data concerning the oil zones. All the obtainable surface evidence of dip, strike, and occurrence of petroleum was also used in the preparation of this map. Where the surface and the well-log evidence were at variance the latter was usually followed. In unsymmetrical features like the Coalinga anticline and Coalinga syncline the plane of the axis of the fold is not vertical, and therefore the anticline as indicated by the contours showing the underground position of certain zones does not lie directly under the trace of the same anticline or syncline on the surface.

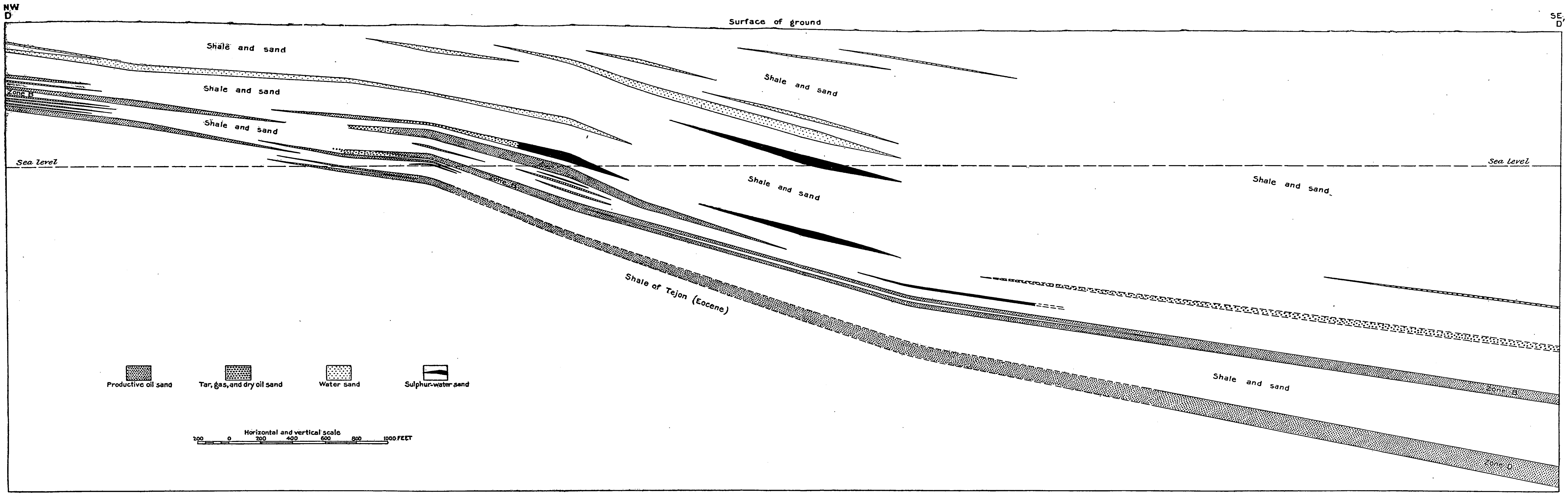
DIFFICULTIES OF PREPARATION AND DEGREE OF ACCURACY.

After all the logs had been carefully plotted on a uniform scale it was found that the greatest obstacle to overcome in the preparation of the contour map was the difficulty of correlating the strata from one well to another and from one part of the field to another. The difficulties of such correlations are doubtless familiar to anyone who has tried to work out the underground structure of any of the California fields. It must be said, however, that the structure in the Coalinga district is more regular and the conditions more favorable for a successful study and mapping of the underground geology than they are in any of the other California fields so far examined by the senior author, not excepting the Santa Maria field, which was studied in 1906 and of which an underground contour map was prepared.[a]

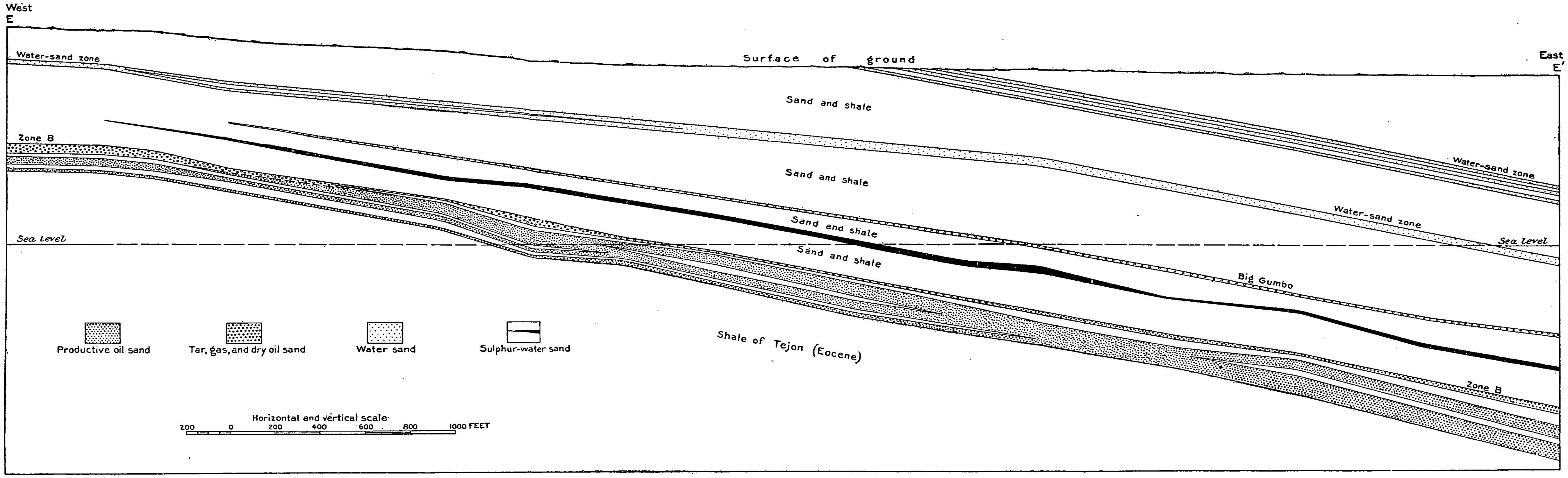
[a] Bull. U. S. Geol. Survey No. 322, Pl. X.



HYPOTHETICAL SECTION ALONG LINE C-C′ ON CONTOUR MAP, PLATE XV.



HYPOTHETICAL SECTION ALONG LINE D-D′ ON CONTOUR MAP, PLATE XV.



HYPOTHETICAL SECTION ALONG LINE E-E' ON CONTOUR MAP, PLATE XV.

The effort has been made to delineate on the present map 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 to be most probably the conditions of underground structure. Within the untested areas the underground contours are of course only hypothetical and are shown by broken lines.

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

DETAILS OF THE PRODUCTIVE AREAS.

OIL CITY FIELD.

LOCATION.

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

GEOLOGY AND STRUCTURE.

The Oil City field is situated along the east side of the belt of shale and interbedded sands of the uppermost member of the Knoxville-Chico (Cretaceous), which has been often referred to as the purple-shale member, the oil being obtained chiefly from the sandy zones in the lower portion. The proved productive ground occupies the same general relation to the plunging Coalinga anticline as the productive territory farther southeast in section 28—that is, it is on the more gently inclined or northeastern flank of the fold. Surface dips of 50° to 90° and even dips overturned past the vertical occur throughout the area along the southwestern limb of the anticline, while a surface dip of 32° is the maximum for the northeastern limb. The well logs indicate a relatively constant dip of about 26°

(42 to 44 feet per hundred feet) southeastward down the axis of the anticline and relatively a somewhat steeper dip in the beds immediately north of it in the productive territory.

GEOLOGY OF THE WELLS.

The wells start either in the upper portion of the purple-shale member of the Cretaceous or in the lower portion of the Tejon (Eocene) and continue in brown, black, and blue shale to the bottoms, except where they pass through the oil sand. From one to three sands are penetrated. The first is from 4 to 15 feet thick and yields the lightest oil, which is amber-colored and which runs as high as 48° Baumé in gravity; gas is also reported from the first sand in other wells, and in still others it is dry. The second and third sands comprise a zone 60 to 100 feet thick, which is petroliferous throughout almost its entire distance in some of the wells, while in others the two sands are separated, the upper usually running from 15 to 20 feet thick and the lower from 40 to 60 feet.

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

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

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

All the sands are comparatively fine grained. The oil usually comes from the softer sands and the lower sand is generally the most productive, although it is entirely unproductive in some of the wells. The wells vary in depth from 300 feet up to nearly 1,700 feet, and the productive zone is reached at depths varying from about 250 to 1,500 feet. The southern part of sec. 20, T. 19 S., R. 15 E., has been pretty thoroughly tested and, though most of the wells have yielded more or less oil, they were not deemed profitable enough to warrant continuous operation. The following log of a typical well in the abandoned territory will show the general character of the Tejon formation for this part of the area:

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

	Feet.
Pink shale	300
Sand with water	330
Dark-colored shale	420
Sand with sulphur water and oil	440
Dark-colored shale	500
White clay shale	520

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

	Feet.
Oil sand	535
Shale	540
White shale	560
Oil sand	575

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

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

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

California Oil and Gas Company, SE. ¼ sec. 19; well No. 1, formation principally shale; abandoned. Same company has a well in the SW. ¼ sec. 20, also abandoned.

Crescent Oil Company, SE. ¼ sec. 20; well No. 1, depth, 900 feet; little oil at 770 feet; gravity, 11° Baumé.

Mutual Oil Company, SE. ¼ sec. 20; well No. 1, depth, 1,800 feet; abandoned.

New York Oil Company, SW. ¼ sec. 20. Well No. 1, depth, 1,000 feet, all in brown shale; no oil; abandoned. Well No. 2, depth, 2,200 feet, in brown shale with few hard sand layers; no oil; abandoned.

Selma-Oil Company, SE. ¼ sec. 20; well No. 1, depth, 1,742 feet; little oil sand.

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

PRODUCT.

The production of the wells in the Oil City area varies from the initial output of one well said to have been 700 barrels of oil per day for a short time to the daily run of certain others, which now will average not more than 4 barrels per day. In several wells the oil is said to have flowed over the top of the derrick when the oil sand was first penetrated, as a result of gas pressure, which soon subsided. All the wells have to be pumped after a short initial period of spontaneous flow. The average daily production at present is about 20 barrels per well. The average normal rate of decrease per well for the field, disregarding the rapid decrease from the initial production, has been between 15 and 20 per cent per year since 1900. The productiveness of the wells increases down the nose of the anticline toward the southeast, especially near the axis of the flexure. This is shown by the fact that wells No. 3 of the Home Oil Company (the original Blue Goose well) and No. 7 of the Coalinga Oil Company have been among the best producers in the group.

The gravity of the oil varies from as high as 42° to 48° Baumé, of which grades there are only small amounts of oil, said to come from the uppermost sand in some of the wells (5 gallons of 48° oil from one well), to the usual run, which tests between 33° and 34° Baumé. There is apparently little variation in gravity between the wells up or down the dip or along the strike. The oil is greenish to brownish in color and shows little viscosity. It is a paraffin oil and very different from the oil that occurs in the oil zones in the Miocene.

EASTSIDE FIELD.

PEERLESS—BRITISH CONSOLIDATED—T. C. AREA.

LOCATION.

This area comprises that part of the Eastside field which includes the northeastern portion of section 21 and the northern part of sections 22, 23, and 24, extending to the line between Tps. 18 and 19 S. at the north end of the area mapped. The companies operating in this area are the Coalinga Peerless, Camwell, Good Luck, British Consolidated (formerly California Diamond), Lorene, T. C., William Graham, Imperial, Bowling Green, and California Oilfields (Limited).

GEOLOGY OF THE WELLS.

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

The map (Pl. XV) indicates by contours the distance of the base of the Big Blue above or below sea level. The Big Blue varies in thickness in the wells, if the distance penetrated be counted as equivalent to the thickness, from about 260 feet at the western edge of the area to over 350 feet in deeper wells toward the east. In fact, one of the deep wells disclosed a continuous shale formation for about 640 feet, but it is not believed that this entire thickness is included in the Big Blue farther west. In the region of section 2 the Big Blue and its included or equivalent red beds and sandy layers are penetrated for about 600 feet in the wells. One of the unique characteristics of the

Big Blue for this area and also for nearly all of the Eastside field consists of the red-shale layers which are at various points interbedded with the blue variety. These red shales are well shown in outcrop in secs. 3 and 10, T. 19 S., R. 15 E., where, owing to their peculiar tints, they may be seen for a distance of several miles. The red shale consists almost entirely of comminuted serpentine, which is naturally green but is turned red by the oxidation of the iron, of which serpentine contains a relatively high percentage. The red shale appears prominently on the sumps, where it forms brilliant coatings as the material is dumped from the bailers.

Water sands from 20 to 175 feet thick are found just above the Big Blue from the western part of the NW. ¼ sec. 22 eastward to the deepest wells. Lenses of water sand are also reported in the Big Blue from the middle of section 14 eastward.

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

A more or less persistent zone of sulphur sands lie from 20 to 180 feet above the first productive zone, zone B, but is not reported in all the wells. In the region of section 2 sulphur water is usually encountered within 50 feet below the bottom of the Big Blue. Sulphur water also occurs below the productive sands in two of the wells only, while certain of the Peerless wells are said to yield no water whatever. These facts clearly indicate that the water occurs in more or less isolated lenses of sand, similar, in a general way, to the lenses carrying the oil.

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

Very little regularity exists in the oil zones, as is shown by the well logs. The productive beds (zones C and D) consist of alternating coarse sands, fine gravels, blue and brown shale, and shells, with coarse gravel at the base of zone D. The productive measures are usually about 225 feet through—that is, from the top of the first productive sand to the brown shale of the Tejon (Eocene)—and, though they comprise both zones C and D, a separation of the two is not possible in many of the wells. The total thickness in the wells from the base of the Big Blue to the brown shale of the Tejon is a little over 600 feet. Toward the northern part of the area under discussion the strata below the base of the Big Blue thin to about 500 feet in the wells, only the lower 150 feet of this being productive.

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

PRODUCT.

Nearly all the wells in this area have been drilled since 1904, so that data concerning decrease in production are rather meager. The production of the wells varies from about 25 to something like 700 barrels, the production increasing down the dip, other things being equal. The T. C. well in section 2 is said to have had an initial production of 400 barrels a day, but the yield has now fallen to 100 or 150 barrels a day, which is believed to be a fair initial average of what would be encountered over most of the area in properly handled wells 1,500 feet or more in depth. The average production for the wells in the area is about 125 barrels per day. The yield depends largely on the handling of the well, for holes going down under practically the same conditions give quite different results under various managements. One well which had an initial production of 200 barrels now yields only 20 to 25 barrels per day. This decrease is probably due not entirely to natural causes but to a sanding up of the hole. The gravity of the product from this area varies from 18° to 24° B. So many sands are perforated that it is usually impossible to tell the gravity of the oil from any particular one. However, the uppermost important productive zone (top of zone C) in the area is believed to yield oil of between 20° and 21° B. gravity. The next sand, say about 80 feet below the first, yields oil of 24° B. gravity, or possibly slightly better, while the lowest sand (base of zone D) which rests directly on the shales of the Tejon formation produces oil of 18° or 20° B. gravity.

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

TECHNOLOGY.

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

STANDARD—CARIBOU—BRITISH CONSOLIDATED AREA.

LOCATION.

The area described in this section covers the northeastern portion of section 27, the southern part of sections 22, 23, and 24, all of sections 25 and 26, and the northern part of sections 35 and 36. The following companies operate in this area: California Oilfields (Limited), Standard, Caribou, Associated, Twenty-Two, Record, Pittsburg, Octave, Sauer Dough, Porter, British Consolidated, and Boston and California.

GEOLOGY OF THE WELLS.

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

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

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

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

Water is now causing trouble in the region of the SE. ¼ sec. 22, T. 19 S., R. 15 E.; the source is believed to be sands occurring in the Vaqueros between zones B and D. Some of the operators lean to the belief that this water has been let into the sand by faulty handling of the wells; others believe that the water was originally in these sands, and to this theory the writers are inclined.

PRODUCT.

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

The gravity of oil in this area varies from 16° to about 24° Baumé. The heavy oil comes from the upper sands (zone B), which are usually more productive in the deeper wells. A well in the W. ½ sec. 26 is said to have yielded 600 barrels of 15° or 16° oil from zone B when first drilled. The middle zone (zone C) produces oil of about 24°, while the lower, coarser, but generally more productive sands (zone D) yield oil of 21° to 22° B.

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

STANDARD—CALIFORNIA OILFIELDS (SEC. 27) AREA.

LOCATION.

This area includes the eastern part of section 28 and the western part of section 27, excluding the portion along the south line of section 27. The Standard and California Oilfields (Limited) are the only companies operating in this area.

GEOLOGY OF THE WELLS.

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

The Big Blue maintains a pretty uniform thickness of about 250 to 300 feet throughout practically the whole of this territory. In the wells along the middle of the line between sections 27 and 28 there is a fairly persistent stratum of water sand immediately overlying the Big Blue. There are other water sands above this lowest one in some of the wells, but none that can be traced far. An interesting stratum, encountered in the wells beginning in the vicinity of the California Oilfields, section 27, No. 20, and extending down into the northern part of section 34, is known as the St. Paul sand. It lies about 830 feet above the base of the Big Blue, or from about 150 to 600 feet below the surface. It is about 30 feet thick and hard, but is believed by some of the operators to be capable of yielding 50 barrels of oil per day, though as far as known it has never been thoroughly tested. This occurrence is rather puzzling, as there are no other oil sands within several hundred feet of it and the origin of its petroleum is difficult to explain.

The oil-bearing formation in the area under discussion extends from the base of the Big Blue for about 655 feet as measured in the wells down to the top of the brown shale of the Tejon (Eocene). This distance between the base of the Big Blue and the brown shale is apparently regular over that part of the area which has been tested. The deepest wells have not penetrated the entire thickness of the oil sands, so that the exact thickness of the sands is not known for wells far down on the dip.

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

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

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

PRODUCT.

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

The concentration of the oil within the Tejon, before its emigration, was also doubtless accentuated along the anticline by the action of the water which is associated with or immediately underlies the oil sands.

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

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

LOCATION.

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

GEOLOGY OF THE WELLS.

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

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

PRODUCT.

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

Another well in the northern part of section 34 yielded on an average about 1,000 barrels per day for over ten months. Still others of these wells run from 600 to 800 barrels per day. The Coalinga-Mohawk well, which penetrates but half of the oil-bearing zone between the base of the Big Blue and the brown shale of the Tejon, is said to have produced at first at the rate of 150 to 200 barrels of 32° oil a day. One well, which yielded 26° B. oil as long as it flowed, now yields a mixture of 23° B. oil when it is pumped. This implies that the lighter oil is probably under the greater gas pressure, and when this pressure is removed the heavy oil either forces back the lighter fluid or allows only a small percentage of it to enter the well. The lower zones (zones C and D) in one well are said to yield a stratum of 29° B. oil at the top, 22° B. in the middle, and 26° B. at the base, with an average of about 28° B.

STANDARD—STOCKHOLDERS AREA.

LOCATION.

This area comprises all of section 28 except the extreme eastern edge, which is described in a previous section (p. 201). The Standard and Stockholders oil companies are the only operators.

GEOLOGY OF THE WELLS.

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

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

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

PRODUCT.

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

WESTSIDE FIELD.

CALL—CONFIDENCE AREA.

LOCATION.

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

GEOLOGY OF THE WELLS.

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

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

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

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

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

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

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

PRODUCT.

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

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

MERCANTILE CRUDE—S. W. & B. AREA.

LOCATION.

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

GEOLOGY OF THE WELLS.

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

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

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

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

	Feet.
Surface soil and incoherent sand and gravel, followed by harder shales, sandstone, and gravels	200
First water sand	5–20
Shale	50+
Second water sand.	
Shale, sometimes containing one or more water sands	300
Gravel, more or less persistent, apparently carrying water in several of the wells, especially those nearest the outcrop.	
Shale	100+
"Main sulphur" water.	

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

PRODUCT.

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

ZIER—PORTER & SCRIBNER—M., K. & T. AREA

LOCATION.

This area comprises the southern part of sec. 1, T. 20 S., R. 14 E., the southern part of the American Petroleum and Esperanza properties, sec. 6, T. 20 S., R. 15 E., and the region of sec. 12, T. 20 S., R. 14 E., and secs. 7 and 8, T. 20 S., R. 15 E. The companies operating in this area are the Zier, Ward, Seneca, Cypress, Pennsylvania-Coalinga, Esperanza, Shawmut, Section Seven, Coalinga Pacific, Arica (formerly Porter & Scribner), Brix & Buntin (B. & B.), Spinks, Coalinga Unity, St. Clair, Pilot, New Era, British Consolidated (formerly California and New York), Kern Trading and Oil (Southern Pacific), Coalinga National, Coalinga California, J. J. Cartner, American Petroleum (section 18), Nevada Petroleum (section 18), and M., K. & T. The wells are located on the flanks of the southeastward-dipping monocline which governs the structure in the Westside field.

GEOLOGY OF THE WELLS.

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

As in the areas farther north, zone B thickens rapidly toward the east until in the region of sec. 8, T. 20 S., R. 15 E., indications of petroleum are found throughout a vertical distance of over 1,100 feet. Here zone B is believed to be represented by what is known as the third or light-oil sand of the M., K. & T. wells, which lies several hundred feet above the most productive sands in those holes, is medium grained, nearly 100 feet thick, and is said to yield 22° B. oil.

If zone B is continuous, wells between the Porter & Scribner and the M., K. & T. leases ought to show a gradation in gravity from 17° or 18° B. in the former to 22° B. in the latter, which is much farther down the dip. This decrease in specific gravity (increase in degrees Baumé) down the dip agrees with the mode of variation found in most instances in the other California fields examined by the writers.

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

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

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

Typical well log in Zier–Porter & Scribner–M., K. & T. area.

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

PRODUCT.

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

ASSOCIATED–CALEDONIAN–UNION AREA.

LOCATION.

The area described under this heading embraces the region from the Union lease in sec. 13, T. 20 S., R. 14 E., southward to the southern part of section 36 in the same township and range. It includes well No. 3A and all other Associated wells north of this in section 36; also the properties of the Kern Trading and Oil (Southern Pacific Railroad), Caledonian, Ozark, Premier, Claremont, Wabash, Inca, St. Paul-Fresno, Coalinga Western, Coalinga Petroleum, Circle, Netherlands (formerly Valley Slope), San Juan (formerly Valley Slope), Coalinga Homestake (formerly Cawder), Traders (including what were formerly Angelus, Euclid, Marengo, and Norse), McQuigg & Wrenn (M. & W.) (formerly Blue Diamond), Arizona Petroleum (formery East Puente), St. Elmo (formerly New Home), Queen (formerly Coalinga Banner), S. A. Guiberson, Jr. (formerly Elgar Adams), American Petroleum (sections 18, 19, and 30), Nevada Petroleum (sections 18, 20, and 30), Valley, Coalinga, California (section 18), Maguire, Section One (formerly Coalinga Zenith), and Union oil companies.

STRUCTURE.

The wells in this area are located on the eastward-dipping monocline of the Westside field. Except for a local flexure, which is possibly the continuation of one of the lines of disturbance in the White

Creek syncline, the general position of the beds is regular, and they have an easterly dip of 11° to 22°. The beds apparently flatten out in passing east from the steeper hills in the western and southwestern parts of the area to the valley floor.

GEOLOGY OF THE WELLS.

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

Southward the sand apparently becomes less and less productive, the southernmost well so far drilled which is believed to obtain oil in commercial quantities from this zone being Associated No. 3A. Here the productive sand is practically of the same thickness as the average farther north, but in the wells still farther south the productive sand pinches out or is practically dry. Toward the east the productivity of zone B ceases along a practically north-south line passing near the middle of sec. 30, T. 20 S., R. 15 E. This is indicated by the nonproductiveness of zone B in the Nevada Petroleum wells, although the same zone is unusually productive in the American Petroleum wells, half a mile to the west. The gravity of the oil varies from 13° to 17° B., apparently being heavier toward the outcrop of the beds and lighter down the dip. A variation in gravity between 14° to 15° along the strike is also noticeable, the southernmost wells producing the lighter oil.

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

Zone B consists of three well-defined oil sands throughout the region from the Union wells southward as far at least as the north edge of section 36. The uppermost of these sands varies from 10 to 50 feet in thickness, while the second is usually somewhat thinner. Hard shells are often associated with these lower sands, but in many of the wells blue shale is apparently the only parting. In some instances the sands below zone B are divided into three or four minor layers which show little regularity in thickness between the different wells. Toward the east from the township line of wells the upper sand of zone B first becomes unproductive, then the second sand, and finally the third near the middle of section 30 and the sections north and south of it.

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

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

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

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

Typical well log, Associated-Caledonian-Union area.

	Feet.
Shale	150
Water sand	20-30
Shale, with some dry sand or gravel	200
Water sand	20-50
Blue shale, with some dry sands and occasionally some water sand	600
Tar zone (zone A)	8-50
Blue shale	20-100
Sulphur-water sand	20
Blue shale, with occasionally fine sand layers	100-200
Zone B, consisting of various oil sands of more or less importance, the whole being thinnest near the outcrop and thickening gradually down the dip	100-225

The water is generally shut off in the upper part of the blue-shale zone overlying zone B. Such a proceeding is doubtless flooding the Big Gumbo sand, but as this tar sand is not believed to be productive in any part of the field the flooding is doing no harm. In the Nevada Petroleum and Valley wells the water is shut off below the water sand which underlies zone B, but this proceeding, although flooding zone B, will simply tend to drive the oil upward and westward into the wells where zone B is productive.

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

PRODUCT.

The product in the wells so far drilled in this area comes from zone B, the Jacalitos (upper Miocene) zone. The daily production of the individual wells varies from about 1,500 barrels in the deeper wells to 50 or 60 barrels in the shallower. Many of the wells flow at first and some of the deeper ones continue to flow for two or three years, but most of the wells are pumped after the initial head of gas has blown off. Much sand accompanies the oil, the proportion being as high as 50 per cent at first in some of the wells. Large amounts of gas are produced by most of the wells. The gravity of the oil varies from 12° B. in the shallow wells, those upon the dip, to 17° for the deeper holes. Three sands are recognized in the productive zone, the upper one yielding the lightest oil.

AREA BETWEEN WALTHAM CREEK AND SAN JOAQUIN VALLEY COAL MINE.

LOCATION.

The area treated in the following paragraphs comprises the territory lying between the Cretaceous-Vaqueros (lower Miocene) contact, which extends northwestward from Alcalde, and the valley floor west of Coalinga, and between Waltham Creek and the region of the San Joaquin Valley coal mine in the NW. ¼ sec. 26, T. 20 S., R. 14 E. A portion of this region, namely, that in which the wells of the Sunnyside and Westlake-Rommel oil companies are situated, will be considered separately, following the discussion of the major portion of the area. The oil companies in the region here discussed include the Mount Hamilton, Commercial Petroleum, Summit, Elaine, Lucile, Shreeve, Associated, Kern Trading and Oil (formerly Southern Pacific Railroad), Yellowstone (formerly Coalinga Southern), Sauer Dough, Jefferson (formerly Section Six), California Gas and Oil (formerly T. C.), De Lux, Amy, Silver Tip, Red Top, Aladdin, Muriel (formerly St. Francis), Waratah, Marion (formerly St. Clair), Los Angeles-Coalinga Oil Syndicate, Section One (formerly Coalinga Zenith), Coalinga Great Western (formerly West Coalinga), Smith & Porter (formerly Summit), and some others not yet prosecuting development work.

GEOLOGY.

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

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

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

Unconformably overlying the Knoxville-Chico (Cretaceous) and the Tejon (Eocene) just described, is a series of beds consisting of about 250 feet of sandstones and over 100 feet of soft dark-blue shale. These beds are known to be Vaqueros at the base, but the age of the uppermost member, the shale, is unknown. However, it may possibly be the equivalent of the Big Blue in the north end of the Coalinga field, although in the area under discussion it has been mapped with the Vaqueros, and in the Eastside field it is included in the Santa Margarita (?) formation. The basal sandstone of the Vaqueros formation may be traced from a short distance south of the San Joaquin Valley coal mine southward across the northwest corner of sec. 35, T. 20 S., R. 14 E., along the western edge of the same section, into the middle of the NW. ¼ sec. 2, T. 21 S., R. 14 E., thence southeasterly to the bottom of the canyon near the middle of the south line of the SE. ¼ sec. 2. Thence it passes westward below and north of the summit of the big ridge which extends several miles northwestward from Alcalde. Near the San Joaquin Valley coal mine the Vaqueros overlies the Tejon (Eocene), but near the northwest corner of section 35 it crosses the contact between the Knoxville-Chico (Cretaceous) and the Tejon, and thence southwestward it overlies the Knoxville-Chico. The contact between the Knoxville-Chico and the Tejon is believed to extend southeastward underneath the Vaqueros diagonally through sec. 35, T. 20 S., R. 14 E., and diagonally through sec. 1, T. 21 S., R. 14 E. Its course from the latter region is not definitely known, but can be surmised as stated on pages 238–239. The tracing of this contact beneath the Vaqueros is important, because the oil is derived from the Eocene shale, and it is believed that wherever the Vaqueros or other formations overlie the Tejon they will be found more or less petroliferous, while in the areas where the same formations overlie the Knoxville-Chico they will be found barren or to contain only such petroleum as has migrated along the strata from areas underlain by the Tejon. It is worthy of note in this connection that along practically the whole extent of the outcrop of the base of the Vaqueros from the San Joaquin Valley coal mine southward to the southern part of sec. 2, T. 21 S., R. 14 E., the basal beds are more or less petroliferous. The indications are so strong in certain places, notably in the SE. ¼ sec. 2, that tunnels have been run into the base of the Vaqueros sands with the expectation of obtaining petroleum in commercial quantities.

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

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

Explanation of hypothetical section (fig. 8) along line F–F′ on contour map (Pl. XV), from Anticline Canyon to California Oil and Gas Company's well No. 1, beginning with lower strata.

[Dip approximately 20° NE.]

Vaqueros (lower Miocene), beds *a*, *b*, *c*, and *d*.

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

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

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

d. Largely clay, about 250 feet thick; may be the equivalent of the Big Blue in the Eastside field.

Jacalitos (early upper Miocene), beds *e*, *f*, *g*, *h*, *i*, *j*, and *k*.

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

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

g. Consists of clay shale and apparently thickens somewhat toward the valley, especially between the Shreeve and Lucile wells.

h. A persistent layer of soft, pebbly sandstone, recognized in both the Shreeve and Lucile well logs.

i. Ten-foot layer of clay.

j. Another pebbly sandstone layer, apparently not so persistent as bed *h*.

k. An important and widespread blue clay.

Etchegoin (uppermost Miocene), beds *l*, *m*, *n*, *o*, *p*, and *q*.

l. This sand zone consists of brown sand at the base, 10 feet of hard sandstone above it, then a layer of sand, another layer of sandstone, and finally a soft sandstone at the top.

m. Soft blue shale, 15 to 200 feet thick.

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

o. Sand and soft sandstone, pebbly at the bottom, with numerous fossils. Known as a fossil bed in the wells in some parts of the field; contains such species as *Pecten oweni* Arnold, *Glycymeris*, etc. It is the *Glycymeris* zone, not far above the base of the Etchegoin formation.

p. Bluish clay about 100 feet thick.

q. From bed *q* down to the detritus-covered valley floor in the vicinity of the Lucile well No. 1 the beds exposed are largely coarse sands with occasional pebbly layers. Toward the edge of the hills some of the beds contain cobbles of considerable size and fossils indicating the same horizon as the *Pecten coalingaensis* zone, near the top of the Etchegoin in the Kreyenhagen Hills. Usually spoken of by the drillers as "surface formation," as they appear to be largely incoherent and of heterogeneous character. Total thickness of the Etchegoin exposed is about 750 feet. Uppermost beds in the wells possibly represent a part of the Tulare formation.

STRUCTURE.

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

near the fracture to 35° or 40° some distance south of it. North of the fracture the beds dip about 20° NE. and abut sharply against the steep southward-dipping beds. From the east line of the SE. ¼ sec. 12 the line of fracture apparently bends abruptly toward the southeast and either dies out beneath the superficial deposits of Alcalde Canyon or is connected in some way with the Jacalitos anticline.

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

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

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

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

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

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

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

GEOLOGY OF THE WELLS.

The wells in this area [a] lie for the most part on the south-southeastward continuation of the great eastward-dipping monocline

[a] Wells drilled in this district since the publication of the writers' preliminary report (Bull. U. S. Geol. Survey No. 357, Nov. 23, 1908) have shown that certain of the conclusions drawn regarding sec. 6, T. 21 S., R. 15 E., were erroneous. These, together with Plate III of that report, have therefore been revised to agree with the latest data obtainable October 15, 1909.

which controls the oil-bearing formation of the Westside field. Somewhere south of sec. 6, T. 21 S., R. 15 E., probably in section 7 or 18, the strike changes to an easterly direction as the result of movements along the Jacalitos anticline and associated structural lines. It will be noticed by an examination of the contour map (Pl. XV) that the formations have a practically uniform dip of about 18° or 20° down to the edge of the more pronounced hills. At the edge of the hills the dip flattens out considerably. It should be observed in this connection that the topography in a general way reflects this change in dip. This is an important item to remember, as in other parts of the field where there are no wells and in which surface outcrops are lacking it may be possible to judge in a general way of the position of the underground formations by a critical examination of the topography of the region under observation. As a result of the bowing of the strata the dips are apparently steepest in section 36, but flatten out and become more regular north of this area. In the southern part of section 6 and also the northern part of section 7 the dips are very steep at the surface outcrop. The locus of the steep dip apparently extends from the surface underground in a northerly direction and has its maximum effect on the oil sands in the NW. ¼ sec. 6 and in the SE. ¼ sec. 36. Details of the change in dips and strike are indicated by contours on the map (Pl. XV), and will not be discussed further here.

All of the wells within this area start down in the soft surface sands and clays, which, below the uppermost superficial stratum, are believed to belong to the Etchegoin or possibly to the Tulare formation. Before reaching the uppermost oil zone (zone B) the wells pass through four or five well-defined zones of sandstone with as many interbedded layers of soft blue shale. Many of the sands carry pebbles up to the size of a marble, and some of the blue shales are also pebbly. Water sands are encountered at various depths, some of them producing large quantities of more or less mineralized water. The Lucile well No. 1 and the West Coalinga well No. 1 produce a great deal of water, but from entirely different formations, the first from the Jacalitos (upper Miocene), the latter probably from the Knoxville-Chico (Cretaceous). Water is usually encountered between zones B and D, one sand in the base of or just below zone B carrying sulphur in some of the wells, and another persistent layer occurring just above zone D. Water is also encountered between the uppermost or fine-grained light-oil sand and the next sand (heavy-oil sand) below in zone D. This last-mentioned water stratum is believed to yield the water produced with the oil in the Lucile No. 1, Aladdin, and near-by wells which have penetrated the heavy-oil beds. Where the heavy-oil strata of zone D are lacking, as in certain of the wells in the western part of section 6, water marks the base of the productive zone, which here consists only of the uppermost strata of zone D. Some very hard sandstone shell layers are encountered in the wells, and in one or two places these appear to be rather persistent laterally. The hard layer reported as the "big shell" in some of the wells is apparently not the same stratum that is designated by that name in certain others.

The first oil zone (zone B) varies in thickness from about 60 to 150 feet. In some of the wells it is reported as nearly solid sand, while in others it is a zone of alternating sandstone and shale. Oil or gas or both are reported from it in a few of the deeper wells, but in most the zone is apparently dry. It is believed that indications of petroleum must have been found in this well and overlooked by the driller, or else they were not considered of enough importance to record in the log. So far as known no well in this area produces from this zone. The individual sands of zone B vary from fine-grained thin-bedded layers intercalated with sandy shale to coarse conglomeratic sand carrying small cobbles. As previously mentioned, this zone may be studied in the east wall of the canyon running up to the Henshaw water well (SW. ¼ sec. 35, T. 20 S., R. 14 E.), about half a mile southeast of this well.

Oil zone B is underlain by a persistent stratum of mineralized water, either salt or sulphur or both, in nearly all the wells. In some this flow of water was encountered at the base of a hard sandstone shell underlying the oil strata, but in others it is reported in the lowest oil sand of the zone. Oil zone B is separated from the lower or zone D by between 150 and 200 feet of shale and shell. Some water sands and tar sands are reported in the space between zones B and D in some of the wells, but these do not appear to be very persistent. Most of the wells have penetrated zone D, but touch only its uppermost sands. The reason for this is generally that the gas pressure is great enough either to make the well flow or to fill it up with sand. The uppermost beds of zone D are fine grained and carry oil of fairly light gravity. Oil of 32° B. has been reported in one of the wells, and the gravity of all the upper beds seems to range from this down to 22° B.

Below the zone of light-oil sands is a coarser sand carrying fossil shells and believed to be the same as the bed at the base of bed *b* in the section given on page 191. The oil from this lower zone is much heavier than that from the upper and averages somewhere near 16° or 17° B. in gravity; the lower sand also is very much more productive than the finer sands and is therefore tapped wherever possible. It is the belief of the writers that this lower oil sand will furnish long-lived wells, for the holes which simply tap its uppermost layers are very productive, and the 150 or 200 feet of sands which are believed to underlie the upper beds in the deeper wells are doubtless heavily impregnated with oil.

The following is a log characteristic of the wells in this area:

Log of Aladdin Oil Company's well No. 1, sec. 6, T. 21 S., R. 15 E.

	Feet.
Brown sandy formation	320
Dark water sand	395
Brown shale	500
Sand and gravel	515
Blue shale	560
Brown shale	605
Blue shale	685
Dark sand	705
Blue shale	728
Water sand	750
Blue shale	810
Shale and shells	900
Blue shale	1,000
Shale and shells	1,055
Sand	1,070
Shale and shells	1,150
Dark sand	1,190
Shale and shells	1,240
Sand	1,258
Shells and shale	1,330
Hard sandstone (underreamed)	1,350
Sticky blue	1,370
Sandy shale	1,410
Hard blue clay	1,425
Blue shell and shales	1,460
Sandy shale	1,475
Hard sandstone	1,490
Sticky blue	1,515
Sandy shale	1,520
Shell	1,522
Sticky blue	1,590
Sandy shale	1,660
Gray shale	1,700
Blue shale	1,750
Sand and gravel	1,780
Hard conglomerate	1,815
Sand	1,840
Blue shale	1,875
Blue and sandy shale	2,012
Sand and broken shale	2,060
Sticky blue shale	2,115
Pebbles and sand	2,118
Shale (underreamed)	2,168
Shell (underreamed)	2,170
Shale (underreamed)	2,205
Sandy shale	2,218
Sand and shells (underreamed)	2,290
Sticky blue clay	2,360

	Feet.
Blue shale and shells	2,440
Shale	2,485
Dark sand	2,505
Oil sand, white	2,530
Hard oil sand	2,533
Coarse oil sand	2,543
Hard shell	2,558
Oil sand and oyster shell	2,585

PRODUCT.

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

The most phenomenal well in this area is the Silver Tip, which gushed gas, sand, and oil when zone D was first penetrated, then sanded up, and finally, when it was cleaned out, gushed a second time at the rate of 20,000 barrels a day for a few hours. For the first few days of its productiveness it flowed and sanded intermittently; after two months it is now (November 1, 1909) yielding 2,500 barrels a day.

AREA EMBRACING SEC. 2, T. 21 S., R. 14 E.

LOCATION.

Under this heading will be discussed the underground geology in the E. ½ sec. 2, T. 21 S., R. 14 E., and the southern part of sec. 32, T. 20 S., R. 14 E., which has been tested by the wells of the Sunnyside Oil Company (Henshaw water well) and Westlake-Rommel Oil Company.

GEOLOGY OF THE WELLS.

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

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

PRODUCT.

The discussion of the product accompanying the preceding area (p. 226) applies to the whole region between Waltham Creek and the San Joaquin Valley coal mine.

KREYENHAGEN FIELD.

LOCATION.

The region south of Coalinga as far as Dudley, Kings County, including the Kettleman and Kreyenhagen hills and Reef Ridge, has been known for many years as the Kreyenhagen oil district. For the sake of brevity of discussion in the present report this territory has been included as a part of the Coalinga district and has been divided into two fields, the Kreyenhagen field and the Kettleman Hills field.

The area discussed as the Kreyenhagen field lies on the southeastern flanks of Reef Ridge and extends from the general region of Jacalitos Creek to Dagany Gap, 3½ miles southeast of Dudley. The area in which oil development has been carried on is a narrow band between Canoas Creek and the region of Big Tar Canyon.

CONTOUR MAP.

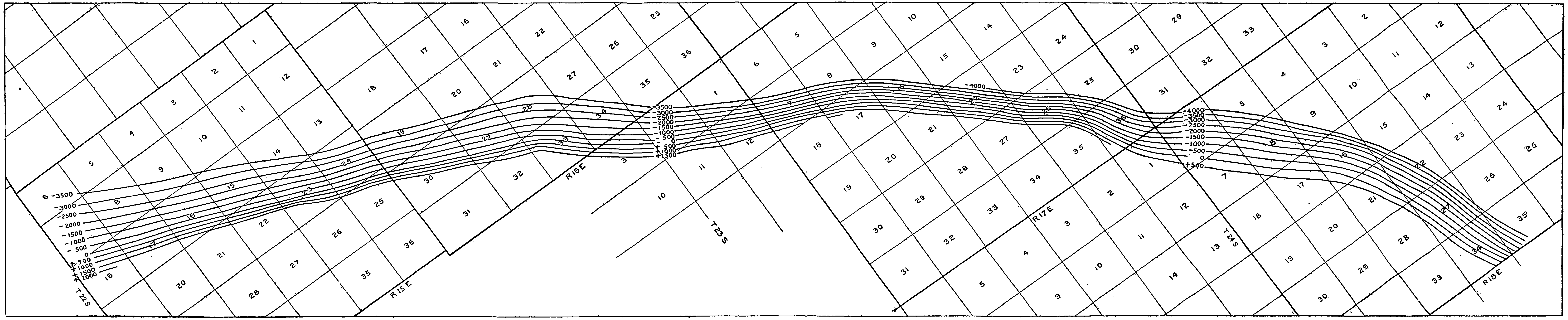
The contour map of the Kreyenhagen field (Pl. XXII) is intended primarily to give a generalized representation of the monocline on the northeastern flanks of Reef Ridge and the rate at which the formations pitch below the surface. The underground contour lines indicate the approximate depth above (marked +) and below (marked −) sea level of the upper portion of the Vaqueros sandstone or the lower portion of the hard white shales mapped as Santa Margarita(?) formation; in other words, the distance below sea level of the horizon that is supposed to be the highest one at which oil may be found.

The structural lines on this map were drawn solely on the basis of the apparent dip of the beds on the surface and without the aid of any underground data such as are afforded by the oil wells in the Coalinga field. The contours are entirely hypothetical.

GENERAL GEOLOGY AND OCCURRENCE OF OIL.

Reef Ridge and the region immediately adjacent to it, both southwest and northeast, are a part of the great monocline of rocks which forms the east flank of the main Diablo Range. The formations involved in the geology are the conglomerates, sandstones, and shales of the Knoxville-Chico (Cretaceous); the sandstones and shales of the Tejon (Eocene); the sandstone and shale of the Vaqueros (lower Miocene); the shale of the Santa Margarita (?) (upper middle Miocene); and the sandstone, shale, and gravel of the Jacalitos formation (upper Miocene). The oil, as in the Coalinga field proper, is believed to have originated in the shales of the Tejon formation, but has migrated to the sandstones of the Tejon that underlie the shales of that formation, to sands interbedded with those shales, and to the overlying Vaqueros sandstone. Numerous tar springs that rise from the Tejon and Vaqueros within the area under discussion show that those formations contain oil. Among the principal springs of this kind may be mentioned those in Canoas Creek, which come from the upper part of the Vaqueros; those on or near the Clark ranch farther south, in the vicinity of Garza Creek, also in the Vaqueros; the famous tar spring in Big Tar Canyon, which comes from the upper part of the Tejon; and the springs in Little Tar Canyon and north of it, which come from the upper part of the shales of the Tejon. Numerous other seepages and springs are found along the outcrop of the Tejon and Vaqueros, but within the area mapped none, to the knowledge of the writers, are found farther north than Canoas Creek or farther south than the head of Little Tar Canyon.

Indications of petroleum are found in the basal shale layers in the Tent Hills anticline 2 miles southeast of Dudley, but no true seep-



CONTOUR MAP OF THE KREYENHAGEN FIELD.

Contour lines show position of top of Vaqueros oil-bearing formation relative to sea level. (For surface contours see Pl. I.)

ages are known between the one in Little Tar Canyon and Sulphur Spring, in the Devils Den district. The Castle Mountain fault, which cuts off the Tejon and Vaqueros formations near the head of Little Tar Canyon, is believed also to eliminate these same formations below the Santa Margarita (?) formation southward for a considerable distance below the head of Little Tar Canyon. Owing to the steep dip in the formations along Reef Ridge the petroliferous zone is necessarily very narrow. The extent of the zone in which it seems possible that productive wells may be put down is shown on the map (Pl. I). Water accompanies the oil in all the seepages along this belt and has caused the failure of many test holes, which will be described later.

GROUPS OF WELLS DISCUSSED.

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

GEOLOGY OF WELLS IN THE TEJON FORMATION.

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

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

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

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

The well of the Baby King Oil Company is located immediately behind Reef Ridge, in the NE. ¼ sec. 11, T. 23 S., R. 16 E., in the canyon of the first stream west of Big Tar Canyon. It starts down in strata lying near the contact between the Tejon (Eocene) and Vaqueros (lower Miocene) formations. It is said to have struck oil of 30° B. gravity at 400 feet and oil of 18° B. gravity at 1,110 feet; a short distance below this last point flowing water was encountered. At the time of the writers' visit in September, 1907, the well was flowing about one-half miner's inch of water, accompanied by occasional blebs of black heavy oil and some gas.

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

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

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

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

GEOLOGY OF WELLS IN FORMATIONS ABOVE THE TEJON.

The Black Mountain Oil Company sank two wells in the SW. ¼ NW. ¼ sec. 33, T. 22 S., R. 16 E. These wells both start down in the dark shale of the Santa Margarita (?) formation and obtain their oil from the top of the Vaqueros sandstone. The log of well No. 1 of this company is as follows:

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

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

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

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

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

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

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

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

A. M. Anderson and associates (El Cerrito Oil Company) were drilling in the summer of 1908 on a well in the NW. ¼ sec. 14, T. 23 S., R. 17 E. The well starts down near the contact between the Etchegoin (upper Miocene) and Tulare (Pliocene-Pleistocene) formations, and is said to have been located on the evidence of a supposed oil-sand outcrop a few hundred feet south of the well site.

KETTLEMAN HILLS FIELD.

LOCATION.

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

GEOLOGY AND INDICATIONS OF OIL.

The formations which rise to the surface in the anticline are the Etchegoin and Tulare, described fully under "Geology." The structure of the hills is that of a simple arched anticline, with low dips near the axis and steeper ones toward the flanks. The maximum dip on the northeast flank is about 31°; that on the southwest 45°. The late W. P. Kerr informed the senior author that he was told by one of the government land surveyors who visited the Kettleman Hills over twenty years ago that at that time the surveyor saw what he supposed was an oil seepage on the southeastern flank of the hills, in the southeastern part of T. 21 S., R. 17 E., or the northeastern part of T. 22 S., R. 17 E. Neither Mr. Kerr nor the senior author, who visited this locality in 1907 and made a careful examination, was able to find any traces of an oil seepage in this region, although several places were noted where mineral waters have oozed from the rocks in the rainy season. It is believed that the Kettleman Hills offer no direct surface evidence of petroliferous deposits.

GEOLOGY OF THE WELLS.

Seven or more wells have been put down in the hills and none have been successful; but owing to their position and relatively slight depth they afford no adequate test of the territory. (See pp. 241–245 for conclusions concerning future development.) Two wells, the Gibbs and Oceanic, are on the northeastern flank of the anticline; the others are on the southwestern flank. None are within the area outlined on the accompanying map as possibly productive.

The Gibbs Oil Company's well is in the eastern part of the NW. ¼ sec. 28, T. 21 S., R. 17 E., and is the farthest north of all the wells in the Kettleman Hills. It is about 1 mile east of the axis of the Coalinga anticline and starts down in beds near the top of the Etchegoin (upper Miocene) formation.

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

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

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

The Florence Oil Company has two wells in the NW. ¼ sec. 15, T. 22 S., R. 17 E. They are on the southwest flank of the Coalinga anticline, about a mile from the axis, and near the surface penetrate strata at the bottom of the Tulare formation. They are said to have attained a depth of 720 feet and to have encountered considerable gas, but no oil.

The Esperanza Oil Company bored two wells in the SW. ¼ sec. 14, T. 22 S., R. 17 E. One was 1,100 feet deep, but was abandoned on account of water; the other reached 840 feet, when drilling was suspended. The wells lie on the southwestern flank of the anticline, over a mile from the axis, and start in the uppermost beds of the Etchegoin formation.

The well of the Stockton Oil Company in the NW. ¼ sec. 30, T. 22 S., R. 18 E., the farthest south of all the test wells in the hills, lies on the southwestern flank of the anticline about 2 miles distant from the axis. The well starts down in beds near the contact between the Etchegoin and Tulare formations, and is said to have gone to a depth of 670 feet with no results in the way of gas or oil.

CONCLUSIONS CONCERNING FUTURE DEVELOPMENT.

GENERAL STATEMENT.

The conclusions here to be discussed as to the course that future development will take in the Coalinga district are based on the belief that the asphalt oil, which forms the bulk of the product of the district, is originally derived from the shales of the Tejon (Eocene) formation and that upon migration it collects both in the sands interbedded with these shales and in the porous portions of the overlying Miocene formations. All the conditions indicate that this belief is well founded. The purple-shale member of the Chico (Upper Cretaceous), in which the paraffin oil is supposed to have originated, was probably eroded away in the central and southern portions of the district before the deposition of the Tejon. It is, therefore, not supposed to have any bearing on the future developments except in the very northern portion of the district.

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

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

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

(*c*) Associated porous beds occupying such a position relative to the source of the oil and to impervious barriers as to permit 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 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 as bounding the possibly productive territory are those in which the top of the supposed oil zone has been calculated as possibly within a vertical distance of 4,500 feet from the surface. A depth of 4,500 feet below the surface has been arbitrarily taken as the maximum to which it is possible to drill by present methods in the region under discussion, although it is not the maximum depth of holes in California that have been drilled with a Standard rig. It may be possible to go deeper than this, but for the present this limit seems sufficient. 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 and price of oil—that local conditions must determine the result in each specific case.

It seems very unlikely that oil even in small amounts will be found in any of the rocks underlying the Tejon (Eocene)—that is, in the

Cretaceous or Franciscan formations (see Pl. I)—while it will very likely be found in the Tejon and in the formations immediately overlying it, whether in paying quantities depending on the factors mentioned 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 those 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.

TERRITORY NORTHWEST OF EASTSIDE FIELD.

The well of the T. C. Oil Company in sec. 2, T. 19 S., R. 15 E., has proved the productivity of the east flank of the Coalinga anticline almost as far north as the northern edge of the area shown on the map accompanying this report. Near there the beds bend from a strike almost due north to one N. 30° or 40° W., the dip at the same time steepening to 30° or more in secs. 34 and 35, T. 18 S., R. 15 E. A number of wells have been recently drilled near the northern edge of the territory mapped and have reached the top of the Eocene shale without obtaining petroleum in commercial quantity. The absence of any large quantity of oil is probably to be explained by the steepening of the dip, with the consequent decreasingly favorable conditions for the entrance of the oil into the Miocene sand and its accumulation there. The conclusion to be drawn is that the northern limit of productive area for the Miocene in the Eastside field has very nearly been reached. The untested possibility, however, still remains that oil may be obtained by wells sunk below the Miocene, through the Tejon, and into the paraffin-oil zone of the Chico.

REGION OF THE EASTSIDE FIELD.

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

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

Within the area of shale and interbedded sandstone of the uppermost member of the Chico (Upper Cretaceous), extending from Oil City northward beyond secs. 29 and 30, T. 18 S., R. 15 E., locations favorable for productive wells are believed to remain yet undeveloped. Surface indications lead to the belief that wherever in this area the sands interbedded with the purple-shale member of the Chico are porous they contain appreciable and in some places probably commercial quantities of petroleum at available depths. As the quality of the oil obtained from the Chico oil zone is usually considerably higher than that found in the Miocene, small producers in the Chico area should pay where the same production would involve a loss elsewhere. It is believed that a well site so chosen that the prospective sand would be encountered at 600 feet or more below the surface would be the most favorable for exploiting this territory. Furthermore, it is believed that productive sands in the Tejon may be tapped by wells which start in overlying formations, but predictions as to favorable locations for such tests would be unreliable, owing to the unconformable relation of the overlying beds to the Chico.

REGION OF ANTICLINE RIDGE AND GUIJARRAL HILLS.

Along the southwestern edge of the developed territory in the Eastside field the axis of the Coalinga anticline pitches southeast at about 9° at least as far southeast as the northwest corner of section 12 and probably as far as the southeast corner of the same section. From section 12 toward the southeast the anticline is believed to flatten to the region of the Guijarral Hills, where it rises toward the Kettleman Hills. The productive territory will be limited to that portion of the anticline where the productive sands lie at a depth to be profitably reached by the drill.

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

With regard to the first factor (*a*), evidence furnished by wells indicates a pitch of about 9°, or 1,000± feet to the mile.

With regard to the second factor (*b*), a conservative estimate indicates that at its nearest point to the surface in the northern portion of the Kettleman Hills the top of the oil-bearing zone may lie within 3,500 feet of the surface. This estimate assumes that the formations above the oil-bearing Vaqueros are considerably thicker than the same formations in the Eastside field. Just where this thickening of the beds begins it is not possible to find out, but it is believed to be toward the lower end of Anticline Ridge—that is, along the Coalinga anticline a little north of the railroad. All the evidence considered, it seems probable that the pitch indicated by the contours on the map—that is, 9°, or 1,000± feet to the mile along the anticline—is the average as far southeastward as the southeast corner of sec. 12, T. 20 S., R. 15 E., and probably much less in the region of the Guijarral Hills. Owing to the much steeper dip on the southwest flank of the anticline than on the northeast, the productive ground will be found to extend much farther away from the axis on the latter flank than on the former, as indicated by the contour map.

REGION OF THE WESTSIDE FIELD.

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

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

REGION OF THE JACALITOS ANTICLINE.

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

REGION OF REEF RIDGE SOUTH TO DAGANY GAP.

The great monocline of Tertiary beds which flanks Reef Ridge on the east and forms the Kreyenhagen Hills is underlain by the Tejon formation from a point at least as far north as Sulphur Spring Canyon (in sec. 23, T. 22 S., R. 15 E.) to the head of Little Tar Canyon (in sec. 35, T. 23 S., R. 17 E.). Nearly throughout the extent of this

Tejon band it shows unmistakable signs of petroleum contents. Oil also seeps in many places from the Vaqueros sands overlying the Eocene, so that there is no doubt of the presence of petroleum practically throughout the length of the region under discussion. Furthermore, productive wells on Canoas Creek, in Big Tar Canyon and elsewhere (see pp. 227–232), have proved the presence of oil in commercial quantities in at least certain localities. Although the territory does not promise large individual productions the writers believe that productive wells may be put down along practically the whole strip from the region between Jacalitos and Canoas creeks to Little Tar Canyon. West of Jacalitos Creek the Tejon is apparently lacking or else is thin and insignificant; southeast of the head of Little Tar Canyon the Tejon is cut off by the Castle Mountain fault. It is therefore not likely that the productive sands extend far either northwest of Sulphur Spring Canyon or southeast of the head of Little Tar Canyon. There are indications of petroleum in the axis of the Pyramid Hills anticline, southeast of Dudley, and still farther southeastward toward the Devils Den country, so that the extension of the productive belt in a southeasterly direction from Little Tar Canyon is probably only locally affected by the fault. It is to be expected that the lighter oil will be found in the Tejon formation, but the best production will doubtless be found in the sand of the Vaqueros (lower Miocene). The production in either case will probably not be large, for the steep dip of the beds precludes the conditions necessary for great accumulations of oil. The steep dip, however, so increases the distance through which the wells may penetrate the sand that the lack of complete saturation may be partly compensated for by increased exposure of sand in the well. An item that should not be overlooked in drawing conclusions concerning this strip of territory is the probable occurrence of water in or closely associated with the oil sands. Nearly all the oil seepages in the region are accompanied by water, and many of the test wells have been abandoned on account of it, so that trouble from this source should not surprise those who may undertake to exploit the region. The depth to which the oil sands along Reef Ridge may be exploited is limited by the cost of drilling plus operation, in relation to the production and value of the oil; and also by the source of the water that is apparently associated with the oil-bearing beds—whether it is "bottom" or "edge" water. These factors are determinable only by actual test. The area outlined on the map (Pl. I) as probably productive embraces all of the territory along Reef Ridge in which it is thought that the top of the sands of the Vaqueros (lower Miocene) will be encountered at a depth less than 4,500 feet. At some localities seepages indicate that the productive zone is near the base of the formation; at other localities the evidence favors the theory that the top will be found the most productive. All the evidence seen by the writers leads to the conclusion that the productive bodies of petroleum will not be encountered in or above the shale of the Santa Margarita (?) formation, that is, above the top of the Vaqueros (lower Miocene) zone.

REGION OF THE KETTLEMAN HILLS.

The Kettleman Hills were formed by an uplift of the sedimentary formations of this region along the Coalinga anticline. It is an interesting and important problem to consider whether this great arch, the summit of which has subsequently been in large part worn away by erosion, has brought within reach of the surface the beds which are oil bearing a few miles away. The conditions for the accumulation and preservation of oil in this broad, regular, unbroken fold would appear to be good, and the question as to the occurrence of valuable deposits resolves itself principally into two problems—(1) whether the hills are underlain by the Tejon, so that oil is probably present, and (2) whether the oil-bearing beds are brought so near the surface by the anticline as to be accessible. Direct evidence can be obtained upon either of these questions only by the drill, owing to the complete hiding of the oil-bearing formations, if such there be, by a great thickness of overlying formations; but the geologic facts observed in the hills and in other parts of the district afford indirect evidence of considerable importance favoring the theory that the necessary conditions mentioned above exist.

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

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

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

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

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

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

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

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

No surface indications of oil are known to exist in the Kettleman Hills, but it is not likely that oil would have been allowed to escape through the great thickness of overlying beds forming the regularly arching anticline. It is supposed also that the oil is retained by the overarching shale of the Santa Margarita (?) formation. Accumulations of a brownish substance resembling oxidized asphaltum have been observed in the Lost Hills several miles south of the southern end of the Kettleman Hills. The Lost Hills are due to an extension of the Coalinga anticline southward, and it may be that the fold pitches northward and exposes a low portion of the series, into which the possible hydrocarbons have had access. Whether or not such a supposition is founded in fact, the presence of the oxidized asphaltum in the Lost Hills favors the theory that oil will be found in the Kettleman Hills.

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

AREAS CLASSIFIED AS MINERAL LAND IN THE COALINGA DISTRICT.

The following areas within the Coalinga district have been classified as mineral land, and such of these as yet belong to the Government have been withdrawn from all kinds of entry. The lands classified as mineral include all those lying between the outcrop of the base of the lowest oil-bearing beds and a line marking the limits of the area in which the uppermost productive oil zone (zone B in the Coalinga field) can be reached by a well less than 4,500 feet in depth. The lines bounding the area so included are shown on the geologic map (Pl. I). (See pp. 233-245 for relative probability of productiveness of these lands.)

List of mineral lands in Coalinga district.

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

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

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

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

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

T. 20 S., R. 15 E.:
- All of township except secs. 14, 23, 24, 25, 26, 27, 34, 35, and 36, S. ½ sec. 13, SE. ¼ sec. 15, and E. ½ sec. 22.

T. 20 S., R. 16 E.:
- W. ½ secs. 6 and 7, NW. ¼ sec. 18.

T. 21 S., R. 14 E.:
- Sec. 1, E. ½ sec. 2, sec. 12, and N. ½ and SE. ¼ sec. 13.

T. 21 S., R. 15 E.:
- Secs. 4 to 9, W. ½ sec. 3, NW. ¼ sec. 10, S. ½ sec. 16, secs. 17, 18, 21, 22, NW. ¼ and S. ½ sec. 23, secs. 26, 27, E. ½ sec. 28, N. ½ and SE. ¼ sec. 34, and W. ½ sec. 35.

T. 21 S., R. 17 E.:
- Secs. 33, 34, and NW. ¼ and S. ½ sec. 35.

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

T. 22 S., R. 16 E.:
NW. ¼ and S. ½ sec. 19, SW. ¼ sec. 20, SW. ¼ sec. 27, NW. ¼ and S. ½ sec. 28, secs. 29 and 30, N. ½ sec. 31, secs. 32 to 34, and SW. ¼ sec. 35.
T. 22 S., R. 17 E.:
NW. ¼ and S. ½ sec. 1, secs. 2 and 3, E. ½ sec. 4, NW. ¼ and E. ½ sec. 10, secs. 11 and 12, NW. ¼ and E. ½ sec. 13, and NE. ¼ sec. 14.
T. 22 S., R. 18 E.:
Sec. 7, NW. ¼ and S. ½ sec. 8, NW. ¼ and S. ½ sec. 16, secs. 17 and 18, N. ½ sec. 19, secs. 20, 21, and 22, SW. ¼ sec. 25, secs. 26, 27, and 28, NE. ¼ sec. 29, NE. ¼ sec. 33, and secs. 34, 35, and 36.
T. 23 S., R. 16 E.:
S. ½ sec. 1, secs. 2, 3, and 4, N. ½ sec. 10, secs. 11 and 12, and N. ½ sec. 13.
T. 23 S., R. 17 E.:
Sec. 7, S. ½ sec. 8, SW. ¼ sec. 15, NW. ¼ and S. ½ sec. 16, sec. 17, NW. ¼ and E. ½ sec. 18, N. ½ sec. 20, secs. 21 and 22, SW. ¼ sec. 23, SW. ¼ sec. 25, sec. 26, N. ½ and SE. ¼ sec. 27, NE. ¼ sec. 35, and sec. 36.
T. 23 S., R. 18 E.:
Secs. 1, 2, NE. ¼ sec. 3, E. ½ sec. 11, secs. 12, 13, N. ½ and SE. ¼ sec. 24, NE. ¼ sec. 25, SW. ¼ sec. 31.
T. 23 S., R. 19 E.:
W. ½ sec. 6, secs. 7, 18, and 19, W. ½ sec. 20, SW. ¼ sec. 28, sec. 29 and 30, E. ½ sec. 31, secs. 32 and 33, and SW. ¼ sec. 34.
T. 24 S., R. 18 E.:
SW. ¼ sec. 5, secs. 6 and 7, NW. ¼ and S. ½ sec. 9, SW. ¼ sec. 15, sec. 16, N. ½ and SE. ¼ sec. 17, N. ½ and SE. ¼ sec. 21, NW. ¼ and S. ½ sec. 22, sec. 27, E. ½ sec. 28, sec. 34, and W. ½ sec. 35.
T. 24 S., R. 19 E.:
Secs. 3 and 4, N. ½ and SE. ¼ sec. 5, secs. 9, 10, 15, 16, 21, and 22, SW. ¼ sec. 26, secs. 27 and 28, N. ½ and SE. ¼ sec. 33, sec. 34, and NW. ¼ and S. ½ sec. 35.

PRODUCTION AND ESTIMATED SUPPLY.

The following table of production of the Coalinga district by calendar years from 1897 to 1908 was compiled by Miss Belle Hill, under the direction of Dr. David T. Day, of the United States Geological Survey. The production for 1909 has probably been about 15,200,000 barrels, which, with the greatly increased price, has brought the value of the product for the year close to $9,000,000.

Production of petroleum in Coalinga district, 1897 to 1908.

[In barrels of 42 gallons each.]

Year.	Production.	Value.	Year.	Production.	Value.
1897	70,140		1903	2,138,058	$705,559
1898	154,000		1904	5,114,958	1,520,847
1899	439,372		1905	10,967,015	2,657,009
1900	532,000	$532,000	1906	7,991,039	1,848,300
1901	780,650	390,325	1907	8,871,723	3,091,934
1902	572,498	257,629	1908	10,386,168	5,392,916

By a rough estimate, based on the data in the hands of the writers, the amount of available oil contained before exploitation began in that part of the Coalinga district shown on the contour map

(Pl. XV) was 2,800,000,000 barrels of 42 gallons each. Of this amount about 2,000,000,000 barrels was contained in the territory west of the Coalinga syncline and 800,000,000[a] barrels east of the syncline. The total amount that has been taken from the ground up to the present time, including an estimated production of 15,200,000 barrels for 1909, approaches 63,000,000 barrels, which leaves 2,737,-000,000 barrels available after 1909. At the present rate of production this supply would last over two hundred years, but with the rapid rate at which the increase in production is now taking place the time during which the supply will hold out promises to be far less. Moreover, it is not possible to state whether all the oil present can ever be obtained.

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

TRANSPORTATION FACILITIES.

One railroad and three pipe lines constitute the transportation facilities for the oil produced in the Coalinga district.

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

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

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

The Producers' Transportation Company, a subsidiary of the Union Oil Company, is now constructing an 8-inch line between

[a] Recent developments in the Eastside field have tended to reduce the estimate of the probable productive area so much that the original estimate of 875,000,000 barrels for this field has been cut to 800,000,000 barrels.

Coalinga and the Antelope Valley, 45 miles to the southeast, where it will join the main 8-inch line to the coast at Port Harford. This is part of a system of lines which are to join the Kern River, Sunset, Midway, and McKittrick districts with tide water. The distance from Coalinga to Port Harford by this route is a little over 100 miles, the line traversing Polonio, Cholame, and Cuesta passes and passing Dudley, Cholame, Santa Margarita, and San Luis Obispo.

The Associated Oil Company is now laying a new 8-inch line from Sunset through the Midway, McKittrick, and Coalinga districts via Mendota to tide water at San Francisco Bay. This line will be completed early in 1910.

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

OIL COMPANIES AND OIL WELLS IN THE COALINGA DISTRICT.

The following is a practically complete list of all of the oil companies and the wells which they had drilled or were drilling in the Coalinga district up to October 15, 1909. The locations of the wells are indicated wherever known, and the elevations of most wells are given, having been obtained by instrument survey by E. P. Davis, topographer. A table following this one shows the names of companies and the number of wells in the Coalinga district April 30, 1909.

Oil companies and oil wells in Coalinga district.

[Location by Mount Diablo meridian.]

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
Ætna. (See California Oilfields, Ltd.)				*Feet.*
Ajax		[a] 1	SW. ¼ sec. 32, T. 19 S., R. 15 E.	
Aladdin. (See Coalinga Aladdin.)				
American Petroleum		1	SW. ¼ sec. 18, T. 20 S., R. 15 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		5	NW. ¼ sec. 18, T. 20 S., R. 15 E.	
Do		6	do	
Do		7	do	
Do		8	do	
Do		[b] 32	do	
Do		1	SW. ¼ sec. 19, T. 20 S., R. 15 E.	

[a] Abandoned. [b] Drilling.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
American Petroleum		2	SW. ¼ sec. 19, T. 20 S., R. 15 E.	
Do		3	do	
Do		4	do	
Do		[a]5	do	
Do		[a]8	do	
Do		[a]12	do	
Do		[a]16	do	
Do		1	SW. ¼ sec. 30, T. 20 S., R. 15 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		5	NW. ¼ sec. 30, T. 20 S., R. 15 E.	
Do		6	do	
Do		[a]7	SW. ¼ sec. 30, T. 20 S., R. 15 E.	
Do		[a]13	do	
Do	North Thirty	[a]1	NW. ¼ sec. 30, T. 20 S., R. 15 E.	
Do	do	[a]2	do	
Do	do	[a]3	do	
Do	do	[a]4	do	
Amy		1	SE. ¼ sec. 6, T. 21 S., R. 15 E.	800
Angelus. (See Traders.)				
Arica	Porter & Scribner	1	NW. ¼ sec. 7, T. 20 S., R. 15 E.	873
Do	do	[b]2	do	868
Do	do	3	do	848
Do	do	4	do	
Do	do	5	do	
Do	do	6	NE. ¼ sec. 7, T. 20 S., R. 15 E.	
Do	do	7	do	
Arizona Petroleum	East Puente	1	SE. ¼ sec. 14, T. 20 S., R. 14 E.	
Do	do	2	do	
Do	do	3	do	
Do	do	[a]4	do	
Associated		1	SW. ¼ sec. 22, T. 19 S., R. 15 E.	1,255
Do		2	do	1,235
Do		3	do	1,223
Do		4	do	1,208
Do		5	do	1,144
Do	Old No. 1	1A	SE. ¼ sec. 36, T. 20 S., R. 14 E.	835
Do	Old No. 2	1B	do	875
Do	Old No. 4	1C	do	834
Do	Old No. 3	2A	do	831
Do	Old No. 5	3A	do	828
Do		4A	do	
Do		4B	do	
Do		4C	do	
Do		5A	NE. ¼ sec. 36, T. 20 S., R. 14 E.	
Do		5B	do	
Do		5C	do	
Do	Old No. 11	6A	do	
Do		6B	do	
Do		6C	do	
Do	Old No. 13	7A	do	
Do		7B	do	
Do		7C	do	
Do		7D	do	
Do	Old No. 15	8A	do	
Do	Old No. 45	8B	do	
Do	Old No. 43	8C	do	
Do	Old No. 41	8D	do	
Do	Old No. 17	9A	do	
Do	Old No. 19	9B	do	
Do	Old No. 21	9C	do	800
Do	Old No. 23	9D	do	814
Do	Old No. 39	8E	NW. ¼ sec. 36, T. 20 S., R. 14 E.	
Do	Old No. 37	8F	do	
Do	Old No. 25	9E	do	828
Do	Old No. 27	9F	do	843
Do	Old No. 29	9G	do	858
Do	Old No. 31	9H	do	
Do	Old No. 32	9I	do	
Avenal Land and Oil		[b]2	Sec. 18, T. 23 S., R. 17 E.	
Avon. (See California Oilfields, Ltd.)				
B. and B	Brix and Buntin	1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	848
Do		2	do	852
Do		3	do	

[a] Drilling.

[b] Abandoned.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
B. and B	Brix and Buntin	4	SE. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		5	do	
Do		6	do	
Do		8	do	
Baby King		a 1	NE. ¼ sec. 11, T. 23 S., R. 16 E.	
Badger State		a 1	Sec. 1, T. 21 S., R. 14 E	
Best Yet			NW. ¼ sec. 18, T. 21 S., R. 15 E.	
Black Mountain		a 2	NW. ¼ sec. 33, T. 22 S., R. 16 E.	
Blair		b 1	NW. ¼ sec. 14, T. 21 S., R. 15 E.	
Blue Diamond. (See McQuigg & Wren.)				
Blue Goose		a 1	NE. ¼ sec. 20, T. 19 S., R. 15 E.	
Blue Moon		1	SE. ¼ sec., 6 T. 19 S., R. 15 E.	847
Bonanza King		a 1	SW. ¼ sec. 10, T. 19 S., R. 15 E.	
Boston and California		b 1	SE. ¼ sec. 24, T. 19 S., R. 15 E.	
Boychester			NE. ¼ sec. 18, T. 21 S., R. 15 E.	
British Consolidated	California Diamond No. 5.	b 1	SW. ¼ sec. 12, T. 19 S., R. 15 E.	802
Do	California Monarch No. 1.	1	SE. ¼ sec. 26, T. 19 S., R. 15 E.	954
Do	California Monarch No. 2.	b 2	do	889
Do	California-New York	1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	834
Do	do	2	do	848
Do	do	3	do	829
Do	do	4	do	835
Do	do	5	do	843
Do	do	6	do	
Do	California Diamond Buntin No. 1.	a 1	NW. ¼ sec. 24, T. 21 S., R. 15 E.	
Buena Vista. (See Kettleman Hills.)				
Buntin. (See British Consolidated.)				
Caledonian		1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	882
Do		a 2	do	880
Do		3	do	847
Do		4	do	842
California and New York (See British Consolidated.)				
California Diamond. (See British Consolidated; also W. M. & M.)				
California Monarch. (See British Consolidated.)				
California Oil and Gas		a 1	SE. ¼ sec. 19, T. 19 S., R. 15 E.	
Do	T. C	1	NE. ¼ sec. 6, T. 21 S., R. 15 E.	759
Do	do	b 2	do	
California Oilfields, Ltd	Avon, No. 1	1	SW. ¼ sec. 14, T. 19 S., R. 15 E.	1,101
Do	Avon, No. 2	2	NW. ¼ sec. 14, T. 19 S., R. 15 E.	1,035
Do	Kaweah, No. 1	3	NE. ¼ sec. 14, T. 19 S., R. 15 E.	877
Do	Kaweah, No. 2	4	SE. ¼ sec. 14, T. 19 S., R. 15 E.	950
Do	Avon, No. 3	5	NW. ¼ sec. 14, T. 19 S., R. 15 E.	856
Do		1	SE. ¼ sec. 21, T. 19 S., R. 15 E.	1,451
Do		2	do	1,322
Do		3	do	1,444
Do		4	do	1,340
Do		5	do	1,429
Do		6	do	1,461
Do		7	do	1,377
Do		8	do	1,383
Do		9	NE. ¼ sec. 21, T. 19 S., R. 15 E.	1,368
Do	Arline, No. 1	1	SW. ¼ sec. 26, T. 19 S., R. 15 E.	1,007
Do	Arline, No. 2	2	NW. ¼ sec. 26, T. 19 S., R. 15 E.	1,028
Do	Northeastern, No. 1	3	NE. ¼ sec. 26, T. 19 S., R. 15 E.	956
Do		4	SW. ¼ sec. 26, T. 19 S., R. 15 E.	
Do	Section Ten	1	NE. ¼ sec. 10, T. 19 S., R. 15 E.	
Do	do	2	SE. ¼ sec. 10, T. 19 S., R. 15 E.	
Do	do	3	NE. ¼ sec. 10, T. 19 S., R. 15 E.	
Do		1	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,387
Do		2	do	1,363
Do		3	do	1,349
Do		4	do	1,353
Do		5	do	1,380
Do		6	do	1,214
Do		7	do	1,331

[a] Abandoned. [b] Drilling.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
California Oilfields, Ltd		8	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,305
Do		9	do	a 1,319
Do		10	do	a 1,080
Do		11	do	a 1,340
Do		12	SW. ¼ sec. 27, T. 19 S., R. 15 E.	a 1,284
Do		13	NW. ¼ sec. 27, T. 19 S., R. 15 E.	a 1,130
Do		14	do	a 1,270
Do		15	do	a 1,225
Do		16	do	a 1,229
Do		17	do	1,332
Do		18	do	1,340
Do		19	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,256
Do		20	do	1,307
Do		21	do	1,117
Do		22	do	1,144
Do		23	SE. ¼ sec. 27, T. 19 S., R. 15 E.	1,105
Do		24	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,238
Do		25	do	1,246
Do		26	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,273
Do		b 27	SE. ¼ sec. 27, T. 19 S., R. 15 E.	983
Do		28	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,257
Do		29	do	1,188
Do		30	do	a 1,275
Do		31	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,194
Do		32	do	1,166
Do		33	do	1,260
Do		b 34	NE. ¼ sec. 27, T. 19 S., R. 15 E.	1,022
Do		35	NW. ¼ sec. 27, T. 19 S., R. 15 E.	1,168
Do		36	NE. ¼ sec. 27, T. 19 S., R. 15 E.	a 1,180
Do		37	SW. ¼ sec. 27, T. 19 S., R. 15 E.	1,271
Do		38	do	1,234
Do		39	do	1,225
Do		41	NW. ¼ sec. 27, T. 19 S., R. 15 E.	a 1,350
Do		42	NW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		43	SW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		44	do	
Do		45	do	
Do		46	NW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		47	do	
Do		48	do	
Do		49	NE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		50	SW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		51	SE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		52	NW. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		53	NE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		54	SE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		b 55	do	
Do		b 56	do	
Do		b 57	do	
Do		b 58	do	
Do		b 59	do	
Do		b 60	do	
Do		61	NE. ¼ sec. 27, T. 19 S., R. 15 E.	
Do		62	do	
Do		b 63	do	
Do		b 64	do	
Do		1	SW. ¼ sec. 29, T. 19 S., R. 15 E.	1,217
Do		2	do	1,256
Do	Ætna, No. 1	1	SE. ¼ sec. 30, T. 19 S., R. 15 E.	1,225
Do	Westmoreland, No. 1	1	NW. ¼ sec. 34, T. 19 S., R. 15 E.	1,118
Do	Forty, No 1	2	NE. ¼ sec. 34, T. 19 S., R. 15 E.	1,096
Do	Westmoreland, No. 2	3	NW. ¼ sec. 34, T. 19 S., R. 15 E.	1,109
Do	Missouri Coalinga, No. 1	4	do	1,150
Do	Westmoreland, No. 3	5	do	1,085
Do	Forty, No. 3	6	NE. ¼ sec. 34, T. 19 S., R. 15 E.	1,061
Do	Pittsburg-Coalinga, No. 1.	7	do	1,080
Call		1	NW. ¼ sec. 32, T. 19 S., R. 15 E.	1,213
Do		2	do	
Do		b 3	do	
Camwell	Octave, No. 1	1	NE. ¼ sec. 22, T. 19 S., R. 15 E.	1,212
Do	Octave, No. 2	2	do	1,208
Do		3	do	
Do		b 4	do	
Do		b 5	do	

a Approximate. b Drilling.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Call		1	NW. ¼ sec. 32, T. 19 S., R. 15 E.	1,213
Caribou Oil Mining		1	SW. ¼ sec. 22, T. 19 S., R. 15 E.	1,399
Do		2	do	1,356
Do		3	do	1,357
Do		4	do	1,417
Do		5	do	1,391
Do		6	do	1,400
Do		7	do	1,297
Do		8	do	1,234
Do		9	do	1,204
Do		10	do	1,233
Do		11	do	1,313
Do		12	do	1,116
Do		13	do	1,309
Carmelita		[a] 1	SE. ¼ sec. 3, T. 20 S., R. 15 E.	
Circle		1	NE. ¼ sec. 35, T. 20 S., R. 14 E.	
Claremont		1	NE. ¼ sec. 24, T. 20 S., R. 14 E.	[b] 810
Do		2	do	[b] 814
Do		3	do	[b] 805
Do		4	do	792
Do		5	do	
Do		6	do	
Do		10	do	
Do		11	do	
Do		12	do	
Do		13	do	
Do		14	do	
Do		1	NE. ¼ sec. 4, T. 20 S., R. 15 E.	1,022
Coalinga	Producers and Consumers, No. 1.	[a] 1	NW. ¼ sec. 20, T. 19 S., R. 15 E.	[b] 1,405
Do		2	do	1,453
Do	Producers and Consumers, No. 2.	[a] 2	do	[b] 1,410
Do		3	do	1,453
Do	Producers and Consumers, No. 3.	3	do	1,421
Do		4	do	1,449
Do		5	do	1,465
Do		6	do	1,435
Do		7	do	1,579
Do		9	do	1,499
Coalinga Aladdin	Aladdin	1	NE. ¼ sec. 6, T. 21 S., R. 15 E.	787
Coalinga Aztec	E. W. Risley	[c] 1	SE. ¼ sec. 31, T. 19 S., R. 15 E.	
Coalinga California		[c] 1	NW. ¼ sec. 8, T. 20 S., R. 15 E.	
Coalinga Crystal	Z. L. Phelps		NW. ¼ sec. 12, T. 21 S., R. 14 E.	
Coalinga Gem			E. ½ sec. 18, T. 21 S., R. 15 E.	
Coalinga Great Western	West Coalinga	[d] 1	NE. ¼ sec. 12, T. 21 S., R. 14 E.	
Do		2	do	
Coalinga Homestake	Cawder	1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	
Do	do	2	do	
Do		[c] 3	do	
Coalinga Mohawk		1	NW. ¼ sec. 12, T. 20 S., R. 15 E.	[b] 850
Coalinga National		[c] 1	N. ½ sec. 8, T. 20 S., R. 15 E.	
Coalinga Pacific		1	NW. ¼ sec. 7, T. 20 S., R. 15 E.	880
Do		2	do	883
Do		3	do	910
Do		4	do	873
Do		5	do	
Coalinga-Peerless		1	NW. ¼ sec. 22, T. 19 S., R. 15 E.	1,362
Do		2	do	1,284
Do		3	do	1,363
Do		4	do	1,360
Do		5	do	1,260
Do		6	do	1,259
Do		7	do	1,261
Do		8	do	1,212
Do		9	do	1,224
Do		10	do	1,168
Do		11	do	1,259
Do		12	do	1,150
Do		13	do	
Do		14	do	
Do		15	do	
Do		[c] 16	do	
Coalinga Petroleum		1	NE. ¼ sec. 14, T. 20 S., R. 14 E.	870
Do		2	do	878

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

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Coalinga Petroleum		3	NE. ¼ sec. 14, T. 20 S., R. 14 E.	887
Do		4	do	883
Do		5	do	
Do		6	do	
Do		7	do	
Do		[a] 8	do	
Coalinga Southern. (See Yellowstone.)				
Coalinga South Pole		[a] 1	SE. ¼ sec. 18, T. 21 S., R. 15 E.	
Coalinga Unity	Shawmut	[a] 1	NE. ¼ sec. 12, T. 20 S., R. 14 E.	
Coalinga Western		1	NE. ¼ sec. 23, T. 20 S., R. 14 E.	968
Do		2	do	977
Do		3	do	960
Do		4	do	910
Do		5	do	887
Do		6	do	960
Do		7	do	869
Do		8	do	
Coast Range		1	SW. ¼ sec. 17, T. 19 S., R. 15 E.	[b] 1,450
Do		2	do	[b] 1,450
Do		3	do	1,451
Do		4	SE. ¼ sec. 17, T. 19 S., R. 15 E.	1,469
Do		5	SW. ¼ sec. 17, T. 19 S., R. 15 E.	1,485
Do		6	do	1,533
Commercial		[c] 2	SE. ¼ sec. 12, T. 21 S., R. 14 E.	
Commercial Petroleum		1	do	869
Do		1	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,236
Do		2	do	1,243
Do		3	do	1,242
Do		4	do	1,253
Do		5	do	1,244
Do		6	do	1,241
Do		7	do	1,259
Do		8	do	1,254
Do		9	do	1,239
Do		10	do	1,220
Do		[a] 11	do	
Do		12	do	
Confidence		2	NW. ¼ sec. 31, T. 19 S., R. 15 E.	[b] 1,280
Do		4	do	[b] 1,275
Do		5	SW. ¼ sec. 31, T. 19 S., R. 15 E.	1,101
Do		6	NW. ¼ sec. 31, T. 19 S., R. 15 E.	1,240
Do		7	do	1,236
Do		8	SW. ¼ sec. 31, T. 19 S., R. 15 E.	1,251
Do		9	do	1,190
Do		10	do	1,227
Do		11	do	1,171
Do	K and C, No. 5	12	do	1,203
Do		[a] 13	do	1,205
Do		[a] 14	do	1,243
Do		([d])	do	
Consolidated Oil and Development.		[c] 1	NE. ¼ sec. 10, T. 23 S., R. 16 E.	
Consolidated	Manchester	[a] 1	NW. ¼ sec. 18, T. 21 S., R. 15 E.	
Crescent		[c] 1	SE. ¼ sec. 20, T. 19 S., R. 15 E.	
Cypress	R. H. Herron, No. 1	1	SE. ¼ sec. 1, T. 20 S., R. 14 E.	917
Do	R. H. Herron, No. 2	2	do	911
Do	R. H. Herron, No. 3	3	do	941
Do	R. H. Herron, No. 4	4	do	738
De Lux		1	SE. ¼ sec. 6, T. 21 S., R. 15 E.	777
Domengine			NE. ¼ sec. 35, T. 18 S., R. 15 E.	
El Capitan (now Kern Trading and Oil).		2	NW. ¼ sec. 31, T. 19 S., R. 15 E.	
El Cerrito		[a] 1	NW. ¼ sec. 14, T. 23 S., R. 17 E.	
Elk		[c] 1	NE. ¼ sec. 22, T. 19 S., R. 15 E.	
Ellis. (See W. M. & M.)				
Empire	J. A. McClurg	[a] 1	NE. ¼ sec. 32, T. 19 S., R. 15 E.	
Esperanza Oil and Gas		1	SW. ¼ sec. 6, T. 20 S., R. 15 E.	997
Do		2	do	989
Do		3	do	972
Do		4	do	956
Do		5	do	981
Do		6	do	943
Do		7	do	936
Do		8	do	916
Do		[c] 2	SW. ¼ sec. 14, T. 22 S., R. 17 E.	
Do		9	SW. ¼ sec. 6, T. 20 S., R. 15 E.	

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

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Esperanza Oil and Gas		10	SW. ¼ sec. 6, T. 20 S., R. 15 E.	
Do		11	do	
Esperanza Land and Oil		a 1	Sec. 30, T. 21 S., R. 15 E.	
Euclid. (See Traders.)				
Florence		b 2	NW. ¼ sec. 15, T. 22 S., R. 17 E.	
Forty. (See California Oilfields, Ltd.)				
Fresno-San Francisco		1	NE. ¼ sec. 1, T. 20 S., R. 14 E.	1,140
Do		2	do	1,128
Do		3	do	1,072
Do		4	do	1,114
Do		5	do	
Do		6	do	
Do		7	do	
Gibbs		b 1	NW. ¼ sec. 28, T. 21 S., R. 17 E.	
Golden Crest	Kreyenhagen, No. 1	a 1	NE. ¼ sec. 12, T. 22 S., R. 15 E.	
Golden State. (Now California Oilfields, Ltd.)		b 1	SE. ¼ sec. 30, T. 19 S., R. 15 E.	
Good Luck	Octave	1	NE. ¼ sec. 22, T. 19 S., R. 15 E.	
Great Western		b 1	SW. ¼ sec. 26, T. 19 S., R. 15 E.	
Guiberson, S. A., jr	Elgar Adams		E. ½ sec. 14, T. 20 S., R. 14 E.	
Guthrey		1	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,267
Do		2	do	1,263
Do		3	do	1,227
Do		3	do	1,242
Guthrey. (See Sauer Dough.)				
Hawkeye State		b 2	Sec. 6, T. 21? S., R. 15? E.	
Henshaw. (See Sunnyside.)				
Herron, R. H. (See Cypress.)				
Highland (Hearst estate)	New York, Nos. 1 and 2	b 2	SW. ¼ sec. 20, T. 19 S., R. 15 E.	
Home		1	NE. ¼ sec. 20, T. 19 S., R. 15 E.	c 1,490
Do		2	do	1,491
Do		3	do	1,567
Do		4	do	1,528
Do		5	do	1,597
Do		6	do	1,519
Do		7	do	1,585
Do		8	do	1,593
Inca		1	NW. ¼ sec. 24, T. 20 S., R. 14 E.	801
Do		2	do	811
Do		3	do	816
Do		4	do	799
Do		5	do	814
Do		6	do	805
Do		7	do	797
Do		8	do	805
Do		9	do	814
Do		10	do	818
Do		11	do	834
Do		12	do	870
Imperial		b 1	NE. ¼ sec. 2, T. 19 S., R. 15 E.	
Do		b 2	do	
Do		b 3	do	
Do		b 4	do	
Independence. (See Standard.)				
Independent		b 1	NE. ¼ sec. 17, T. 19 S., R. 15 E.	
Investment		b 1	SE. ¼ sec. 16, T. 19 S., R. 15 E.	
Iowa		b 1	SW. ¼ sec. 4, T. 22 S., R. 17 E.	
Jacalitos		a 1	Sec. 30, T. 21 S., R. 15 E.	
Jefferson		1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	802
Do		a 2	do	832
K. and C. (See Confidence.)				
Kaweah. (See California Oilfields, Ltd.)				
Kern Trading and Oil		a 22	SE. ¼ sec. 3, T. 19 S., R. 15 E.	
Do		a 25	do	
Do		1	NW. ¼ sec. 11, T. 19 S., R. 15 E.	
Do		4	do	
Do		1	NW. ¼ sec. 31, T. 19 S., R. 15 E.	c 1,210
Do		2	do	1,234
Do		3	do	1,222
Do		b 5	do	
Do		b 6	do	
Do		7	do	1,270
Do		8	do	1,242

a Drilling. b Abandoned. c Approximate.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Kern Trading and Oil (K. T. & O.).		1	NW. ¼ sec. 35, T. 19 S., R. 15 E.	
Do		[a]2	do	
Do		[a]11	SW. ¼ sec. 35, T. 19 S., R. 15 E.	
Do		[a]13	do	
Do		[a]15	do	
Do		1	SW. ¼ sec. 13, T. 20 S., R. 14 E.	
Do		2	do	
Do		3	do	
Do		5	do	
Do		6	do	
Do		7	do	
Do		8	SE. ¼ sec. 13, T. 20 S., R. 14 E.	
Do		9	do	
Do		10	do	
Do		11	do	
Do		12	do	
Do		13	do	
Do		14	do	
Do		[a]16	do	
Do		[a]20	do	
Do		[a]22	do	
Do		1	SW. ¼ sec. 25, T. 20 S., R. 14 E.	811
Do		2	do	803
Do		3	do	
Do		4	do	
Do		9	NW. ¼ sec. 25, T. 20 S., R. 14 E.	
Do		10	do	
Do		11	do	
Do		15	do	
Do		18	do	
Do		20	do	
Do		22	do	
Do		24	do	
Do		25	NE. ¼ sec. 25, T. 20 S., R. 14 E.	
Do		35	do	
Do		37	do	
Do		39	do	
Do		41	do	
Do		43	do	
Do		45	do	
Do		47	SE. ¼ sec. 25, T. 20 S., R. 14 E.	
Do		49	do	
Do		51	do	
Do		53	do	
Do		54	do	
Do		[a]1	NW. ¼ sec. 19, T. 20 S., R. 15 E.	
Do		[a]3	do	
Do		[a]5	do	
Do		[a]1	NW. ¼ sec. 31, T. 20 S., R. 15 E.	
Keystone		[b]1	NW. ¼ sec. 32, T. 19 S., R. 15 E.	
Kings County		[b]1	NE. ¼ sec. 3, T. 23 S., R. 16 E.	
Do		[b]1	SW. ¼ sec. 3, T. 23 S., R. 16 E.	
Kreyenhagen		[b]2	SE. ¼ sec. 32, T. 22 S., R. 16 E.	
Kreyenhagen. (See Golden Crest.)				
Lorene		[b]1	NW. ¼ sec. 12, T. 19 S., R. 15 E.	[c]825
Los Angeles-Coalinga Oil Syndicate.		[a]1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	
Lucile		1	NE. ¼ sec. 6, T. 21 S., R. 15 E.	770
Do		2	do	761
Do		3	do	787
Do		[a]4	do	
Maguire			NW. ¼ sec. 30, T. 20 S., R. 15 E.	
McCreary. (See California Oilfields, Ltd.)				
Maine State		1	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,256
Do		[b]2	do	[c]1,300
Do		3	do	1,274
Do		4	do	1,237
Do		5	do	[c]1,250
Do		6	SE. ¼ sec. 31, T. 19 S., R. 15 E.	1,089
Do		7	do	1,119
Do		8	do	1,119
Do		9	do	1,154
Manchester		[b]1	SW. ¼ sec. 18, T. 21 S., R. 15 E.	909
Marengo. (See Traders.)				

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

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Marion	St. Clair	*a* 1	SW. ¼ sec. 6, T. 21 S., R. 15 E.	
McQuigg & Wren	Blue Diamond No. 1		NE. ¼ sec. 14, T. 20 S., R. 14 E.	920
Do		1	do	
May Brothers		*b* 1	SE. ¼ sec. 14, T. 20 S., R. 14 E.	
Mercantile Crude		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,097
Do		2	do	*c* 1,120
Do		3	do	1,006
Do		4	do	1,002
Do		5	do	
Michigan Oil and Development.		*a* 1	Sec. 17?, T. 19. S., R. 13 E.	
Minnesota (now Southern Pacific R. R.)		*b* 2	NE. ¼ sec. 33, T. 19 S., R. 15 E.	
Missouri-Coalinga. (See California Oilfields, Ltd.)				
M., K. and T.		1	SW. ¼ sec. 8, T. 20 S., R. 15 E.	868
Do		2	do	866
Montjack		*b* 1	NW. ¼ sec. 22, T. 19 S., R. 15 E.	
Mount Hamilton Land and Oil.		*b* 1	SE. ¼ sec. 14, T. 21 S., R. 14 E.	1,002
Muriel	St. Francis	1	SW. ¼ sec. 6, T. 21 S., R. 15 E.	939
Mutual		*b* 1	SE. ¼ sec. 20, T. 19 S., R. 15 E.	
Nathan. (See Arica.)				
Netherlands	Valley Slope	1	SE. ¼ sec. 26, T. 21 S., R. 14 E.	
Do		*a* 2	do	
Nevada Petroleum		*a* 1	NE. ¼ sec. 18, T. 20 S., R. 15 E.	
Do		*a* 1	W. ½ sec. 20, T. 20 S., R. 15 E.	
Do		1	SE. ¼ sec. 30, T. 20 S., R. 15 E.	
Do		*a* 2	do	
Do		*a* 4	do	
Do		*a* 8	NE. ¼ sec. 30, T. 20 S., R. 15 E.	
New Era		1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		2	do	
New Home. (See St. Elmo.)				
New San Francisco Crude		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,135
Do		2	do	1,105
Do		3	do	1,068
Do		4	do	1,098
Do		5	do	1,079
Do		6	do	
Do		7	do	
Do		8	do	
New York. (See Highland.)				
Norse. (See Traders.)				
Northeastern. (See California Oilfields, Ltd.).				
Oceanic		*b* 1	NW. ¼ sec. 1, T. 22 S., R. 17 E.	
Octave. (See Camwell.)				
Oil City Petroleum. (See Standard.)				
Old Keystone		*b* 1	SE. ¼ sec. 8, T. 19 S., R. 15 E.	
Oyama. (See California Oilfields, Ltd.)				
Ozark		1	NE. ¼ sec. 26, T. 20 S., R. 14 E.	*c* 850
Do		2	do	*c* 845
Do		3	do	
Do		4	do	
Peerless Consolidated		*b* 1	NE. ¼ sec. 10, T. 20 S., R. 15 E.	815
Piedmont		*a* 1	Sec. 24, T. 20 S., R. 14 E.	
Pennsylvania Coalinga		1	NE. ¼ sec. 24, T. 20 S., R. 14 E.	1,056
Do		2	SE. ¼ sec. 24, T. 20 S., R. 14 E.	976
Do		3	do	923
Do		4	do	975
Do		5	do	
Do		6	do	
Philadelphia and San Francisco.		1	SE. ¼ sec. 36, T. 19 S., R. 14 E.	1,121
Do		2	do	
Do		3	do	1,107
Phoenix		*b* 3	SE. ¼ sec. 20, T. 19 S., R. 15 E.	
Pilot		1	SW. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		5	do	
Pittsburg		1	SW. ¼ sec. 24, T. 19 S., R. 15 E.	830
Pittsburg-Coalinga. (See California Oilfields, Ltd.)				

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

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
Porter & Scribner. (See Arica.)				*Feet.*
Premier		1	SE. ¼ sec. 24, T. 20 S., R. 14 E.	a 790
Do		2	do	
Producers and Consumers. (See Coalinga.)				
Queen	Coalinga Banner	1	SE. ¼ sec. 14, T. 20 S., R. 14 E.	
Do	do	2	do	
Record		1	SE. ¼ sec. 22, T. 19 S., R. 15 E.	1,189
Do		2	do	1,177
Do		3	do	
Do		4	do	
Do		b 5	do	
Do		b 6	do	
Do		b 7	do	
Red top		b 1	NE. ¼ sec. 6, T. 21 S., R. 15 E.	812
Riverside. (Near Alcalde.)				
Roanoke		c 1	SE. ¼ sec. 36, T. 19 S., R. 14 E.	
Rock		c 1	SW. ¼ sec. 28, T. 19 S., R. 15 E.	
St. Clair		1	SE. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		5	SW. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		6	do	
St. Elmo	New Home	1	SE. ¼ sec. 14, T. 20 S., R. 14 E.	
Do	do	2	do	
Do	do	3	do	
Do	do	4	do	
Do	do	5	do	
St. Francis. (See Muriel.)				
St. Lawrence		c 1	NE. ¼ sec. 12, T. 23 S., R. 16 E.	
St. Paul-Fresno		1	NE. ¼ sec. 23, T. 20 S., R. 14 E.	a 950
Do		2	do	970
Do		3	do	920
Do		4	do	906
Do		5	do	910
Do		6	do	
Do		7	do	
Do		8	do	
Do		9	do	
Santa Clara		c 1	SW. ¼ sec. 30, T. 19 S., R. 15 E.	
Sauer Dough		1	do	1,435
Do		2	do	1,304
Do		3	do	1,313
Do		4	do	1,388
Do		5	do	1,435
Do		6	do	1,283
Do		7	do	1,340
Do		8	do	
Do		9	do	
Do		10	do	
Do	Guthrey	1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	
Section One	Coalinga Zenith		Sec. 35, T. 20 S., R. 14 E.	
Do	do		Sec. 1, T. 21 S., R. 14 E.	
Section Seven		1	NW. ¼ sec. 7, T. 20 S., R. 15 E.	911
Do		2	do	915
Do		3	do	916
Do		4	do	908
Do		b 5	do	a 880
Do		b 6	do	
Section Six. (See Jefferson.)				
Section Ten		c 1	SW. ¼ sec. 10, T. 19 S., R. 15 E.	
Selma. (See Section One.)				
Seneca		1	NW. ¼ sec. 12, T. 20 S., R. 14 E.	
Do		2	do	
Do		3	do	
Do		4	do	
Do		5	do	
Shawmut		1	NE. ¼ sec. 12, T. 20 S., R. 14 E.	878
Do		2	do	882
Do		3	do	892
Do		4	do	a 910
Do		5	do	879
Shreeve		1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	853
Silver Tip		1	SE. ¼ sec. 6, T. 21 S., R. 15 E.	822
Do		b 2	do	
Smith & Porter	Summit	c 1	SW. ¼ sec. 12, T. 21 S., R. 14 E.	
Southeastern		b 1	NW. ¼ sec. 18, T. 20 S., R. 16 E.	

a Approximate. b Drilling. c Abandoned.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Spinks	Shawmut, No. 6	1	NE. ¼ sec. 12, T. 20 S., R. 14 E.	
Do	Shawmut, No. 7	2	do	
Do	Shawmut, No. 8	3	do	
Standard	Independence, No. 1	1	NE. ¼ sec. 28, T. 19 S., R. 15 E.	1,497
Do	Independence, No. 3	3	do	1,440
Do	Independence, No. 4	4	do	1,374
Do	Independence, No. 5	5	do	a 1,450
Do	Independence, No. 6	6	do	1,444
Do	Independence, No. 7	7	do	1,458
Do	Independence, No. 8	8	do	1,484
Do	Independence, No. 9	9	do	1,536
Do	Independence, No. 10	10	do	1,538
Do	Oil City Petroleum, No. 1.	11	SE. ¼ sec. 28, T. 19 S., R. 15 E.	1,371
Do	Oil City Petroleum, No. 2.	12	do	1,404
Do	Oil City Petroleum, No. 3.	13	do	1,372
Do	Oil City Petroleum, No. 4.	14	do	1,376
Do	Oil City Petroleum, No. 5.	15	do	1,448
Do	Oil City Petroleum, No. 6.	16	do	1,373
Do	Oil City Petroleum, No. 7.	17	do	1,348
Do	Oil City Petroleum, No. 8.	18	do	1,340
Do	Oil City Petroleum, No. 9.	19	do	1,361
Do	Oil City Petroleum, No. 10.	20	do	1,321
Do	Oil City Petroleum, No. 11	21	do	1,323
Do	Oil City Petroleum, No. 12.	22	do	1,262
Do	Oil City Petroleum, No. 13.	23	do	1,211
Do	Oil City Petroleum, No. 14.	24	do	1,253
Do	Oil City Petroleum, No. 15.	25	do	1,275
Do	Twenty-eight, No. 14	26	NE. ¼ sec. 28, T. 19 S., R. 15 E.	1,314
Do	Twenty-eight, No. 13	27	do	1,395
Do	Twenty-eight, No. 12	28	do	1,385
Do	Twenty-eight, No. 10	29	do	1,241
Do	Twenty-eight, No. 11	30	do	1,378
Do	Twenty-eight, No. 9	31	do	1,420
Do	Twenty-eight, No. 8	32	do	1,402
Do	Twenty-eight, No. 6	33	do	1,256
Do	Twenty-eight, No. 5	34	do	1,342
Do	Twenty-eight, No. 4	35	do	1,342
Do	Twenty-eight, No. 1	36	do	a 1,380
Do	Twenty-eight, No. 3	37	do	1,364
Do	Twenty-eight, No. 2	38	do	1,428
Do	Twenty-eight, No. 7	39	do	1,421
Do	Twenty-eight, No. 15	40	do	1,456
Do	Twenty-eight, No. 16	41	do	1,505
Do		42	do	
Do		49	do	
Do		44	do	
Do		45	do	
Do		46	SE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		48	NE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		49	do	
Do		50	do	
Do		51	do	
Do		52	do	
Do	Hanford, No. 1	54	NW. ¼ sec. 28, T. 19 S., R. 15 E.	1,356
Do	Hanford, No. 2	55	do	1,379
Do	Hanford, No. 3	56	do	1,404
Do	Hanford, No. 4	57	do	1,385
Do	Hanford, No. 5	58	SW. ¼ sec. 28, T. 19 S., R. 15 E.	1,376
Do	Hanford, No. 6	59	NW. ¼ sec. 28, T. 19 S., R. 15 E.	1,387
Do	Hanford, No. 7	60	do	1,469
Do	Hanford, No. 8	61	SW. ¼ sec. 28, T. 19 S., R. 15 E.	1,341
Do		62	NE. ¼	

a Approximate.

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Standard		63	NW. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		64	SE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		65	do	
Do		66	do	
Do		67	NE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		68	SE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		69	NE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a]70	do	
Do		[a]71	do	
Do		[a]72	do	
Do		[a]73	do	
Do		[a]74	NW. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a]75	SW. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a]76	SE. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a]77	NW. ¼ sec. 28, T. 19 S., R. 15 E.	
Do		[a]78	SW. ¼ sec. 28, T. 19 S., R. 15 E.	
Standard	Fauna, No. 1	([b])	NW. ¼ sec. 28, T. 19 S., R. 15 E.	
Stanislaus		[b]1	NW. ¼ sec. 4, T. 22 S., R. 17 E.	
Star		[b]1	NW. ¼ sec. 34, T. 19 S., R. 15 E.	
Stockholders		1	NE. ¼ sec. 28, T. 19 S., R. 15 E.	1,486
Do		2	do	1,385
Do		3	do	1,394
Do		4	do	1,407
Do		5	do	1,454
Stockton		[b]2	NW. ¼ sec. 30, T. 22 S., R. 18 E.	
Sunnyside	Henshaw	[c]1	SE. ¼ sec. 35, T. 20 S., R. 14 E.	
S. W. and B		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,061
Do		2	do	1,038
Do		3	do	1,031
Do		4	do	982
Do		[c]5	do	
Tavern		[b]1	Sec. 34, T. 18 S., R. 15 E.	
T. C.		1	SW. ¼ sec. 2, T. 19 S., R. 15 E.	958
Traders	Marengo, No. 1	1	SW. ¼ sec. 24, T. 20 S., R. 14 E.	[d]790
Do	Marengo, No. 2	2	do	[d]800
Do	Marengo, No. 3	3	do	[d]795
Do	Marengo, No. 4	4	do	[d]795
Do	Norse, No. 4	5	do	
Do	Norse, No. 3	6	do	
Do	Norse, No. 2	7	do	
Do	Norse, No. 1	8	do	
Do	Norse, No. 5	9	do	
Do	Norse, No. 6	[a]10	do	
Do	Norse, No. 7	[a]11	do	
Do	Traders, Old, No. 4	12	do	833
Do	Traders, Old, No. 5	13	do	[d]843
Do	Euclid, No. 2	22	do	824
Do		23	do	
Do	Euclid, No. 1	24	do	814
Do	Marengo, No. 7	25	do	
Do	Marengo, No. 6	26	do	
Do	Marengo, No. 5	27	do	
Do	Traders, Old, No. 3	32	do	845
Do	Traders, Old, No. 2	33	do	818
Do	Traders, Old, No. 1	34	do	810
Do	Angelus, No. 1	39	NE. ¼ sec. 26, T. 20 S., R. 14 E.	
Do	Angelus, No. 2	40	do	
Do	Angelus, No. 4	43	do	
Twenty-eight. (See Standard.)				
Twenty-two		1	SE. ¼ sec. 22, T. 19 S., R. 15 E.	1,143
Do		[a]2	do	
Turner		[a]1	SW. ¼ sec. 2, T. 20 S., R. 15 E.	[d]1,075
Do		[a]2	do	[d]975
Union		1	NW. ¼ sec. 13, T. 20 S., R. 14 E.	812
Do		2	NE. ¼ sec. 13, T. 20 S., R. 14 E.	811
Do		3	do	810
Do		4	NW. ¼ sec. 13, T. 20 S., R. 14 E.	817
Do		5	do	808
Do		6	do	824
Do		7	do	817
Do		8	do	837
Do		9	do	835
Do		10	do	
Do		11	NE. ¼ sec. 13, T. 20 S., R. 14 E.	
Do		12	do	
Do		13	do	

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

Oil companies and oil wells in Coalinga district—Continued.

Name of oil company.	Name of well.	No. of well.	Location.	Elevation above mean sea level.
				Feet.
Union		14	NE. ¼ sec. 13, T. 20 S., R. 14 E.	
Do		15	do	
Do		16	do	
Do		17	do	
Do		18	do	
Do		19	do	
Valley		1	SW. ¼ sec. 32, T. 20 S., R. 15 E.	
Venus		a 1	NW. ¼ sec. 5, T. 22 S., R. 14 E.	
Wabash		1	NE. ¼ sec. 24, T. 20 S., R. 14 E.	806
Do		2	do	802
Do		3	do	798
Do		4	do	793
Do		5	do	789
Do		6	do	787
Do		7	do	782
Do		8	do	796
Do		9	do	783
Do		10	do	779
Do		11	do	777
Do		12	do	775
Do		13	do	
Do		14	do	
Do		15	do	
Do		16	do	
Do		17	do	
Waratah			SW. ¼ sec. 6, T. 21 S., R. 15 E.	
Ward		1	NW. ¼ sec. 12, T. 20 S., R. 14 E.	933
Do		2	do	934
Do		3	do	
Do		4	do	
Do		5	do	
Do		6	do	
West Coalinga (water)		1	NE. ¼ sec. 12, T. 21 S., R. 14 E.	1,052
Westlake-Rommel		a 3	NE. ¼ sec. 2, T. 21 S., R. 14 E.	
Westmoreland. (See California Oilfields, Ltd.)				
Whale	King	a 1	Sec. 4, T. 22 S., R. 14 E.	
Whittier and Green		a 1	NW. ¼ sec. 26, T. 20 S., R. 14 E.	
Wisconsin		a 1	NE. ¼ sec. 32, T. 19 S., R. 15 E.	
W. K.		1	NW. ¼ sec. 2, T. 20 S., R. 15 E.	920
Do		2	do	1,125
Do		b 3	NE. ¼ sec. 2, T. 20 S., R. 15 E.	c 960
W. M. & M. (formerly California Diamond, No. 3).	Ellis, No. 1	1	NE. ¼ sec. 31, T. 19 S., R. 15 E.	1,192
Do	California Diamond, No. 4.	2	do	1,196
Wright Association		a 1	NW. ¼ sec. 26, T. 20 S., R. 14 E.	
Yellowstone	Coalinga Southern	b 1	NW. ¼ sec. 6, T. 21 S., R. 15 E.	917
York Coalinga		1	NW. ¼ sec. 6, T. 20 S., R. 15 E.	1,123
Do		2	do	1,085
Zenith. (See Section One.)				
Zier		1	SW. ¼ sec. 1, T. 20 S., R. 14 E.	939
Do		2	do	938
Do		3	do	964
Do		4	do	970
Do		5	do	945
Do		6	do	939
Do		7	do	953
Do		8	do	
Do		9	SE. ¼ sec. 1, T. 20 S., R. 14 E.	
Do		10	do	
Do		11	do	
Do		12	do	

a Abandoned. b Drilling. c Approximate.

The following table, showing the number of wells owned by the several companies in each land section in the Coalinga district October 31, 1909, excluding permanently abandoned wells, was compiled from reliable sources in the field by R. W. Dallas and Guy H. Salisbury.

Oil companies and number of wells in Coalinga district October 31, 1909.

Company.	Location.	Drilling wells.	Drilling wells suspended.	Producing wells suspended.	Producing wells.	Number of derricks, old and new.	Date.[a]
OIL CITY FIELD.							
Coast Range Oil Co	Sec. 17, T. 19 S., R. 15 E				2		1897
Coalinga Oil Co	Sec. 20, T. 19 S., R. 15 E				8		1897
Home Oil Co	do				8		1897
EASTSIDE FIELD.							
North Extension Oil Co	Sec. 20, T. 18 S., R. 15 E					1	1908
Big Shell Petroleum Oil Co	Sec. 29, T. 18 S., R. 15 E		1				1906
North Limited Oil Co	Sec. 34, T. 18 S., R. 15 E					1	1908
Imperial Oil Co. (Coalinga)	Sec. 2, T. 19 S., R. 15 E		4				1908
Wm. Graham (T. C. Oil Co.)	do	1	1	1	1		1907
Chas. Wilcox	do					2	1907
Kern Trading and Oil Co	Sec. 3, T. 19 S., R. 15 E	2					1909
California Oilfields, Ltd	Sec. 10, T. 19 S., R. 15 E				3		1908
Kern Trading and Oil Co	Sec. 11, T. 19 S., R. 15 E	2				1	1908
Lorene Oil Co	Sec. 12, T. 19 S., R. 15 E		1				1908
British Cons. Oil Corp., Ltd	do	1					1907
California Oilfields, Ltd	Sec. 14, T. 19 S., R. 15 E	1	1		5		1904
California Oilfields, Ltd	Sec. 21, T. 19 S., R. 15 E	1	1		9		1904
Camwell Oil Syndicate	Sec. 22, T. 19 S., R. 15 E	2			2		1906
Coalinga Peerless Oil Co	do	3		1	13	1	1905
Associated (National 30) Co	do	1			5		1907
Sauer Dough Oil Co	do				10		1900
Caribou Oil Mining Co	do	1			19		1900
Twenty-two Oil Co	do	1	1				1907
Octave Oil Co. (Merced lease)	do	1					1908
Record Oil Co	do	2		1	4		1907
Good Luck Oil Co	do	1					1909
Scott-Clark-Miller et al	Sec. 24, T. 19 S., R. 15 E					1	
Boston and California Oil Co	do		1				1907
Montana Oil Co	do		1				1907
Pittsburg Oil Co	do		1				1906
British Cons. Oil Corp., Ltd	Sec. 26, T. 19 S., R. 15 E	1		1			1906
Porter Oil Co	do					1	1909
California Oilfields, Ltd	do	3	1		1		1906
Do	Sec. 27, T. 19 S., R. 15 E	4	3		82	2	1903
Standard Oil Co	Sec. 28, T. 19 S., R. 15 E	9		10	53	1	1903
Stockholders' Oil Co	do				5		1899
California Oilfields, Ltd	Sec. 34, T. 19 S., R. 15 E	3			12	1	1906
Kern Trading and Oil Co	Sec. 35, T. 19 S., R. 15 E	3			1	1	1908
Medara Oil Co	Sec. 36, T. 19 S., R. 15 E						1909
Turner Oil Co	Sec. 2, T. 20 S., R. 15 E		2				1907
W. K. Oil Co	do	4			2		1907
Coalinga Mohawk Oil Co	Sec. 12, T. 20 S., R. 15 E			1		2	1907
Electra Oil Co	Sec. 6, T. 20 S., R. 15 E					1	1909
Southeastern Limited Oil Co	Sec. 18, T. 20 S., R. 16 E	1					1909
Light Oil Extension Oil Co	Sec. 6, T. 20 S., R. 16 E					1	1909
WESTSIDE FIELD.							
California Oilfields, Ltd	Sec. 29, T. 19 S., R. 15 E				2		1903
Ætna Petroleum Oil Co	Sec. 30, T. 19 S., R. 15 E		1				1901
Kern Trading and Oil Co	Sec. 31, T. 19 S., R. 15 E				5		1902
Confidence Oil Co	do			1	10		1901
Maine State Oil Co	do		2		4		1901
Guthrey Oil Co	do		1	1	2		1907
Commercial Petroleum Co	do	2		2	7		1901
Woy, Mechan, and Madsen	do		1	1			1905
Empire Oil Co	Sec. 32, T. 19 S., R. 15 E	1					1909
Call Oil Co	do	1			2		1906

[a] Date original company began work drilling for oil. The absence of date indicates that no actual work other than assessment work has been done.

Oil companies and number of wells in Coalinga district October 31, 1909—Continued.

Company.	Location.	Drilling wells.	Drilling wells suspended.	Producing wells suspended.	Producing wells.	Number of derricks, old and new.	Date.
WESTSIDE FIELD—continued.							
American Petroleum Co	Sec. 32, T. 19 S., R. 15 E.						1908
Fresno-San Francisco Oil Co	Sec. 1, T. 20 S., R. 14 E.			3	4		1903
Penn-Coalinga Petroleum Co	do			1	4	1	1902
Cypress Oil Co	do				4		1903
Zier Oil Co	do				12	1	1902
Acorn Oil Co	Sec. 2, T. 20 S., R. 14 E.	1					1909
Gold Tip Oil Co	do	1					
Shawmut Oil Co	Sec. 12, T. 20 S., R. 14 E.	1		1	4		1905
Ward Oil Co	do				6		1907
Seneca Oil Co	do				5		1908
St. Clair Oil Co	do			1	2		1908
Pilot Oil Co	do				5		1908
New Era Oil Co	do			1	1		1908
Buntin & Brix Oil Co	do	1		2	3		1906
British Cons. Oil Corp., Ltd. (P. M. D. & O.).	do	1			5		1904
Union Oil Co	Sec. 13, T. 20 S., R. 14 E.	3			15	1	1903
Kern Trading and Oil Co	do	5			9	2	1908
Coalinga Petroleum Co	Sec. 14, T. 20 S., R. 14 E.			3	4	1	1905
Queen Oil Co	do				2		1908
St. Elmo Oil Co. (Home Oil Co.)	do				5		1907
Arizona Petroleum Co	do	1			3		1909
Coalinga Western Oil Co	Sec. 23, T. 20 S., R. 14 E.			5			1906
St. Paul-Fresno Oil Co	do				7		1901
Kern Trading and Oil Co	do				3		1908
Inca Oil Co	Sec. 24, T. 20 S., R. 14 E.	1		2	21	2	1903
Traders' Oil Co	do			2	13	2	1907
Wabash Oil Co	do	1		2	13		1902
Claremont Oil Co	do	1			9	1	1907
Premier Oil Co	do	2			8	1	1907
Kern Trading and Oil Co	Sec. 25, T. 20 S., R. 14 E.	6	1	3	13	1	1904
Ozark Oil Co	Sec. 26, T. 20 S., R. 14 E.			1	3		1907
Traders Oil Co	do				4		1907
Wrenn & McQuigg	do		1				1909
Caledonian Oil Co	do			3	1		1902
Coalinga Homestake Oil Co	do				3		1908
Netherlands Oil Co	do	2					1909
San Juan Oil Co	do						1909
Circle Oil Co	Sec. 35, T. 20 S., R. 14 E.				1		1908
Associated Oil Co	Sec. 36, T. 20 S., R. 14 E.	9	2	2	21	1	1907
Claremont Oil Co	Sec. 4, T. 20 S., R. 15 E.	1				2	1907
Mercantile Crude Oil Co	Sec. 6, T. 20 S., R. 15 E.			2	3		1902
York Coalinga Oil Co	do	1		2	3	1	1902
S. W. and B. Oil Co	do		1		4		1906
New San Francisco Crude Oil Co	do	1			6		1906
Esperanza Oil and Gas Co	do			2	9	1	1900
Section Seven Oil Co	Sec. 7, T. 20 S., R. 15 E.			2	3		1903
Coalinga Pacific Oil Co	do			1	4		1904
Arica Oil Co. (Porter & Scribner)	do	1		3	1	1	1903
M., K. and T. Oil Co	Sec. 8, T. 20 S., R. 15 E.	1		1			1901
California-Coalinga Oil Co	do	1					1909
Coalinga-National Petroleum Co	do	1					1909
Peerless Consolidated Oil Co	Sec. 10, T. 20 S., R. 15 E.		1				1907
American Petroleum Co	Sec. 18, T. 20 S., R. 15 E.	2		1	6		1908
Nevada Petroleum Co	do	1					1909
Kern Trading and Oil Co	Sec. 19, T. 20 S., R. 15 E.	3				1	
American Petroleum Co	Sec. 19, T. 20 S., R. 15 E.	4			4		1909
Nevada Petroleum Co	Sec. 20, T. 20 S., R. 15 E.	1					
American Petroleum Co	Sec. 30, T. 20 S., R. 15 E.	6			7	5	1908
Nevada Petroleum Co	Sec. 30, T. 20 S., R. 15 E.	3			1		1909
Kern Trading and Oil Co	Sec. 31, T. 20 S., R. 15 E.	1					
Valley Oil Co	Sec. 32, T. 20 S., R. 15 E.	1					1909
Elaine Oil Co	Sec. 12, T. 21 S., R. 14 E.					1	1909
Fifty-seven Oil Co	Sec. 12, T. 21 S., R. 15 E.	1					
Coalinga Great Western Co	do	1					1909
Coalinga Unity Co	do					1	1909
Coalinga Twelve Co	do					1	1909
California Oil and Gas Co	Sec. 6, T. 21 S., R. 15 E.	1	1	1	1		1907
Lucile Oil Co	do	1		1	2		1906
Shreeves Oil Co	do	1					1907
Muriel Oil Co	do	1					1907
Jefferson Oil Co	do	1			1	1	1908

Oil companies and number of wells in Coalinga district October 31, 1909—Continued.

Company.	Location.	Drilling wells.	Drilling wells suspended.	Producing wells suspended.	Producing wells.	Number of derricks, old and new.	Date.
WESTSIDE FIELD—continued.							
Sauer Dough Oil Co	Sec. 6, T. 21 S., R. 15 E.		1				1908
Amy Oil Co	do			1			1909
De Luxe Oil Co	do	1					1909
Coalinga Aladdin Oil Co	do			1			1909
Coalinga Red Top Oil Co	do	1					1909
Silver Tip Oil Co	do				1		1909
Blue Moon Oil Co	do	1					1909
Los Angeles Coalinga Oil Syndicate	do	1					1909
Marion Oil Co	do				1		1909
KREYENHAGEN FIELD.							
Boychester Oil Co	Sec. 18, T. 21 S., R. 15 E.					1	1909
Coalinga Hub Oil Co	Sec. 22, T. 21 S., R. 15 E.	1					1909
Coalinga Alpha Oil Co	do	1					1909
Azores Oil Co	Sec. 26, T. 21 S., R. 15 E.	1				1	1909
Glaydas Oil Co	do						1909
People's Associated Oil Co	Sec. 32, T. 21 S., R. 15 E.	1					1908
Express Oil Co	Sec. 24, T. 21 S., R. 15 E.	1				1	
Golden Crest Oil Co	Sec. 12, T. 22 S., R. 15 E.	1					1907
Robertson Oil Co	Sec. 6, T. 22 S., R. 16 E.					1	1909
British Cons. Oil Corp., Ltd	do						1909
Southern Coalinga Oilfields	do						1909
Moslem Oil Co	Sec. 20, T. 22 S., R. 16 E.					1	1909
Black Mountain Oil Co	Sec. 33, T. 22 S., R. 16 E.			2			1900
Smith & Byrner	do	1					1909
Lake View Oil Co	Sec. 26, T. 21 S., R. 17 E.		1				1908
Esperanza Land and Oil Co	Sec. 30, T. 21 S., R. 15 E.	1					1905
Jacalitos Oil Co	do		1				1907
Mount Hamilton Land and Oil Co	Sec. 14, T. 21 S., R. 14 E.		1				1903
Blair Oil Co	Sec. 14, T. 21 S., R. 15 E.	1					1908
Cornelius Oil Co	Sec. 4, T. 23 S., R. 16 E.						
El Cerrito Oil Co	Sec. 14, T. 23 S., R. 17 E.	1					1907
Art Anderson et al	Sec. 22, T. 23 S., R. 17 E.					1	1909
Uno Oil Co	Sec. 26, T. 23 S., R. 17 E.						
Normandie Oil Co	Sec. 30, T. 23 S., R. 18 E.	1					1909
Etsenhausen Oil Co	Sec. 27, T. 24 S., R. 18 E.					1	
Best Yet Oil Co						1	
Baird Oil Co		1					1909
Bohemian Oil Co		1					1909
Echo Oil Co						1	
Portola Oil Co		1					1909
Coalinga South Pole Oil Co						1	
NORTHWEST FIELD.							
Michigan Oil and Development Co	Sec. 8, T. 19 S., R. 13 E.		1				1907
Wartham Oil Co	Sec. 33, T. 20 S., R. 13 E.		1				1908
SUMMARY OF FIELDS.							
Oil City field					18		
Eastside field		48	19	15	228	17	
Westside field		80	13	55	304	29	
Kreyenhagen field		15	3	2		10	
Northwest field			2				
		143	37	72	550	56	

CHEMICAL AND PHYSICAL EXAMINATION OF THE PETROLEUMS OF THE COALINGA DISTRICT.

By Irving C. Allen.

METHODS OF EXAMINATION.

Specific gravity.—The specific gravity was determined by means of a Westphal balance when the quantity of the oil was more than 9 cubic centimeters, and by means of a Nicoll picnometer when the quantity was less. The Westphal balance is well known, and no description is necessary.

As the Nicoll picnometer is of special though simple construction, it is probably less well known, and a brief description is here given. Its accuracy with the lighter oils is unquestioned; with the more viscous oils some difficulty is encountered in drying the end tubes before the final weighings, but with care accurate results to the fourth decimal place can be attained. Its value lies in the ease with which it can be made and in the facility with which it can be used to determine the specific gravity of small quantities of liquids, even as little as 0.2 to 0.3 gram.

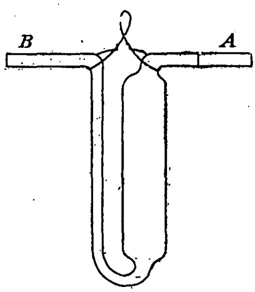


Figure 9.—Small picnometer.

It is made as follows: A quarter to sixteenth inch tube of soft glass, depending on the size of the picnometer desired, is drawn out in two places with an interval of about one inch into two tubes of capillary diameter. It will almost always occur that one of these capillary tubes will be of slightly greater diameter than the other, and this capillary (A) is bent through an angle of 90°. The other or smaller capillary (B) is bent through 180° back along the body of the tube to a point opposite the first, then again through 90° away from the first, as shown in figure 9. The ends of A and B are cut off at about equal distances from the body of the tube and carefully smoothed off in a flame. A mark is etched on the larger tube (A) about midway between the bend and the end. The whole is fitted with a fine platinum wire so that it can be suspended from the balance arm. A rubber cap is made for tube A.

Now the tube with cap is weighed empty (W_1). The cap is removed and the tube is then drawn full of distilled water at a temperature of 15° C., and the water, with the aid of a bit of filter paper applied to B, is drawn accurately to the mark on A. The cap is replaced and the tube and contents weighed (W_2). $W_2 - W_1$ gives the water content of the picnometer at 15° C.

The same procedure with an oil gives W_3, and $W_3 - W_1$ gives the oil content at 15° C; and $\frac{W_3 - W_1}{W_2 - W_1}$ gives the specific gravity of the oil at 15° C.

Because the Baumé scale for indicating gravity, in the writer's opinion a deplorable system, is in common use, and for the convenience of those unfamiliar with the specific gravity, the corresponding Baumé degree is set opposite each specific-gravity degree.

Flash point.—The flash point was determined in an Abel or a Pensky closed tester, the instrument being carefully screened to avoid air currents.

Calorific value.—The calorific value was determined in a Berthelot combustion bomb (Dinsmore-Atwater model)—that is, by burning a small quantity of the oil in pure oxygen under a pressure of 30 atmospheres. This method is rapid and accurate and is in general use.

Sulphur.—The sulphur was determined by carefully washing out the contents of the bomb, after the combustion, with distilled water, precipitating the sulphuric acid therein with barium chloride in the usual way, and calculating the percentage of sulphur.

Fractional distillation.—For the proximate analysis or fractional distillation the form and size of retort recommended by Engler (Redwood on Petroleum) was adopted, with the change, however, that the side tube turns upward instead of downward at an angle of 75° with the neck for a length of 4 centimeters, and is then bent downward to the original angle of 75°. This, with care in adjusting the flame, prevents the bumping over of the retort contents and insures a cleaner distillate. First the oil is distilled under normal pressure to 200° to 250° C. (Cracking begins at about 330° C.) The receiver is then replaced with a fresh one and the distillation continued under a vacuum approaching 40 centimeters of mercury pressure, the best attainable with the water vacuum pump at hand, to a temperature of 330° to 350° C.—that is, until practically all liquid is over and only a hard brittle mass of asphaltum remains when cooled. From 330° up cracking sometimes occurs, though not always, the oils differing markedly in this respect from the Pennsylvania oils, and as a result practically all available "oils" are separated from the asphaltum and sediment.

These distillations are united and carefully fractioned in the ordinary Engler retort, taking fractions every 25° C. according to the procedure of Engler. The specific gravity of these fractions is also determined. The distillations are done by weight, retorts and all receivers being weighed empty and with contents, thus reducing the loss to a minimum—that is, from 1 per cent to 4 and 5 per cent with the more volatile oils.

This interrupted or intermittent Engler method of distillation leaves much to be desired. Mixtures of bodies so closely resembling one another in all their properties as those constituting crude petroleum are very difficult of separation, and the values given in the accompanying tables can not be considered as absolute, but will give a very fair idea of the technological constituents of these petroleums, and will aid in the more elaborate separations to be carried on later.

The method of continuous or uninterrupted distillation now considered to yield the most uniform results will be adopted in the bulletins to follow.

RESULTS OF EXAMINATION.

The table that follows shows in detail the results of the examination of these oils. In the columns under the headings "Naphtha," "Burning oil," "Lubricating oil," "Asphaltum," and "Paraffin wax," the results of the fractional distillation are summarized in order to give an idea of the bodies of economic importance to be found in the distillates.

The sulphur and water content of these oils is low, comparing most favorably with that of other California oils, and the calorific value is uniform and good.

Results of chemical and physical examination of the petroleums of the Coalinga district.

Laboratory No.	Lease.	Well No.	Location.	Geologic zone.	Date of sampling (1907).	Specific gravity at 15° C.	Baumé at 60° F.	Flash point.
							°B.	°F.
1	California Oilfields, Ltd.	1	Sec. 14, T. 19 S., R. 15 E.	Top of D	Oct. 31	0.9326	20.2	92
2	Peerless	7	Sec. 22, T. 19 S., R. 15 E.	do	do	0.9335	20.0	72
3	Do	11	do	Bottom of D	do	0.9493	17.6	128
4	Sauer Dough (A.O.)	5	do	D	do	0.9220	22.0	63
5	A. O. National 30	1	do	D	do	0.9291	20.8	87
7	Carabou	1	do	Top of D	do	0.9215	22.1	60
8	Record	1	do	Bottom of D	Oct. 30	0.9393	19.2	121
10	Standard	{27 28	Sec. 28, T. 19 S., R. 15 E.	C and D	do	0.9243	21.6	75
12	California Oilfields, Ltd.	13	Sec. 27, T. 19 S., R. 15 E.	C	do	0.8718	30.7	Below 53
14	Do	31	do	D	Oct. 31	0.9097	24.2	Below 53
16	California Monarch	1	Sec. 26, T. 19 S., R. 15 E.	Top of D	do	0.9324	20.3	111
17	California Oilfields, Ltd.	8	Sec. 34, T. 19 S., R. 15 E.	B	do	0.9299	20.7	66
19	W. K.	1	Sec. 2, T. 20 S., R. 15 E.	Top of D	do	0.9305	20.6	87
21	Coast Range (Old Home).	3	Sec. 17, T. 19 S., R. 15 E.	Chico	Oct. 10	0.8533	34.2	Below 53
23	Coalinga	7	Sec. 20, T. 19 S., R. 15 E.	do	do	0.8519	34.5	Below 53
24	Home	5	do	do	do	0.8570	33.5	Below 53
25	Hanford	7	Sec. 28, T. 19 S., R. 15 E.	C and D	do	0.9439	18.4	115
28	Standard	11	do	do	do	0.9416	18.8	Below 65
31	Commercial Petroleum.	1	Sec. 31, T. 19 S., R. 15 E.	B	do	0.9341	20.0	92
32	Do	9	do	B	do	0.9401	19.0	96
33	Maine State or Guthrey 3.	3	do	Top of B	do	0.9568	16.4	+167
35	California Monarch (Maine State).	8	do	B and top of D	do	0.9451	18.2	150
36	Confidence	11	do	B	do	0.9615	15.7	Above 167
39	Kern Trading	3	do	B	do	0.9457	18.2	131
40	Mercantile Crude	1	Sec. 6, T. 20 S., R. 15 E.	Top of B	do	0.9559	16.5	Above 167
41	Do	4	do	Second sand in B.	do	0.9706	14.3	Above 167
42	York Coalinga	2	do	B	do	0.9672	14.8	Above 167
43	New San Francisco Crude.	5	do	B	do	0.9738	13.8	Above 167
45	Esperanza	6	do	Top of B	do	0.9472	17.9	130
47	Zier	4	Sec. 1, T. 20 S., R. 14 E.	B	Oct. 9	0.9760	13.5	Above 167
48	Do	5	do	B	do	0.9662	15.0	Above 167
50	R. H. Herron	1	do	B	do	0.9771	13.3	Above 167
53	Pennsylvania Coalinga.	3	do	Top of B	Oct. 10	0.9503	17.4	153
55	Shawmut	2	Sec. 12, T. 20 S., R. 14 E.	Bottom of B	Oct. 9	0.9499	17.5	155
56	Section Seven	4	Sec. 7, T. 20 S., R. 15 E.	B	Oct. 10	0.9501	17.5	146
58	Coalinga Pacific	1	do	Top of B	Oct. 9	0.9526	17.1	145
60	Union	2	Sec. 13, T. 20 S., R. 14 E.	B	do	0.9750	13.6	Above 167
61	Do	4	do	Top of B	do	0.9655	15.0	Above 167
62	Do	9	do	Probably B	do	0.9715	14.1	Above 167
64	Coalinga Petroleum.	4	Sec. 14, T. 20 S., R. 14 E.	B	do	0.9810	12.7	Above 167
65	New Home	1	do	B	do	0.9783	13.1	Above 167
66	Do	2	do	B	do	0.9777	13.2	......
68	Coalinga Western	3	Sec. 23, T. 20 S., R. 14 E.	B	do	0.9820	12.6	Above 167
72	St. Paul Fresno	4	do	B	do	0.9833	12.4	Above 167

Results of chemical and physical examination of the petroleums of the Coalinga district—Continued.

Laboratory No.	Lease.	Well No.	Location.	Geologic zone.	Date of sampling (1907).	Specific gravity at 15° C.	Baumé at 60° F.	Flash point.
							°*B*.	°*F*.
73	Inca	5	Sec. 24, T. 20 S., R. 14 E.	B	Oct. 9	0.9581	16.2	+167
75	Do	7	do	B	do	0.9601	15.9	Above 167
77	Wabash	8	do	B	do	0.9583	16.2	Above 167
78	Do	10	do	B	do	0.9585	16.2	Above 167
79	Do	6	do	B	do	0.9581	16.2	+167
80	Cal. and N. Y. or P. M. & D. Co.	1	Sec. 12, T. 20 S., R. 14 E.	B and possibly top of D.	do	0.9517	17.2	148
81	Do	4	do	B	do	0.9670	14.8	Above 167
82	Fresno and San Francisco.	4	Sec. 1, T. 20 S., R. 14 E.	B	Oct. 10	0.9729	14.0	Above 167
83	Lucile	1	Sec. 6, T. 21 S., R. 15 E.	Lower part of upper section of D.	do	0.9533	17.0	131

Results of chemical and physical examination of the petroleums of the Coalinga district—Continued.

Laboratory No.	Lease.	Well No.	Calorific value.	Sulphur.	Water.	Fractional distillation (not refined).							
						75°-100°.		100°-125°.		125°-150°.		150°-175°.	
						Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.
				P. ct.	*P. ct.*								
1	California Oilfields Ltd	1	10,601	0.40	0.05					0.7454	0.33	0.7800	0.95
2	Peerless	7	10,584	0.40	0.00							0.7994	5.65
3	Do	11	10,592	0.60	0.05							0.7824	0.36
4	Sauer Dough (A.O.)	5	10,608	0.37	0.00	0.8652	0.25	07347	0.88	0.7755	2.60	0.7943	3.67
5	A. O. National 30	1	10,656	0.39	0.12				0.36	0.7615	1.23	0.7908	2.52
7	Carabou	1	10,632	0.39	0.00			0.7406	0.39	0.7590	1.39	0.7933	5.15
8	Record	1	10,596	0.53	0.12						0.23	0.8252	0.76
10	Standard	{27 28}	10,599	0.37	0.00		0.30	0.7268	0.75	0.7682	1.80	0.7903	5.27
12	California Oilfields, Ltd	13	10,685	0.35	0.00	0.6860	2.97	0.7173	4.22	0.7526	6.16	0.7814	5.56
14	Do	31	10,619	0.35	0.00			0.7231	0.40	0.7467	1.66	0.7846	4.57
16	California Monarch	1	10,576	0.38	0.00				0.47	0.7513	0.87	0.7861	2.14
17	California Oilfields, Ltd	8	10,581	0.44	0.12	0.7412	0.73	0.7518	0.65	0.7702	0.73	0.7869	2.54
19	W. K	1	10,605	0.40	0.00			0.7604	0.51	0.7764	0.25	0.7963	3.08
21	Coast Range (Old Home)	3	10,657		0.00	0.7719	0.67	0.7742	10.64	0.8075	18.53	0.8290	15.85
23	Coalinga	7	10,748	0.03	0.00	0.7522	1.83	0.7768	5.35	0.8100	18.01	0.8309	15.51
24	Home	5	10,683	0.05	0.00	0.7308	0.63	0.7688	3.97	0.8032	21.72	0.8294	16.92
25	Hanford	7	10,577	0.51	0.00			0.7536	0.45	0.7769	0.67	0.7960	0.97
28	Standard	11	10,515	0.50	0.00			0.7143	0.58	0.7566	0.90	0.7785	1.68
31	Commercial Petroleum	1	10,563	0.47	0.00				0.16	0.7726	0.48	0.7991	1.23
32	Do	9	10,633	0.50	0.00			0.7424	0.78	0.7753	0.73	0.7929	0.95
33	Maine State or Guthrey 3	3	10,502	0.48	0.10	0.7441	0.36		0.14	0.7632	0.29	0.8025	0.72
35	California Monarch (Maine State)	8	10,514	0.48	0.60							0.7924	0.74
36	Confidence	11	10,493	0.55	0.09								
39	Kern Trading	3	10,517	0.60	0.00	0.7165	0.95	0.7510	1.74	0.7823	2.45	0.7981	2.84
40	Mercantile Crude	1	10,495	0.63	0.00							0.8016	0.59
41	Do	4	10,432	0.71	0.00	0.7176	0.38	0.7463	0.38		0.33	0.7889	0.22
42	York Coalinga	2	10,456	0.70									0.32
43	New San Francisco Crude	5	10,305	0.70	0.87								
45	Esperanza	6	10,523	0.51	0.00		0.11	0.7790	0.47	0.8022	0.29	0.8150	1.06
47	Zier	4	10,242	0.72	0.00							0.8294	0.46
48	Do	5	10,448	0.64	Trace.								
50	R. H. Herron	1	10,365	0.73	0.00								
53	Pennsylvania Coalinga	3	10,545	0.51	0.00							0.8023	1.39
55	Shawmut	2	10,539	0.54	0.00					0.7979	0.27	0.7980	0.60
56	Section Seven	4	10,508	0.54	Trace.					0.7870	0.65	0.8158	0.86
58	Coalinga Pacific	1	10,478	0.57	0.00								
60	Union	2	10,422	0.72	0.00								
61	Do	4	10,408	0.72	0.00							0.8268	0.54
62	Do	9	10,446	0.71	Trace.								
64	Coalinga Petroleum	4	10,402	0.69	0.11	0.7060	0.32	0.7369	0.37	0.7641	0.48	0.7853	0.37
65	New Home	1	10,369	0.70	0.82								
66	Do	2	10,361	0.71	0.75							0.7879	0.28
68	Coalinga Western	3	9,887	0.70	5.36								
72	St. Paul Fresno	4	10,356	0.76	0.30								
73	Inca	5	10,491	0.60	0.00							0.8087	0.35
75	Do	7	10,505	0.59	0.00								
77	Wabash	8	10,497	0.59	0.09					0.7951	0.41	0.8046	0.37
78	Do	10	10,480	0.59	0.06					0.8036	0.12	0.8036	0.34
79	Do	6	10,463	0.60	0.32								
80	Cal. and N. Y. or P. M. & D. Co	1	10,548	0.54	0.06							0.7716	0.45
81	Do	4	10,432	0.68	0.12								
82	Fresno and San Francisco	4	10,415	0.77	0.05							0.7872	0.17
83	Lucile	1	10,416	0.54	0.74			0.7800	0.40	0.7886	0.45	0.7986	0.59

Results of chemical and physical examination of the petroleums of the Coalinga district—Continued.

Laboratory No.	Lease.	Well No.	Fractional distillation (not refined)—Continued.									
			175°-200°.		200°-225°.		225°-250°.		250°-275°.		275°-300°.	
			Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.
1	California Oilfields, Ltd.	1	0.8152	3.81	0.8400	4.38	0.8606	5.86	0.8754	6.29	0.8904	8.81
2	Peerless	7	0.8269	1.59	0.8386	5.00	0.8630	5.58	0.8801	7.32	0.8962	10.67
3	Do	11	0.8104	1.75	0.8284	2.07	0.8536	4.85	0.8726	6.87	0.8897	6.30
4	Sauer Dough(A.O.)	5	0.8229	5.03	0.8428	5.45	0.8650	6.87	0.8808	8.58	0.9002	11.25
5	A. O. National 30	1	0.8105	4.62	0.8404	6.05	0.8633	6.77	0.8788	7.06	0.8958	10.52
7	Carabou	1	0.8202	4.57	0.8449	4.76	0.8647	5.28	0.8809	7.60	0.8945	6.35
8	Record	1	....	1.83	0.8492	4.48	0.8679	6.30	0.8825	6.98	0.8990	9.80
10	Standard	{27, 28}	0.8215	3.99	0.9045	5.27	0.8656	8.13	0.8833	8.96	0.8971	8.50
12	California Oilfields, Ltd.	13	0.8053	5.02	0.8249	4.22	0.8444	5.24	0.8626	5.89	0.8791	5.37
14	Do	31	0.8067	3.92	0.8302	3.36	0.8527	5.42	0.8703	6.83	0.8841	8.28
16	California Monarch.	1	0.8159	3.96	0.8398	5.30	0.8682	7.74	0.8824	9.64	0.8978	8.69
17	California Oilfields, Ltd.	8	0.8079	2.54	0.8365	5.52	0.8585	6.17	0.8756	8.21	0.8918	9.15
19	W. K.	1	0.8305	3.97	0.8495	4.54	0.8678	8.96	0.8860	8.58	0.9002	10.23
21	Coast Range (Old Home)	3	0.8469	8.56	0.8704	9.83	0.8983	9.57	0.9145	8.69	0.9223	5.22
23	Coalinga	7	0.8537	9.35	0.8747	7.79	0.8987	9.21	0.9192	9.00	0.9288	4.26
24	Home	5	0.8473	9.33	0.8727	9.89	0.9004	12.05	0.9178	7.45	0.9272	4.66
25	Hanford	7	0.8216	2.60	0.8546	2.38	0.8693	7.07	0.8899	6.32	0.9047	7.89
28	Standard	11	0.8159	2.91	0.8449	2.97	0.8652	5.29	0.8859	7.10	0.9119	7.94
31	Commercial Petroleum	1	0.8233	3.05	0.8509	5.40	0.8682	5.94	0.8867	8.23	0.9026	8.66
32	Do	9	0.8154	2.40	0.8410	4.47	0.8636	6.21	0.8795	7.16	0.8967	9.61
33	Maine State or Guthrey 3	3	0.8130	1.37	0.8418	3.66	0.8646	6.54	0.8822	5.97	0.8985	9.64
35	California Monarch (Maine State)	8	0.8180	1.73	0.8352	2.91	0.8584	3.90	0.8774	6.51	0.8945	7.50
36	Confidence	11	0.8123	0.47	0.8370	1.36	0.8606	3.46	0.8759	4.65	0.8946	7.65
39	Kern Trading	3	0.8266	3.47	0.8462	4.74	0.8648	6.87	0.8851	9.24	0.9018	8.06
40	Mercantile Crude	1	0.8208	1.23	0.8456	2.45	0.8671	4.15	0.8828	6.07	0.8986	6.55
41	Do	4	0.8225	1.14	0.8504	1.31	0.8632	3.43	0.8811	6.26	0.8978	8.71
42	York Coalinga	2	0.8314	0.53	0.8645	2.65	0.8730	3.02	0.8864	5.50	0.9032	6.09
43	New San Francisco Crude	5	0.8646	0.41	0.8602	1.02	0.8731	3.46	0.8882	3.51	0.9039	9.15
45	Esperanza	6	0.8443	1.53	0.8501	3.00	0.8689	6.23	0.8902	7.76	0.9046	7.52
47	Zier	4	0.8388	0.87	0.8612	0.93	0.8749	2.15	0.8865	5.57	0.9030	7.48
48	Do	5	0.8207	0.36	0.8519	1.19	0.8713	4.97	0.8866	5.03	0.9015	6.40
50	R. H. Herron	1	....	......	0.8505	0.40	0.8725	1.48	0.8863	4.51	0.8965	5.99
53	Pennsylvania Coalinga	3	0.8297	1.51	0.8503	3.25	0.8696	6.21	0.8868	5.80	0.9037	8.07
55	Shawmut	2	0.8253	2.33	0.8488	3.35	0.8635	3.95	0.8844	7.41	0.9042	8.70
56	Section Seven	4	0.8365	2.16	0.8553	3.07	0.8754	6.68	0.8919	6.52	0.9084	7.60
58	Coalinga Pacific	1	0.8181	1.72	0.8438	3.11	0.8669	5.32	0.8853	5.89	0.9014	8.39
60	Union	2	0.8093	0.47	0.8522	0.99	0.8688	2.10	0.8853	5.49	0.9027	6.89
61	Do	4	0.8292	1.12	0.8504	1.21	0.8589	3.88	0.8857	5.88	0.9031	6.69
62	Do	9	0.8352	0.50	0.8544	0.90	0.8675	3.19	0.8852	4.98	0.9029	7.95
64	Coalinga Petroleum	4	0.8326	0.96	0.8611	1.23	0.8755	2.56	0.8884	4.59	0.9042	7.68
65	New Home	1	....	Trace.	0.8166	0.36	0.8598	0.72	0.8793	4.31	0.8985	6.21
66	Do	2	0.8064	0.42	0.8412	0.51	0.8674	2.25	0.8865	3.55	0.8989	6.32
68	Coalinga Western	3	....	......	0.8553	0.54	0.8786	2.03	0.8877	3.62	0.9007	5.74
72	St. Paul Fresno	4	....	......	0.8445	0.74	0.8752	1.08	0.8865	4.52	0.9014	4.37
73	Inca	5	0.8218	1.05	0.8491	2.10	0.8685	4.90	0.8884	7.23	0.9052	7.12
75	Do	7	0.8234	1.32	0.8478	1.45	0.8662	4.15	0.8822	5.77	0.9007	6.81
77	Wabash	8	0.8271	0.42	0.8444	2.02	0.8634	5.06	0.8828	5.85	0.8992	7.96
78	Do	10	0.8335	0.46	0.8475	1.94	0.8635	2.79	0.8821	5.54	0.8984	8.16
79	Do	6	0.8235	0.53	0.8481	2.33	0.8634	3.75	0.8802	5.07	0.8973	6.97
80	Cal. and N. Y. or P. M. & D. Co.	1	0.8076	1.23	0.8404	2.63	0.8590	4.15	0.8811	7.40	0.8984	7.12
81	Do	4	....	......	0.8522	0.90	0.8614	2.08	0.8797	5.78	0.8981	7.46
82	Fresno and San Francisco	4	0.8277	0.30	0.8496	0.50	0.8691	2.03	0.8811	5.58	0.8968	6.38
83	Lucile	1	0.8191	0.89	0.8443	2.33	0.8683	4.71	0.8817	4.76	0.8967	6.35

Results of chemical and physical examination of the petroleums of the Coalinga district—Continued.

Laboratory No.	Lease.	Well No.	Fractional distillation (not refined)—Continued.							
			300°-325°.		325°-350°.		350°-375°.		375°-400°.	
			Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.	Sp. g.	P. ct.
1	California Oilfields, Ltd.	1	0.9050	8.05	0.9147	7.53	0.9217	19.82	0.9382	3.76
2	Peerless	7	0.9097	8.69	0.9212	36.06	....	....	....	....
3	Do	11	0.9040	8.22	0.9189	9.20	0.9282	11.93	0.9387	9.61
4	Sauer Dough (A.O.)	5	0.9123	8.23	0.9214	8.00	0.9303	17.35	....	....
5	A. O. National 30	1	0.9104	9.22	0.9180	18.66	0.9375	15.78	....	....
7	Carabou	1	0.9062	6.39	0.9183	7.98	0.9138	15.38	0.9332	3.80
8	Record	1	0.9118	8.65	0.9154	10.71	0.9090	11.09	0.9563	4.94
10	Standard	{27 28}	0.9120	8.43	0.9176	19.80	0.9331	9.90	....	....
12	California Oilfields, Ltd.	13	0.8926	4.97	0.9063	7.67	0.9141	11.84	....	....
14	Do	31	0.8947	7.03	0.9083	9.34	0.9145	11.90	0.9230	6.32
16	California Monarch	1	0.9103	8.38	0.9157	15.41	0.9233	18.50	....	....
17	California Oilfields, Ltd.	8	0.9034	9.08	0.9078	14.89	0.9160	15.32	0.9632	5.38
19	W. K.	1	0.9112	8.38	0.9184	17.53	0.9421	11.32	....	....
21	Coast Range (Old Home)	3	0.9323	2.34	0.9522	1.34	....	(a)	....	(a)
23	Coalinga	7	0.9384	2.30	....	....	....	(a)	....	(a)
24	Home	5	0.9334	3.20	0.9419	1.19	....	(a)	....	(a)
25	Hanford	7	0.9186	10.12	0.9303	9.08	0.9386	17.18	....	....
28	Standard	11	0.9164	7.56	0.9298	9.69	0.9371	8.97	0.9513	4.97
31	Commercial Petroleum	1	0.9186	10.91	0.9226	13.96	0.9308	5.46	....	....
32	Do	9	0.9100	7.49	0.9084	30.18	0.9469	7.60	....	....
33	Maine State or Guthrey 3	3	0.9148	9.42	0.9234	20.78	0.9442	16.03	....	....
35	California Monarch (Maine State)	8	0.9092	7.65	0.9233	8.59	0.9313	9.08	0.9442	7.21
36	Confidence	11	0.9117	7.35	0.9250	7.79	0.9363	15.26	0.9483	8.59
39	Kern Trading	3	0.9175	10.27	0.9265	20.78	0.9557	7.50	....	....
40	Mercantile Crude	1	0.9126	7.98	0.9270	6.97	0.9358	8.41	0.9492	4.25
41	Do	4	0.9133	11.00	0.9172	26.89	0.9469	4.35	....	....
42	York Coalinga	2	0.9160	7.57	0.9330	8.84	0.9433	7.04	....	....
43	New San Francisco Crude	5	0.9200	11.29	0.9300	20.65	0.9700	5.64	....	....
45	Esperanza	6	0.9204	9.23	0.9302	11.52	0.9381	12.57	0.9680	2.94
47	Zier	4	0.9184	8.93	0.9335	11.14	0.9439	14.67	....	....
48	Do	5	0.9170	7.78	0.9336	9.75	0.9386	11.00	0.9580	4.66
50	R. H. Herron	1	0.9108	7.37	0.9254	10.34	0.9323	7.66	0.9454	5.83
53	Pennsylvania Coalinga	3	0.9206	7.08	0.9330	10.10	0.9360	11.32	....	....
55	Shawmut	2	0.9202	7.79	0.9333	9.57	0.9366	11.35	0.9543	4.06
56	Section Seven	4	0.9229	8.35	0.9350	5.93	0.9424	12.34	....	....
58	Coalinga Pacific	1	0.9182	8.92	0.9280	10.21	0.9367	12.70	0.9593	4.36
60	Union	2	0.9188	7.88	0.9348	10.28	0.9469	10.21	....	....
61	Do	4	0.9190	7.84	0.9294	11.49	0.9441	14.66	....	....
62	Do	9	0.9191	6.88	0.9329	7.62	0.9447	6.38	0.9528	2.80
64	Coalinga Petroleum	4	0.9201	9.07	0.9335	12.06	0.9486	14.41	0.9862	1.28
65	New Home	1	0.9112	6.47	0.9261	7.59	0.9367	9.85	0.9509	5.75
66	Do	2	0.9129	10.48	0.9285	9.31	0.9365	19.60	0.9844	1.26
68	Coalinga Western	3	0.9147	5.61	0.9289	8.14	0.9405	7.46	0.9523	4.97
72	St. Paul Fresno	4	0.9162	7.08	0.9291	8.90	0.9381	9.39	0.9680	4.18
73	Inca	5	0.9219	9.74	0.9362	7.53	0.9449	7.06	0.9567	2.80
75	Do	7	0.9168	8.83	0.9285	11.60	0.9390	13.39	0.9649	1.09
77	Wabash	8	0.9149	9.71	0.9251	12.10	0.9384	21.08	....	....
78	Do	10	0.9159	9.13	0.9299	7.42	0.9394	10.79	0.9524	4.16
79	Do	6	0.9121	7.45	0.9264	9.67	0.9356	12.68	0.9543	6.50
80	Cal. and N. Y. or P. M. & D. Co.	1	0.9128	8.02	0.9268	8.91	0.9352	12.95	0.9436	11.88
81	Do	4	0.9129	6.83	0.9261	7.86	0.9395	9.42	0.9461	8.33
82	Fresno and San Francisco	4	0.9115	6.72	0.9254	8.62	0.9331	14.58	0.9558	6.17
83	Lucile	1	0.9088	6.45	0.9229	7.78	0.9349	9.82	0.9452	6.19

[a] See column headed "Paraffin wax."

Results of chemical and physical examination of the petroleums of the Coalinga district—Continued.

Laboratory No.	Lease.	Well No.	Naphtha[a] (below 150° C.).	Burning oil[a] (150°-300° C.).	Lubricating oil[a] (300°-400° C.).	Asphaltum (above 400° C.).	Paraffin wax.	Residue.	Loss.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1	California Oilfields, Ltd	1	0.33	30.10	39.16	25.30	....	3.57	1.49
2	Peerless	7	0.00	35.71	44.75	8.83	....	5.94	4.77
3	Do	11	0.00	22.20	38.96	31.97	....	5.58	1.24
4	Sauer Dough (A. O.)	5	3.73	40.85	33.58	16.22	....	2.54	3.08
5	A. O. National 30	1	1.59	37.54	43.66	8.07	....	4.47	4.55
7	Carabou	1	1.78	33.71	33.55	24.62	....	5.33	1.01
8	Record	1	0.23	30.15	35.39	28.24	....	3.86	2.01
10	Standard	{27, 28}	2.85	40.12	38.13	10.09	....	5.27	3.54
12	California Oilfields, Ltd	13	13.35	31.30	24.48	20.31	....	6.89	3.67
14	Do	31	2.06	32.38	34.59	25.10	....	4.27	1.60
16	California Monarch	1	1.34	37.47	42.29	12.65	....	3.32	2.93
17	California Oilfields, Ltd	8	2.11	34.13	44.67	12.92	....	2.25	3.92
19	W. K.	1	0.76	39.36	37.23	17.02	....	1.92	3.71
21	Coast Range (Old Home)	3	29.84	57.72	3.68	2.68	3.54	1.20	1.34
23	Coalinga	7	25.19	55.12	2.30	8.12	4.47	1.62	3.18
24	Home	5	26.32	60.30	4.39	1.89	4.18	1.60	1.32
25	Hanford	7	1.12	27.23	36.38	30.65	....	1.79	2.83
28	Standard	11	1.48	27.89	31.19	36.15	....	1.42	1.87
31	Commercial Petroleum	1	0.64	32.51	30.33	28.45	....	6.04	2.03
32	Do	9	1.51	30.80	45.27	14.87	....	4.03	3.52
33	Maine State or Guthrey 3	3	0.79	27.90	46.23	17.83	....	3.59	3.66
35	California Monarch (Maine State)	8	0.00	23.29	32.53	41.07	....	1.53	0.98
36	Confidence	11	0.00	17.59	38.99	40.68	....	1.84	0.81
39	Kern Trading	3	5.14	35.22	38.55	14.30	....	3.00	3.79
40	Mercantile Crude	1	0.00	21.04	27.61	48.75	....	1.86	0.74
41	Do	4	1.09	21.07	42.24	27.33	....	4.90	3.37
42	York Coalinga	2	0.00	18.11	23.45	55.95	....	1.75	0.74
43	New San Francisco Crude	5	0.00	17.55	37.58	38.71	....	3.05	2.24
45	Esperanza	6	0.87	27.10	36.26	32.19	....	2.23	1.35
47	Zier	4	0.00	17.46	34.74	43.16	....	2.55	2.09
48	Do	5	0.00	17.95	33.19	45.16	....	1.97	1.73
50	R. H. Herron	1	0.00	12.38	31.20	49.46	....	5.48	1.48
53	Pennsylvania Coalinga	3	0.00	26.23	28.50	39.35	....	4.82	1.10
55	Shawmut	2	0.27	26.34	32.77	37.43	....	2.38	0.81
56	Section Seven	4	0.65	26.89	26.62	42.35	....	2.26	1.23
58	Coalinga Pacific	1	0.00	24.43	36.19	36.13	....	1.72	1.53
60	Union	2	0.00	15.94	28.37	53.77	....	0.40	1.52
61	Do	4	0.00	19.32	33.99	42.36	....	2.50	1.83
62	Do	9	0.00	17.52	23.68	56.78	....	1.12	0.90
64	Coalinga Petroleum	4	1.17	17.39	36.82	40.13	....	1.87	2.51
65	New Home	1	0.00	11.60	29.66	54.64	....	2.31	0.97
66	Do	2	0.00	13.33	40.65	41.53	....	1.82	1.92
68	Coalinga Western	3	0.00	11.93	26.18	54.54	....	1.27	0.72
72	St. Paul Fresno	4	0.00	10.71	29.55	57.42	....	0.59	1.43
73	Inca	5	0.00	22.75	27.13	48.43	....	1.05	0.64
75	Do	7	0.00	19.50	34.91	40.34	....	3.46	1.79
77	Wabash	8	0.41	21.68	42.89	30.33	....	2.53	2.07
78	Do	10	0.12	19.23	31.50	45.78	....	2.34	0.97
79	Do	6	0.00	18.65	36.30	41.99	....	1.69	1.05
80	California and N. Y. or P. M. & D. Co	1	0.00	22.98	41.76	31.62	....	2.30	1.28
81	Do	4	0.00	16.22	32.44	49.31	....	1.50	0.41
82	Fresno and San Francisco	4	0.00	14.96	36.09	44.84	....	2.79	1.27
83	Lucile	1	0.85	19.63	30.24	46.75	....	1.09	0.70

[a] These values represent the unrefined fractions.

PLATE XXIII.

PLATE XXIII.

CHICO (UPPER CRETACEOUS) FOSSILS.

VOLUTODERMA GABBI White.

	Page.
Figure 1. Natural size. Catalogue No. 20112, U.S.N.M.; copied from Bull. U. S. Geol. Survey No. 51, pl. 3, fig. 1. Found at locality 3 in the Coalinga district; also occurs as far north as Puget Sound region..........	60

PERISSOLAX BREVIROSTRIS Gabb.

Figure 2. Natural size. Copied from Whiteaves, Geol. Survey Canada, Mes. Foss., vol. 1, pt. 5, pl. 43, fig. 3, 1903. Found at locality 4 in the Coalinga district; a not uncommon species in the Chico of the Pacific coast..........	60

TELLINA? OOIDES Gabb.

Figure 3. Exterior of imperfect left valve, showing a little of the original shell material, altitude 43 mm., natural size. Catalogue No. 31075, U.S.N.M. Found at locality 3 in the Coalinga district, and at other Chico localities on the west coast..........	60

MACTRA ASHBURNERI Gabb.

Figure 4. Exterior of small right valve, longitude 28 mm., × 2. Catalogue No. 31074, U.S.N.M. Found at locality 3 in the Coalinga district; also common at most Chico localities..........	60

MEEKIA SELLA Gabb.

Figure 5. Exterior of cast of right valve, altitude 18 mm., × 2. Catalogue No. 31073, U.S.N.M. Locality 3 in Coalinga district; also common at other Chico localities on the Pacific coast..........	60

AVICULA LINGUÆFORMIS Evans and Shumard.

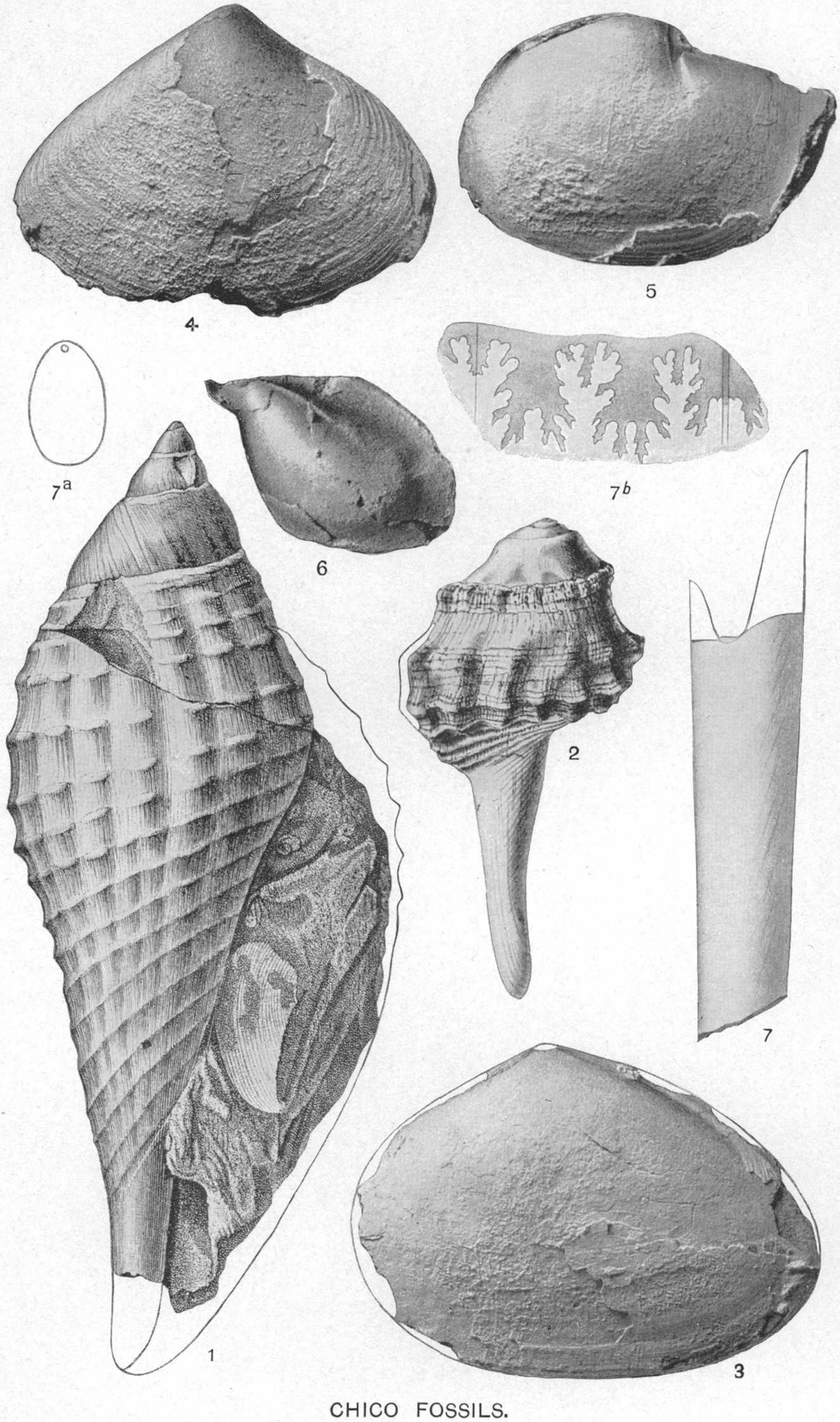
Figure 6. Exterior of cast of small left valve, altitude 14 mm., × 2. Catalogue No. 31076, U.S.N.M. Locality 11..........	60

BACULITES CHICOENSIS Trask.

Figure 7. Natural size. Copied from Gabb, Pal. California, vol. 1, pl. 17, figs. 27, 27a, 1864.

7a. Cross section. Idem, figure 27a.

7b. Septum. Idem, plate 14, figure 28b.



CHICO FOSSILS.

PLATE XXIV.

PLATE XXIV.

TEJON (EOCENE) PELECYPODA.

Venericardia planicosta Lamarck.

Page.

Figure 1. Left valve; longitude 84 mm. Eocene; Little Falls, Wash. Catalogue No. 164973, U.S.N.M. This is the most widespread and characteristic Eocene species in the world.

Corbula parilis Gabb.

Figure 2. Exterior of right valve restored, longitude 6 mm., × 2. Catalogue No. 165621, U.S.N.M. Locality 4801 70

Septifer dichotomus Gabb.

Figure 3. Exterior of right valve restored, longitude 22 mm., × 2. Catalogue No. 165623, U.S.N.M. Locality 4801 70

Ostrea idriaensis Gabb.

Figure 4. Exterior of right valve, longitude 27 mm., natural size. Catalogue No. 165674, U.S.N.M. Locality 4801 70

Figure 5. Exterior of left valve, longitude 35.5 mm., natural size. Catalogue No. 165674, U.S.N.M. Locality 4801. A common species in certain California Eocene localities 70

Spondylus carlosensis F. M. Anderson.

Figure 6. Exterior of imperfect specimen, altitude 20 mm., natural size. Catalogue No. 165628, U.S.N.M. Locality 4617. So far unknown outside the Coalinga district 70

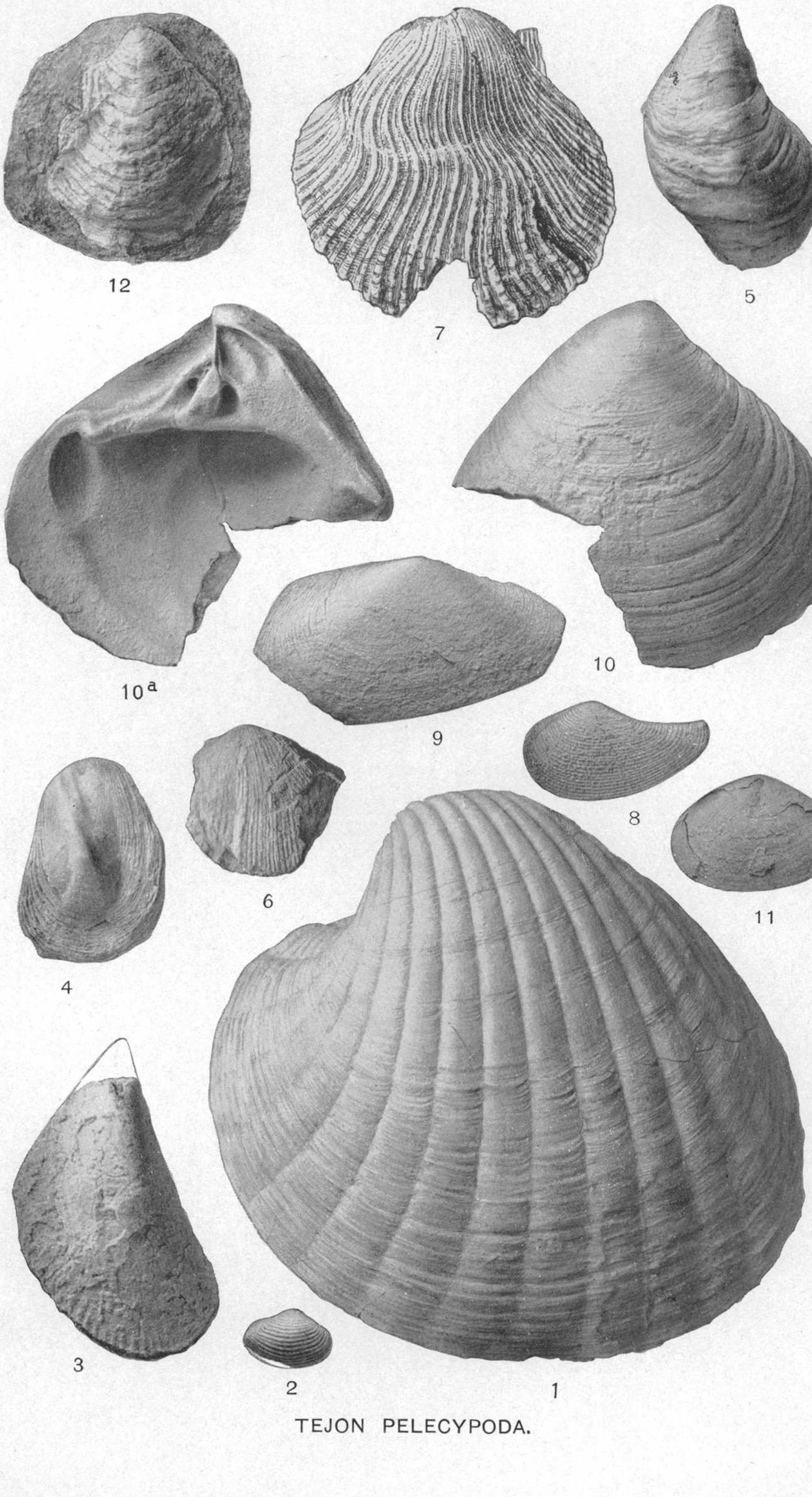
Figure 7. Type of species, natural size. Copied from Proc. California Acad. Sci., 3d ser., Geology, vol. 2, no. 2, pl. 13, fig. 1.

Leda gabbi Conrad.

Figure 8. Exterior of cast of left valve, longitude 13 mm., × 2. Catalogue No. 165662, U.S.N.M. Locality 5014. A common species in the Tejon 70

Tellina hornii Gabb.

Figure 9. Exterior of left valve of slightly imperfect specimen, longitude 42 mm., natural size. Catalogue No. 165656, U.S.N.M. Locality 4617. A species found at many Tejon localities 70



TEJON PELECYPODA.

CRASSATELLITES GRANDIS Gabb.

TELLINA JOAQUINENSIS Arnold.

OSTREA AVICULIFORMIS F. M. Anderson.

PLATE XXV.

PLATE XXV.

TEJON (EOCENE) PELECYPODA.

PLACUNANOMIA INORNATA Gabb.

Page.

Figure 1. Exterior of upper or convex valve, longitude 20 mm., × 2. Catalogue No. 165632, U.S.N.M. Locality 4801. A common form in the supposed brackish-water facies of the Tejon.............. 70

PECTEN PECKHAMI Gabb.

Figure 2. Exterior of gutta-percha cast of right valve, altitude 13 mm., natural size. Catalogue No. 165642, U.S.N.M. Locality 4616. Ranges from the Eocene to the Miocene................................ 70

2a. Exterior of left valve. Altitude 13.5 mm., natural size.

CARDIUM COOPERI Gabb.

Figure 3. Exterior of slightly broken right valve, altitude 21.5 mm., × 2. Catalogue No. 165637, U.S.N.M. Locality 4617. A species found most abundantly in the lower Eocene, but sometimes also in the Tejon.. 70

MERETRIX GABBI n. sp.

Figure 4. Exterior of right valve, longitude 29 mm., natural size. Type, Catalogue No. 165640, U.S.N.M. Locality 4801.................... 70

MERETRIX OVALIS Gabb.

Figure 5. Exterior of left valve, longitude 13 mm., × 2. Catalogue No. 165629, U.S.N.M. Locality 4801. A rather rare species................ 70

ORBITOLITES sp. *a*.

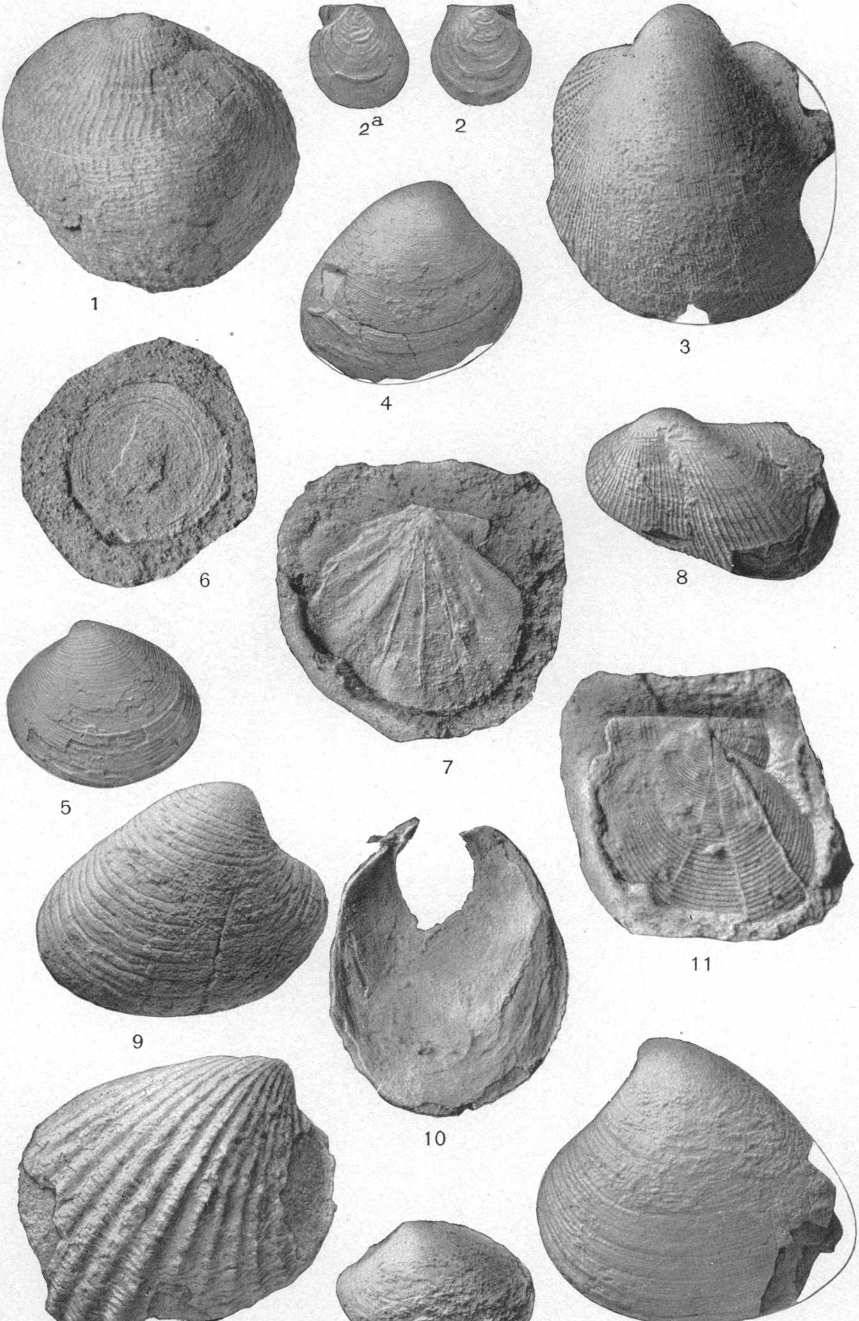
Figure 6. Top, maximum diameter 7.5 mm., × 3. Catalogue No. 165625, U.S.N.M. Locality 4617. A species of foraminifer common in the Tejon.. 70

PECTEN INTERRADIATUS Gabb.

Figure 7. Exterior of cast of right valve, altitude 9 mm., × 3. Catalogue No. 165667, U.S.N.M. Locality 5013. Also known in the shales of the Tejon at New Idria 70

BARBATIA MORSEI Gabb.

Figure 8. Exterior of slightly imperfect left valve, longitude 16.5 mm., × 2. Catalogue No. 165635, U.S.N.M. Locality 4801. A common species in the Eocene..................................... 70



TEJON PELECYPODA.

MERETRIX HORNII Gabb.

Page.

Figure 9. Exterior of right valve, longitude 20 mm., × 2. Catalogue No. 165641, U.S.N.M. Locality 4617. A common Eocene species......... 70

PLACUNANOMIA INORNATA Gabb.

Figure 10. Exterior of lower or flat valve, longitude 20 mm., × 2. Catalogue No. 165633, U.S.N.M. Locality 4609.............................. 70

PECTEN INTERRADIATUS Gabb.

Figure 11. Exterior of gutta-percha cast, showing external surface somewhat distorted, altitude 7 mm., × 4. Catalogue No. 165634, U.S.N.M. Locality 4616.. 70

VENERICARDIA ALTICOSTA Gabb.

Figure 12. Exterior of slightly imperfect specimen, longitude 41 mm., natural size. Catalogue No. 165626, U.S.N.M. Locality 4621. Much rarer than *V. planicosta* Lamarck.............................. 70

MERETRIX UVASANA Conrad.

Figure 13. Exterior of lower or flat valve, longitude 20 mm., × 2. Catalogue No. 165633, U.S.N.M. Locality 4619. A common Tejon species. 70

CRASSATELLITES GRANDIS Gabb.

Figure 14. Exterior of left valve, altitude 38 mm., natural size. Catalogue No. 165639, U.S.N.M. Locality 4619.......................... 70

PLATE XXVI.

PLATE XXVI.

TEJON (EOCENE) GASTEROPODA AND ECHINODERMATA.

CASSIDULUS CALIFORNICUS F. M. Anderson.

Page.

Figure 1. Top view of imperfect specimen, longitude 21 mm., × 2. Catalogue No. 165664, U.S.N.M. Locality 4622. So far known only from this locality 70

1a. Bottom of same specimen.

POTAMIDES CARBONICOLA Cooper.

Figure 2. Back of imperfect specimen, longitude 19 mm., × 2. Catalogue No. 165651, U.S.N.M. Locality 4801. So far known only from the type locality 71

3. Back of another specimen, longitude 16 mm., × 2. Catalogue No. 165651, U.S.N.M. Same locality as figure 2.

TRITONIUM CALIFORNICUM Gabb.

Figure 4. Front of young and imperfect specimen, longitude 8 mm., × 4. Catalogue No. 165644, U.S.N.M. Locality 4619. A rather rare species; grows to much larger size than the figured specimen...... 71

SERPULORBIS sp. *a*.

Figure 5. Top, maximum diameter of specimen 15 mm., × 2. Catalogue No. 165659, U.S.N.M. Locality 4617. A common form at some localities of the Tejon 71

RIMELLA CANALIFERA Gabb.

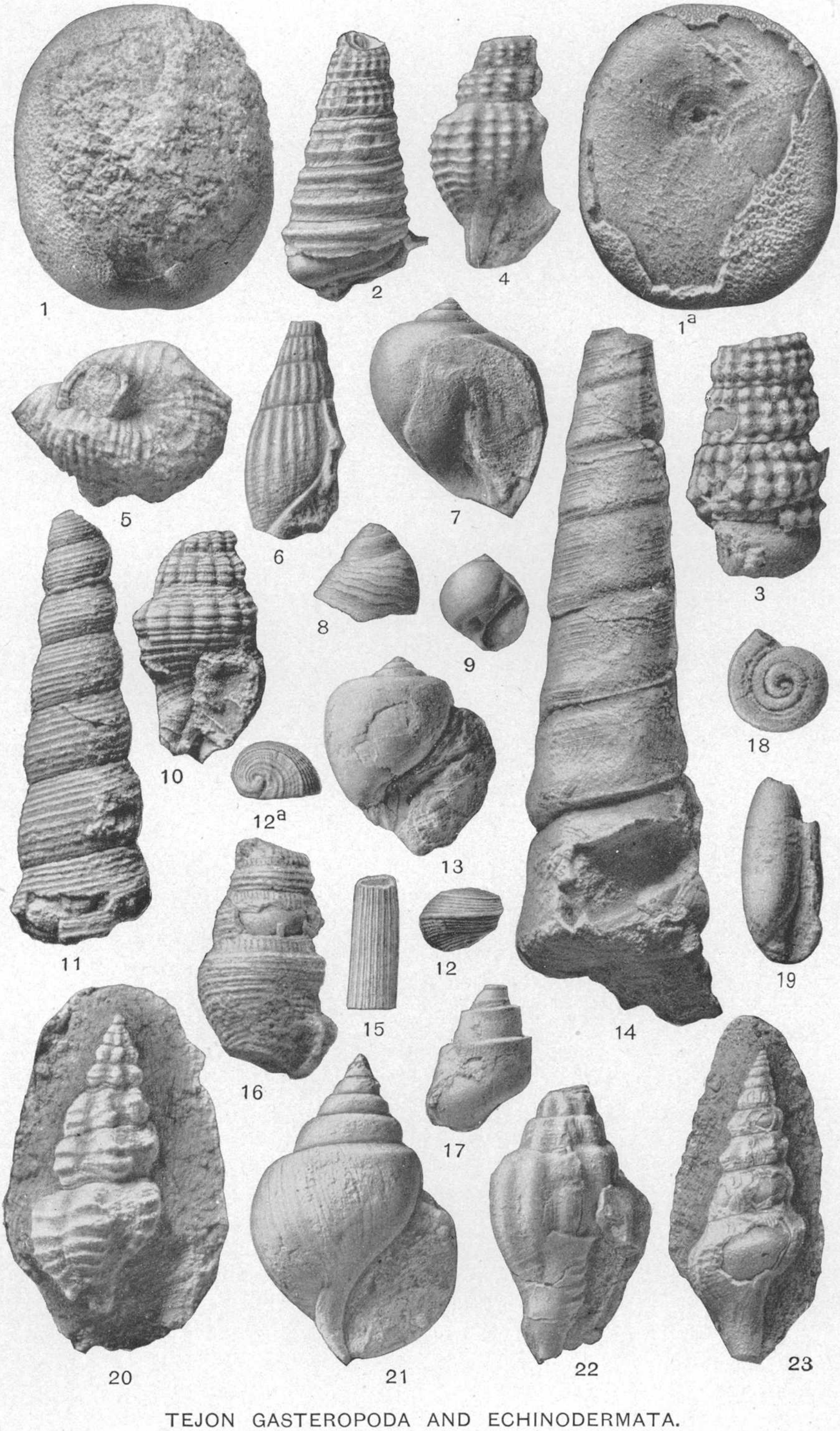
Figure 6. Front of imperfect specimen, longitude 15 mm., × 2. Catalogue No. 165646, U.S.N.M. Locality 4618. This species has an expanded lip which is produced upward along the body and penultimate whorls. A common and characteristic Eocene form.... 71

AMAUROPSIS OVIFORMIS? Gabb.

Figure 7. Front of imperfect specimen, altitude 29 mm., natural size. Catalogue No. 165654, U.S.N.M. Locality 4617 71

GALERUS EXCENTRICUS Gabb.

Figure 8. Side view, altitude 12 mm., natural size. Catalogue No. 165643, U.S.N.M. Locality 4801. A very common and characteristic Eocene species 71



TEJON GASTEROPODA AND ECHINODERMATA.

LUNATIA HORNII Gabb.

Page.

Figure 9. Front view, altitude 13.3 mm., natural size. Catalogue No. 165620, U.S.N.M. Locality 4801. Often grows much larger than the specimen figured 71

TRITONIDEA KREYENHAGENI Arnold.

Figure 10. Front of décolleté and slightly imperfect specimen, longitude 16 mm., × 2. Type, catalogue No. 165657, U.S.N.M. Locality 4801 71

TURRITELLA UVASANA Conrad.

Figure 11. Side of a décolleté specimen, longitude 31 mm., × 2. Catalogue No. 165653, U.S.N.M. Locality 4617. A common and characteristic Eocene species, showing considerable variation as regards sculpture 71

NERITA TRIANGULATA Gabb.

Figure 12. Back and part of top, maximum diameter 12 mm., natural size. Catalogue No. 165700, U.S.N.M. Locality 4801. A characteristic Eocene species 71

12a. Top of same specimen.

LUNATIA sp. *a*.

Figure 13. Front of imperfect specimen, altitude 27 mm., natural size. Catalogue No. 165652, U.S.N.M. Locality 4801 71

TURRITELLA PACHECOENSIS Stanton.

Figure 14. Exterior of imperfect young specimen, longitude 44.5 mm., × 2. Catalogue No. 165636, U.S.N.M. Locality 4617. Usually more common in the lower Eocene, but also found in the Tejon 71

DENTALIUM COOPERI Gabb.

Figure 15. Side, longitude 9 mm., × 2. Catalogue No. 165622, U.S.N.M. Locality 4619. A common and long-lived species 71

PLEUROTOMA DOMENGINEI Arnold.

Figure 16. Side of imperfect specimen, longitude 11 mm., × 3. Type, catalogue No. 165647, U.S.N.M. Locality 4619 71

LOXOTREMA TURRITA Gabb.

Figure 17. Back of imperfect specimen, longitude 20 mm., natural size. Catalogue No. 165649, U.S.N.M. Locality 4801. A peculiar and characteristic Tejon species 71

SPIROGLYPHUS? TEJONENSIS Arnold.

Figure 18. Top of coil, maximum diameter 7.5 mm., × 2. Type, catalogue No. 165658, U.S.N.M. Locality 4617 71

CYLICHNA COSTATA Gabb.

Page.

Figure 19. Front view of imperfect specimen, longitude 13 mm., × 2. Catalogue No. 165655, U.S.N.M. Locality 4617. A common Eocene form very much like some later species of the same genus...... 71

PLEUROTOMA GUIBERSONI Arnold.

Figure 20. Rear view of imperfect specimen, longitude 13.5 mm., × 3. Type, catalogue No. 165648, U.S.N.M. Locality 4619................ 71

AMAUROPSIS ALVEATA Conrad.

Figure 21. Front view of specimen with slightly broken lip, altitude 43 mm., natural size. Catalogue No. 165650, U.S.N.M. Locality 4619. An exceedingly widespread and characteristic species in the Eocene.. 71

CANCELLARIA IRELANIANA Cooper.

Figure 22. Front view of imperfect specimen, longitude 39 mm., natural size. Catalogue No. 165645, U.S.N.M. Locality 4619................ 71

PLEUROTOMA FRESNOENSIS Arnold.

Figure 23. Front view of specimen from which the canal is missing, longitude 21 mm., × 2. Type, catalogue No. 165631, U.S.N.M. Locality 4619.. 71

PLATE XXVII.

PLATE XXVII.

VAQUEROS (LOWER MIOCENE) FOSSILS: LOWER HORIZON.

OSTREA TITAN Conrad.

Page.

Figure 1. Exterior of left valve, longitude 90 mm., natural size. Catalogue No. 165565, U.S.N.M. Lower Vaqueros formation; locality 4773. This rather diminutive variety is found abundantly below the "reef bed" on Laval grade, 9 miles north of Coalinga. 86

DOSINIA MATHEWSONII Gabb.

Figure 2. Exterior of right valve, altitude 56 mm., natural size. Catalogue No. 165596, U.S.N.M. Vaqueros formation; locality 4803. This species is believed to be characteristic of the lower and middle Miocene.. 86

MYTILUS MATHEWSONII Gabb var. EXPANSUS Arnold.

Figure 3. Exterior of nearly perfect right valve, longitude 157 mm., natural size. Catalogue No. 165661, U.S.N.M. Vaqueros formation; locality 4803. This species is believed to be characteristic of the Vaqueros; the typical form is usually found in the upper half of the Miocene.. 86

SEPTIFER COALINGENSIS Arnold.

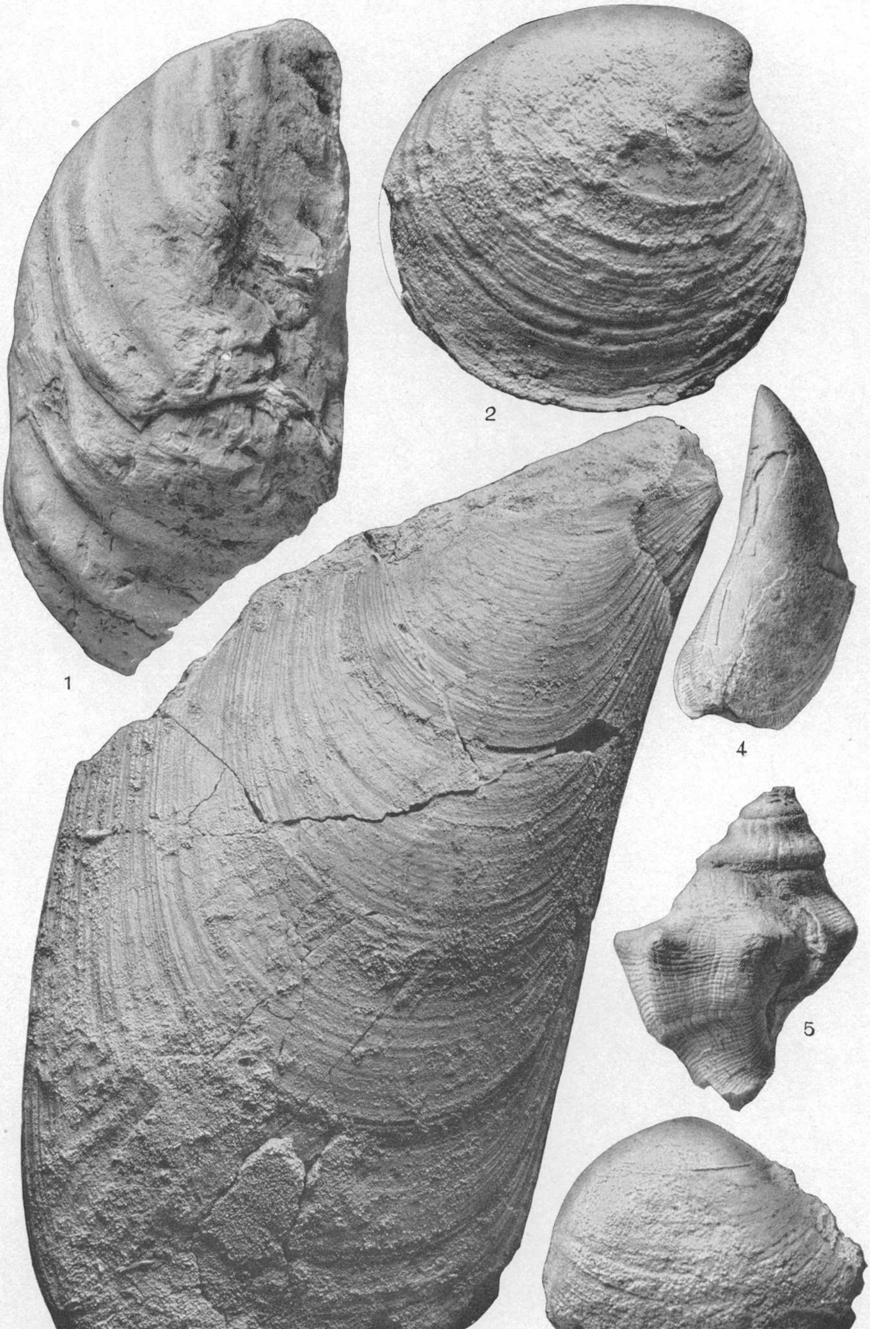
Figure 4. Exterior of left valve, longitude 45 mm., natural size. Type, catalogue No. 165580, U.S.N.M. Supposed Vaqueros formation; locality 4634.. 85

TROPHON (FORRERIA) GABBIANUM F. M. Anderson.

Figure 5. Back of imperfect specimen, altitude 44 mm., natural size. Catalogue No. 165572, U.S.N.M. Vaqueros formation; locality 4860. (See Pl. XXVIII, fig. 5)............................ 86

MULINIA DENSATA Conrad var. MINOR Arnold.

Figure 6. Exterior of slightly imperfect right valve. Type, catalogue No. 165601, U.S.N.M. Vaqueros formation; locality 4777......... 86



VAQUEROS FOSSILS.

PLATE XXVIII.

PLATE XXVIII.

VAQUEROS (LOWER MIOCENE) FOSSILS: LOWER HORIZON.

METIS aff. ALTA Conrad.

Page.

Figure 1. Exterior of right valve, longitude 32 mm., × 2. Catalogue No. 165567, U.S.N.M. Vaqueros formation; locality 4627. This lower Miocene *Metis* may be different from the Recent *M. alta*, but the state of preservation of the fossils precludes a definite determination 85

2. Left valve of same specimen.

CONUS HAYESI Arnold.

Figure 3. Back of slightly imperfect specimen, longitude 60 mm., natural size. Type, catalogue No. 165566, U.S.N.M. Vaqueros formation; locality 4861 86

SCUTELLA MERRIAMI F. M. Anderson.

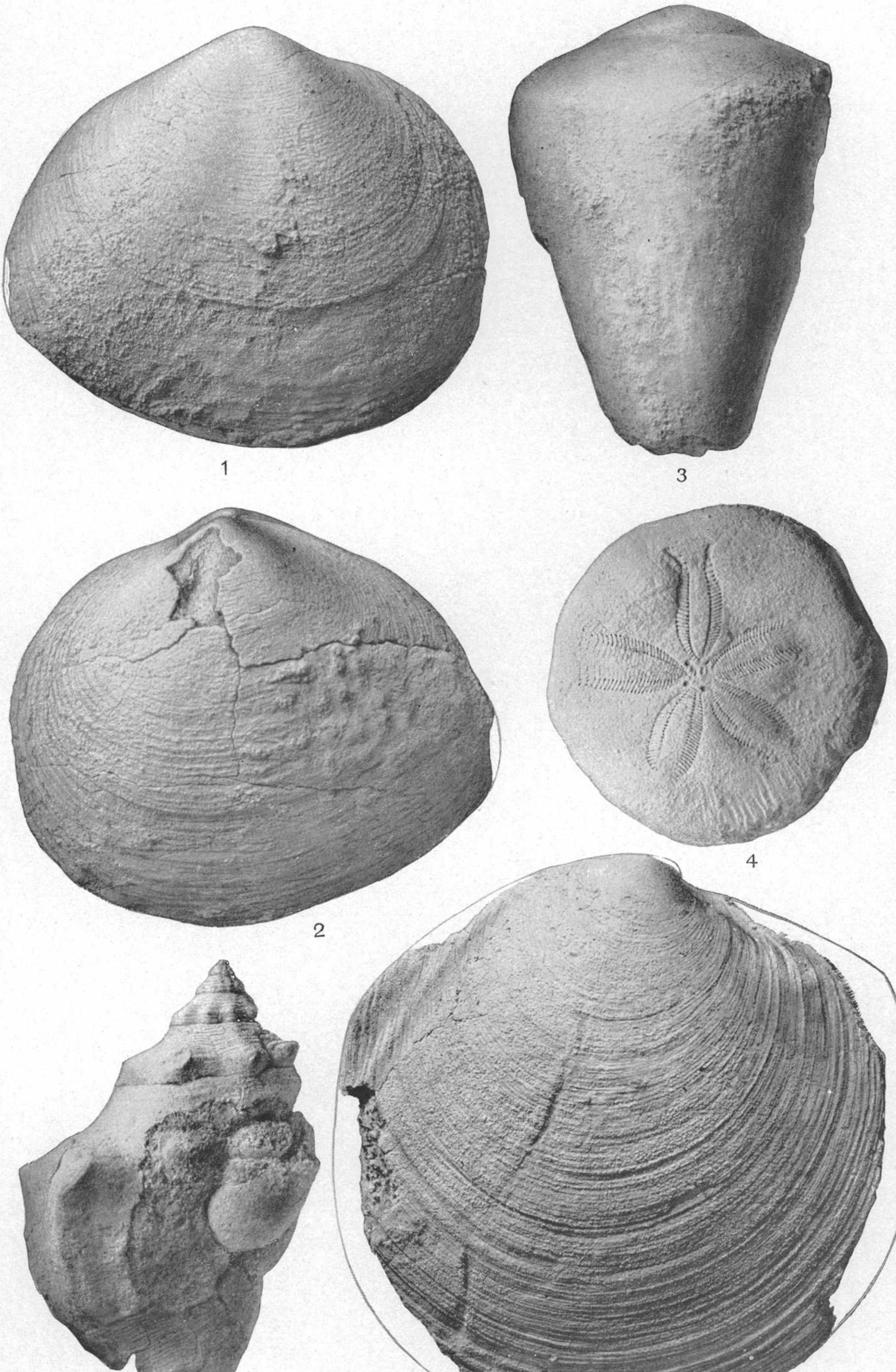
Figure 4. Top, maximum diameter 21 mm., natural size. Catalogue No. 165584, U.S.N.M. Vaqueros formation; locality 4775. This little echinoid from which the "button bed" in the Vaqueros derives its name is found at many localities in the Coalinga district, and is believed to be characteristic of the Vaqueros or lower Miocene 86

TROPHON (FORRERIA) GABBIANUM F. M. Anderson var. CANCELLARIOIDES Arnold.

Figure 5. Back of imperfect specimen, longitude 56 mm., natural size. Type, catalogue No. 165605, U.S.N.M. Vaqueros formation; locality 4861. (See Pl. XXVII, fig. 5) 86

PHACOIDES (MILTHA) SANCTÆCRUCIS Arnold.

Figure 6. Exterior of nearly perfect right valve, longitude 75 mm., natural size. Type, catalogue No. 165569, U.S.N.M. Vaqueros formation; locality 4861 86



VAQUEROS FOSSILS.

PLATE XXIX.

PLATE XXIX.

VAQUEROS (LOWER MIOCENE) FOSSILS: LOWER AND UPPER HORIZONS.

ARCA OSMONTI Dall.

Page.

Figure 1. Exterior of left valve, longitude 49 mm., natural size. Catalogue No. 165563, U.S.N.M. Vaqueros formation; locality 4859. This species is believed to be characteristic of the lower Miocene. The specimen figured is from the type locality. Found also in Santa Monica Mountains, near Los Angeles.................. 86

1a. Umbones of same specimen.

2. Exterior of left valve of a broader specimen, longitude 39 mm., natural size. Catalogue No. 165563, U.S.N.M.

TROPHON (FORRERIA) BARTONI Arnold.

Figure 3. Imperfect specimen, altitude 33 mm., natural size. Type, catalogue No. 165571, U.S.N.M. Vaqueros formation; locality 4861.. 86

PECTEN ANDERSONI Arnold.

Figure 4. Exterior of right valve, longitude 37 mm., natural size. Catalogue No. 165583, U.S.N.M. Vaqueros formation; locality 4803. This species is believed to be characteristic of the Miocene. It is found abundantly in certain layers of the "reef beds," where it makes up the entire rock for small thicknesses.............. 86

ZIRPHÆA DENTATA Gabb.

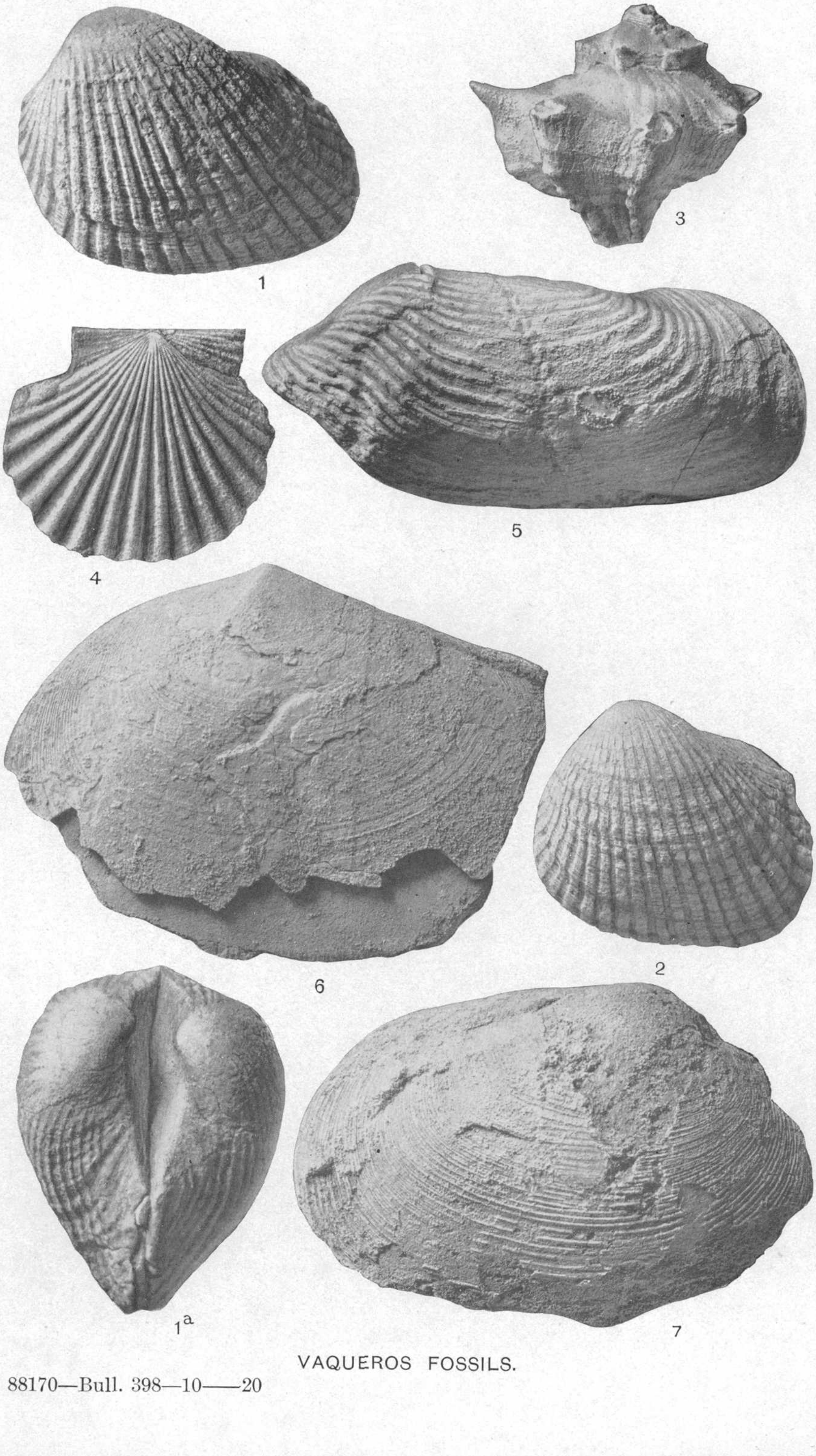
Figure 5. Exterior of left valve, longitude 73 mm., natural size. Catalogue No. 165573, U.S.N.M. Vaqueros formation; locality 4803. This species is believed to be characteristic of the Miocene.... 86

MACOMA PIERCEI Arnold.

Figure 6. Exterior of left valve of imperfect specimen, longitude 75 mm., natural size. Type, catalogue No. 165595, U.S.N.M. Upper Vaqueros formation; locality 4631............................ 85

SAXIDOMUS VAQUEROSENSIS Arnold.

Figure 7. Exterior of left valve, longitude 69 mm., natural size. Type, catalogue No. 165570, U.S.N.M. Upper Vaqueros formation; locality 4631.. 85



VAQUEROS FOSSILS.

88170—Bull. 398—10——20

PLATE XXX.

PLATE XXX.

VAQUEROS (LOWER MIOCENE) FOSSILS: UPPER HORIZON.

Turritella ocoyana Conrad.

Page.

Figure 1. Back of imperfect specimen, longitude 50 mm., natural size. Catalogue No. 165593, U.S.N.M. Vaqueros formation; locality 4631. This is one of the most characteristic fossils of the Vaqueros, especially in the San Joaquin Valley and in southern California. 85

2. Back of two whorls of an exceedingly large specimen, altitude 42 mm., natural size. Catalogue No. 165574, U.S.N.M. Upper Vaqueros formation; locality 4631.

Venus pertenuis Gabb.

Figure 3. Exterior of right valve, longitude 88 mm., natural size. Catalogue No. 165597, U.S.N.M. Upper Vaqueros formation; locality 4631. This species is believed to be characteristic of the Miocene..... 85

Phacoides acutilineatus Conrad.

Figure 4. Exterior of left valve, altitude 35.5 mm., natural size. Catalogue No. 165564, U.S.N.M. Upper Vaqueros formation; locality 4803. This species ranges from the lower Miocene to the lower Pliocene fauna. Formerly called *Lucina acutilineata*.......... 86

Agasoma santacruzana Arnold.

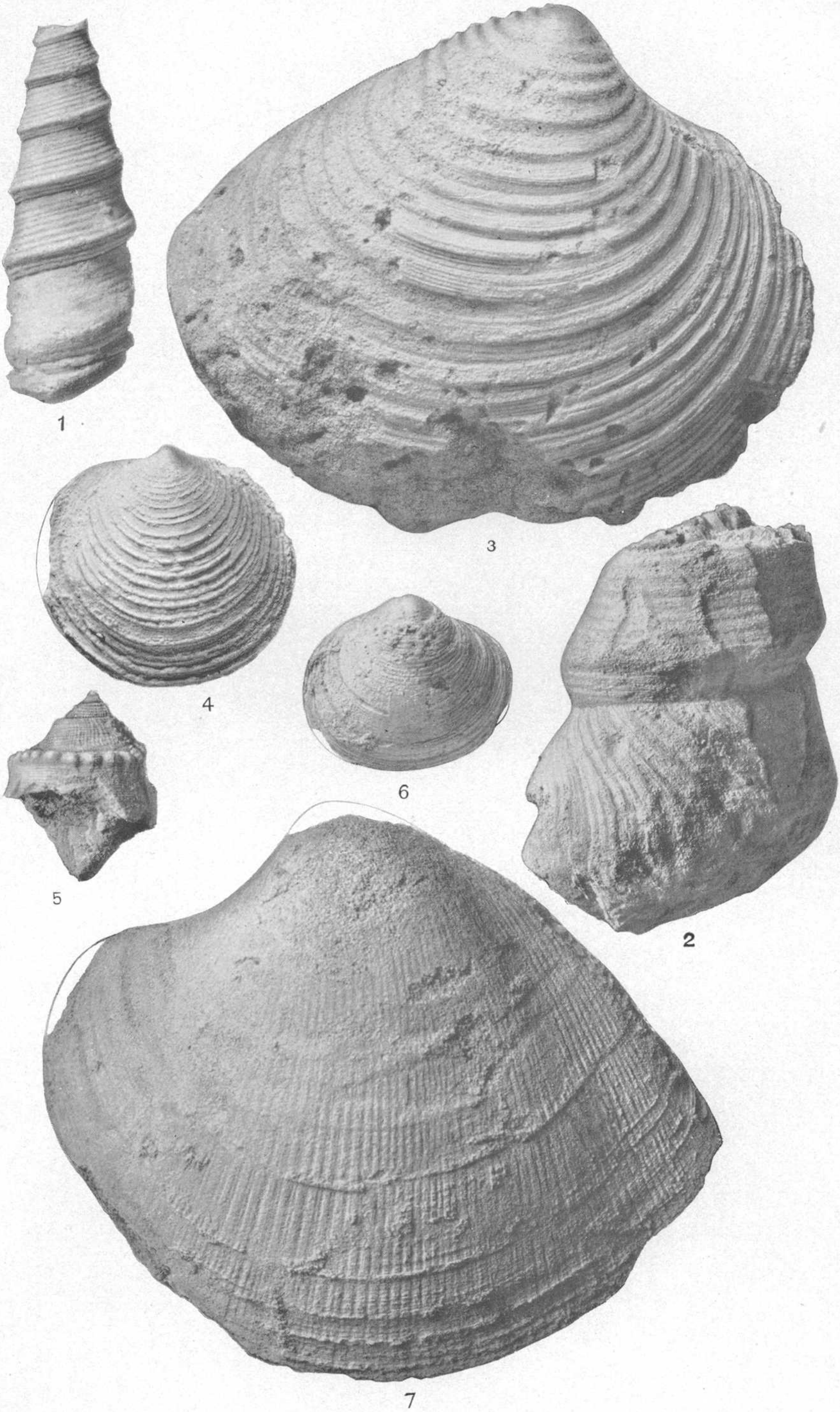
Figure 5. Front of imperfect specimen, consisting of spire and part of body whorl, latitude 19 mm., natural size. Catalogue No. 165609, U.S.N.M. Vaqueros formation; locality 4631. This species is believed to be characteristic of the Vaqueros.................. 85

Corbicula dumblei F. M. Anderson.

Figure 6. Exterior of right valve, longitude 28 mm., natural size. Catalogue No. 165581, U.S.N.M. Vaqueros formation; locality 4628. This species is found abundantly in the Vaqueros oil sand where it outcrops in Anticline Canyon southwest of Coalinga......... 85

Chione temblorensis F. M. Anderson.

Figure 7. Exterior of imperfect and decorticated left valve, longitude 92 mm., natural size. Catalogue No. 165612, U.S.N.M. Upper Vaqueros formation; locality 4631. This species, which is characterized by its central beaks and narrow form, is believed to be characteristic of the Vaqueros formation........................ 85



VAQUEROS FOSSILS.

PLATE XXXI.

PLATE XXXI.

VAQUEROS (LOWER MIOCENE) FOSSILS: UPPER HORIZON.

DOSINIA PONDEROSA Gray.

Page.

Figure 1. Exterior of left valve, altitude 78 mm., natural size. Catalogue No. 165660, U.S.N.M. Upper Vaqueros formation; locality 4631. This species ranges from the lower Miocene to the Recent fauna.. 85

CARDIUM (TRACHYCARDIUM) VAQUEROSENSIS Arnold.

Figure 2. Exterior of imperfect right valve, altitude 98 mm., natural size. Catalogue No. 165598, U.S.N.M. Upper Vaqueros formation; locality 4631.. 85

CONUS OWENIANUS F. M. Anderson.

Figure 3. Front, altitude 16 mm., natural size. Catalogue No. 165606, U.S.N.M. Upper Vaqueros formation; locality 4631. This species, which is characterized by spiral striations, is believed to be characteristic of the Vaqueros.................................. 85

OCINEBRA TOPANGENSIS Arnold.

Figure 4. Back, longitude 25 mm., natural size. Catalogue No. 165608, U.S.N.M. Upper Vaqueros formation; locality 4631. This species, which is also found in the Santa Monica Mountains, is believed to be characteristic of the Vaqueros formation........ 85

CANCELLARIA ANDERSONI Arnold.

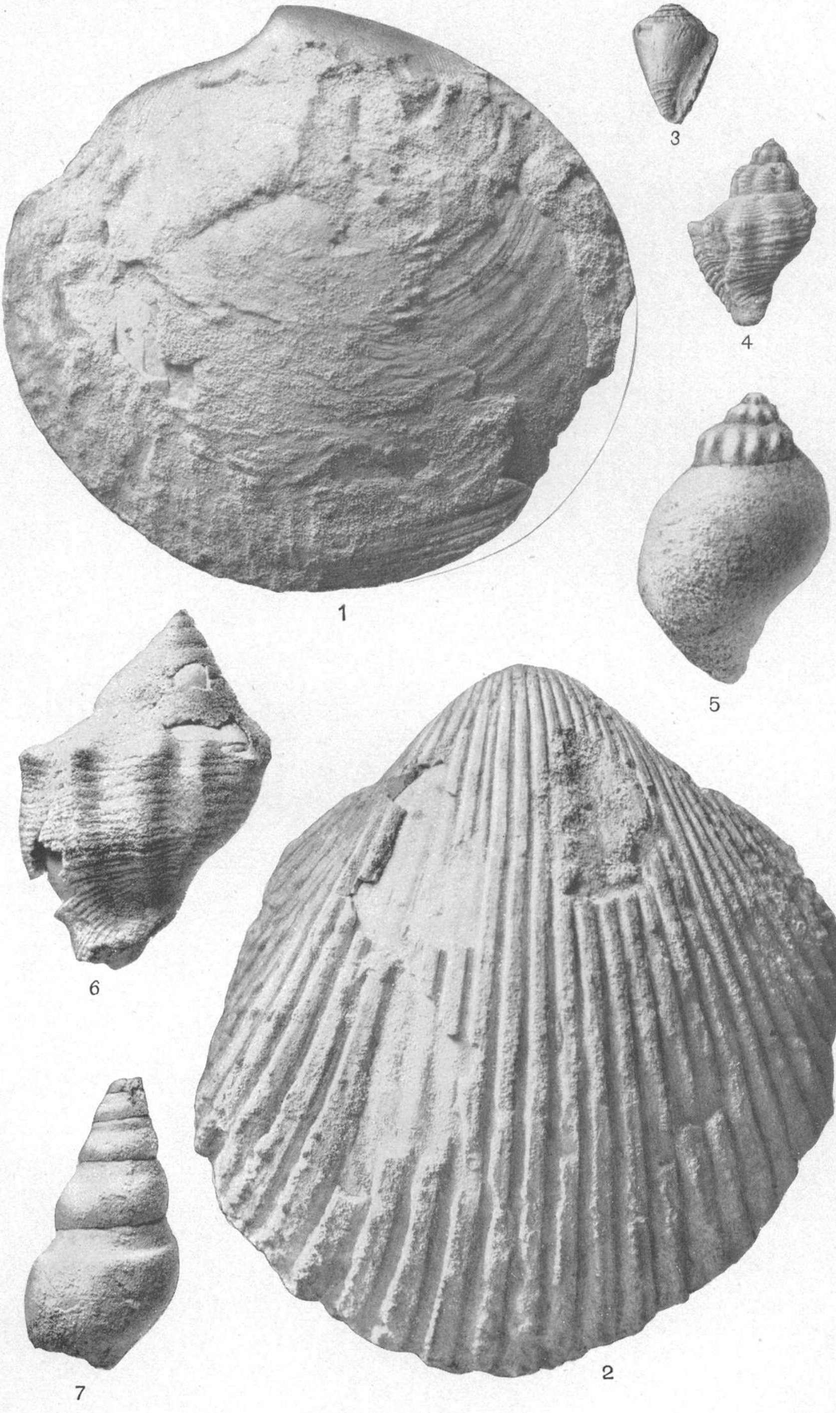
Figure 5. Back, longitude 21 mm., × 2. Type, catalogue No. 165607, U.S.N.M. Upper Vaqueros formation; locality 4631....................... 85

CANCELLARIA VETUSTA Gabb.

Figure 6. Back, longitude 51 mm., natural size. Catalogue No. 165600, U.S.N.M. Upper Vaqueros formation; locality 4631. This species is believed to be characteristic of the Vaqueros........ 85

PLEUROTOMA (BATHYTOMA) PIERCEI Arnold.

Figure 7. Back of imperfect specimen, altitude 39.5 mm., natural size. Type, catalogue No. 165578, U.S.N.M. Upper Vaqueros formation; locality 4631.. 85



VAQUEROS FOSSILS.

PLATE XXXII.

PLATE XXXII.

SANTA MARGARITA (UPPER MIDDLE MIOCENE) FOSSILS.

Tamiosoma gregaria Conrad.

Page.

Figure 1. Side, group of individuals, maximum altitude 187 mm., one-half natural size. Catalogue No. 165618, U.S.N.M. Santa Margarita (?) formation; locality 4766. This unique form, which is closely related to the barnacles, is believed to be characteristic of the upper Miocene and is usually found abundantly in the fossiliferous portions of the Santa Margarita (?) formation............. 94

Hinnites giganteus Gray.

Figure 2. Exterior of right valve, longitude 52 mm., natural size. Catalogue No. 165586, U.S.N.M. Santa Margarita (?) formation; locality 4651. This species ranges from the middle Miocene to the Recent fauna. The specimen figured is an immature, fair-sized individual.. 94

Pecten estrellanus Conrad.

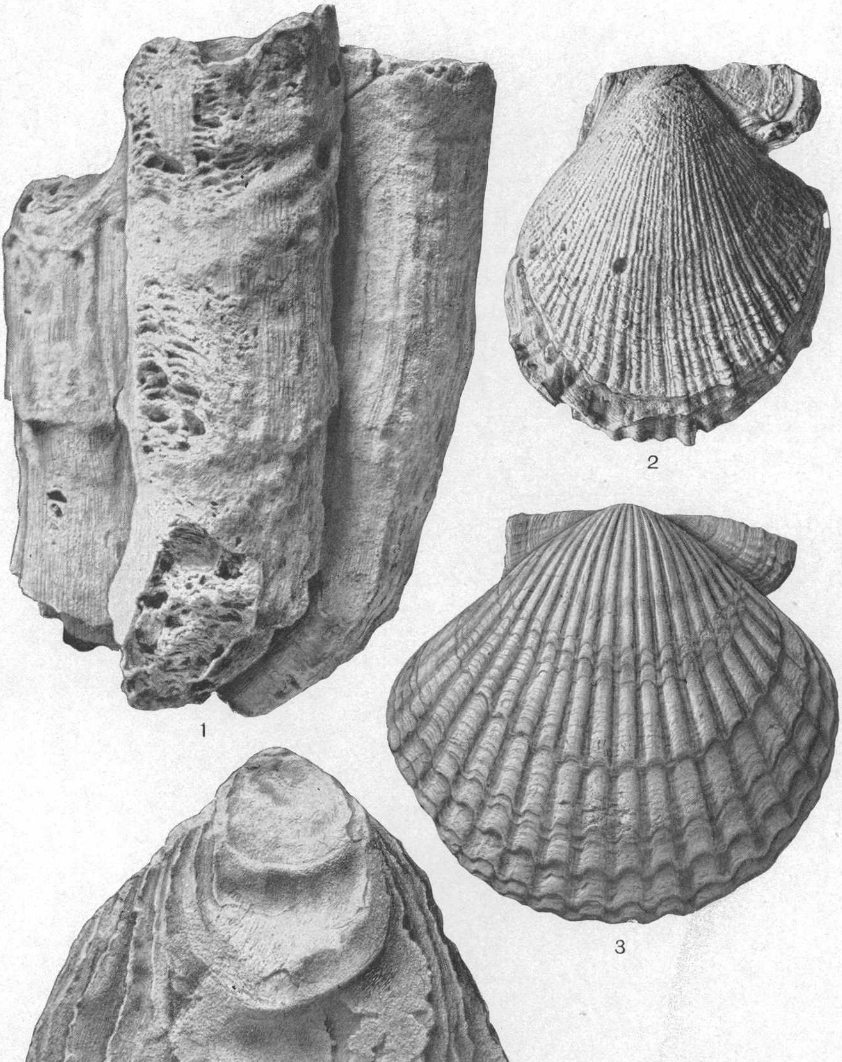
Figure 3. Exterior of right valve, altitude 111 mm., one-half natural size. Catalogue No. 165616, U.S.N.M. Santa Margarita (?) formation; locality 4766. This species is exceedingly common in the Santa Margarita (?) and Jacalitos formations, but may extend into the Vaqueros... 94

Trophon (Forreria) carisaensis F. M. Anderson.

Figure 4. Front, longitude 41 mm., natural size. Type, catalogue No. 165591, U.S.N.M. Santa Margarita (?) formation; locality 4766. This species is characterized by its moderate size and the spines which are located in the middle of the whorl. It is believed to be characteristic of the Santa Margarita (?) formation.............. 94

Ostrea titan Conrad.

Figure 5. Exterior of right valve; longitude 174 mm., one-half natural size. Catalogue No. 165617, U.S.N.M. Santa Margarita (?) formation; locality 4766.. 94



SANTA MARGARITA FOSSILS.

PLATE XXXIII.

PLATE XXXIII.

SANTA MARGARITA (UPPER MIDDLE MIOCENE) AND JACALITOS (UPPER MIOCENE) FOSSILS.

ASTRODAPSIS WHITNEYI Rémond.

Page.

Figure 1. Top of back of imperfect specimen, maximum diameter 76 mm., natural size. Catalogue No. 165594, U.S.N.M. Santa Margarita (?) formation; locality 4766. This species is believed to be characteristic of the Santa Margarita (?) formation in the Coalinga district.. 94

OSTREA TITAN Conrad.

Figure 2. Exterior of left valve, altitude 290 mm., one-half natural size. Catalogue No. 165617, U.S.N.M. Santa Margarita (?) formation; locality 4766. This magnificent *Ostrea* is found abundantly throughout the Miocene, especially in the upper half of the middle Miocene; it sometimes attains a length of 20 inches and a weight of over 20 pounds.. 94

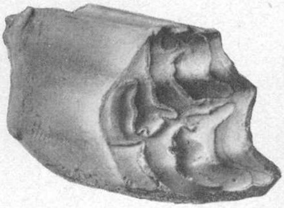
PLIOHIPPUS sp. *a*.

Figure 3. Side, longitude 49 mm., natural size. Catalogue No. 165665, U.S.N.M. Jacalitos formation; NW. ¼ sec. 22, T. 19 S., R. 15 E. The extinct horse, of which this tooth is all that was found, is believed to be characteristic of the upper Miocene...................... 98

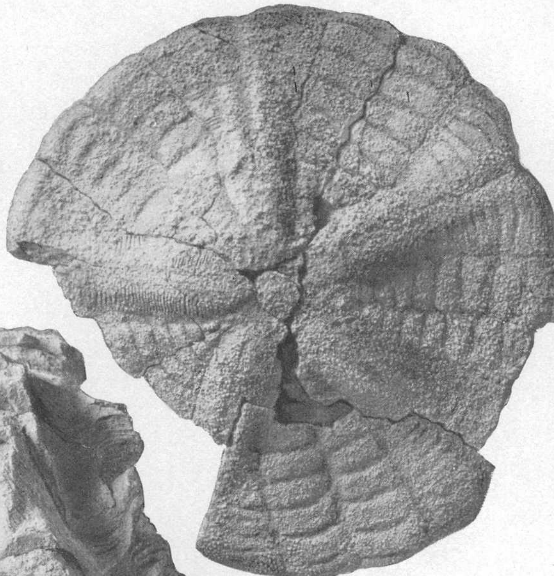
3a. Crown of same specimen.

THAIS CRISPATUS Chemnitz.

Figure 4. Front of décolleté and otherwise slightly imperfect specimen, longitude 44 mm., natural size. Catalogue No. 165532, U.S.N.M. Upper Jacalitos formation; locality 4763. This species ranges from the upper Miocene to the Recent fauna and is an exceedingly variable species, some specimens being almost smooth, others strongly sculptured. The genus *Thais* has heretofore been commonly known as *Purpura*........................... 110



3a



1

4

2

3

SANTA MARGARITA AND JACALITOS FOSSILS.

88170—Bull. 398—10——21

PLATE XXXIV.

PLATE XXXIV.

SANTA MARGARITA (UPPER MIDDLE MIOCENE) AND JACALITOS (UPPER MIOCENE) FOSSILS.

Pecten crassicardo Conrad.

Page.

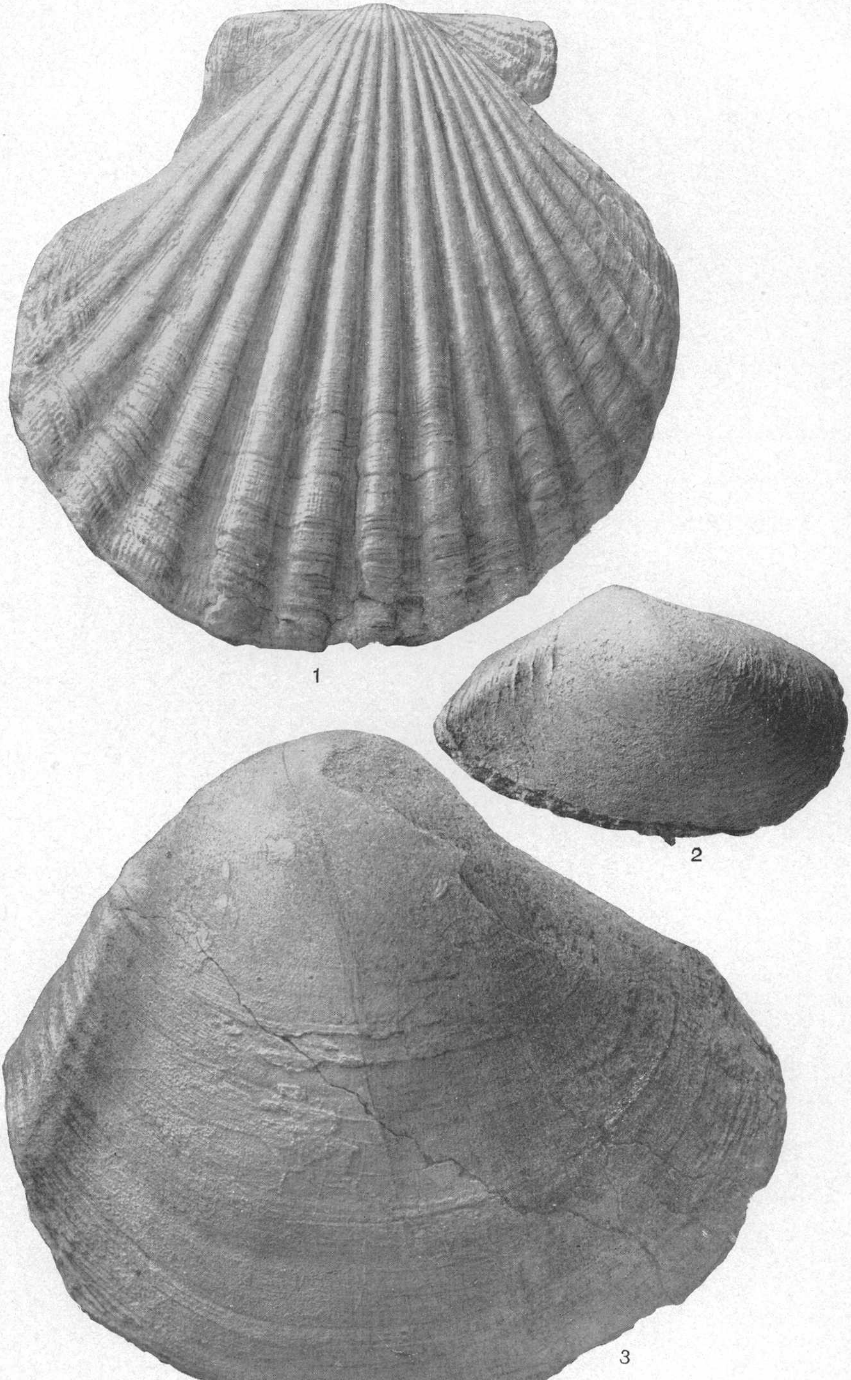
Figure 1. Exterior of right valve, altitude 165 mm., one-half natural size. Catalogue No. 165615, U.S.N.M. Santa Margarita (?) formation; locality No. 4766. This species is characterized by its large size, fine radial striations, and lack of prominent intercalary rib. Ranges throughout the Miocene. Is usually more abundant in the middle and upper portions 94

Macoma vanvlecki Arnold.

Figure 2. Exterior of right valve, longitude 54 mm., natural size. Type, catalogue No. 165576, U.S.N.M. Jacalitos formation; locality 4763. (See Pl. XXXIX, fig. 1) 110

Schizodesma abscissa Gabb.

Figure 3. Exterior of right valve, longitude 100 mm., natural size. Catalogue No. 165604, U.S.N.M. Jacalitos formation; locality 4765. This species is believed to be characteristic of the upper Miocene.... 110



SANTA MARGARITA AND JACALITOS FOSSILS.

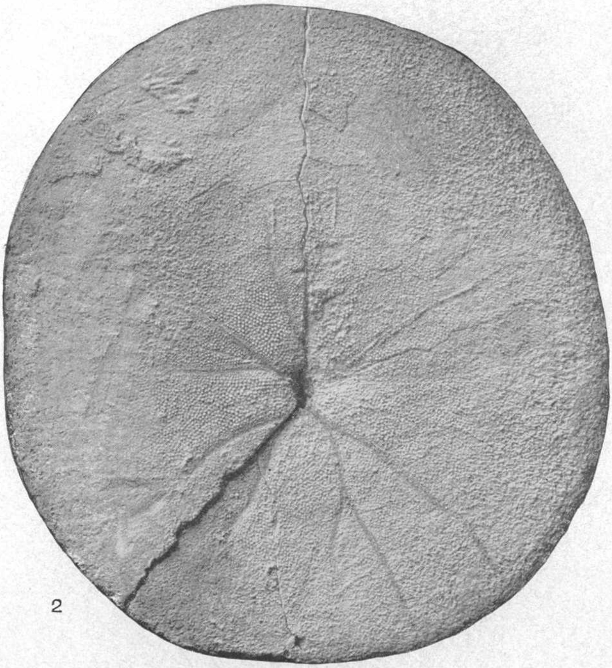
PLATE XXXV.

PLATE XXXV.

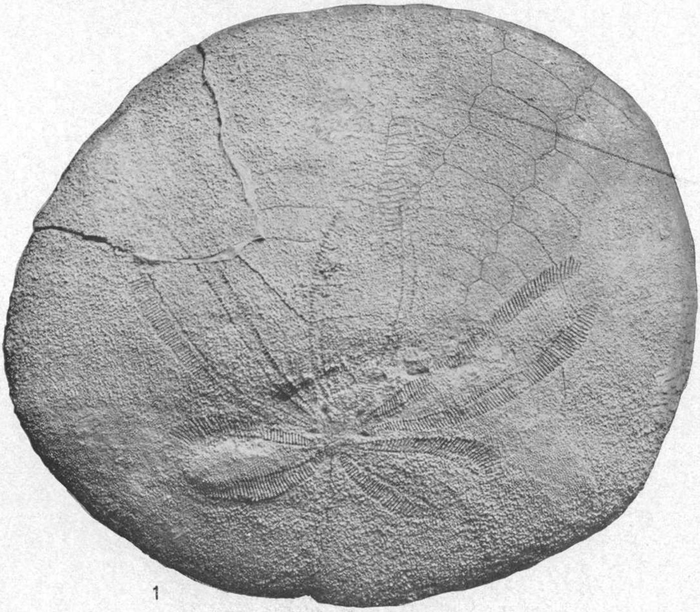
JACALITOS (UPPER MIOCENE) ECHINODERMATA.

ECHINARACHNIUS GIBBSII Rémond.

		Page.
Figure 1.	Top, longitude 81 mm., natural size. Catalogue No. 165611, U.S.N.M. Jacalitos formation; locality 4747. This large variety is believed to be characteristic of the lower part of the Jacalitos.....	110
2.	Bottom of another specimen, longitude 87 mm., natural size. Same locality.	



2



1

JACALITOS ECHINODERMATA.

PLATE XXXVI.

PLATE XXXVI.

JACALITOS (UPPER MIOCENE) FOSSILS.

MONIA MACROSCHISMA Deshayes.

Page.

Figure 1. Exterior of left valve, longitude 66 mm., natural size. Catalogue No. 165602, U.S.N.M. Jacalitos formation; locality 4767. This species ranges from upper Miocene to the Recent fauna. Erroneously called *Placunanomia macroschisma* 110

TELLINA ARAGONIA Dall.

Figure 2. Exterior of right valve, longitude 48 mm., natural size. Catalogue No. 165577, U.S.N.M. Jacalitos formation; locality 4765. This species, which was originally described from the Empire formation at Coos Bay, Oregon, is believed to be characteristic of the upper Miocene.. 110

TROPHON (FORRERIA) PONDEROSUM Gabb.

Figure 3. Back of young specimen, longitude 43 mm., natural size. Catalogue No. 165590, U.S.N.M. Etchegoin formation; locality 4642. This species is common in the Jacalitos formation and rare in the Etchegoin 109

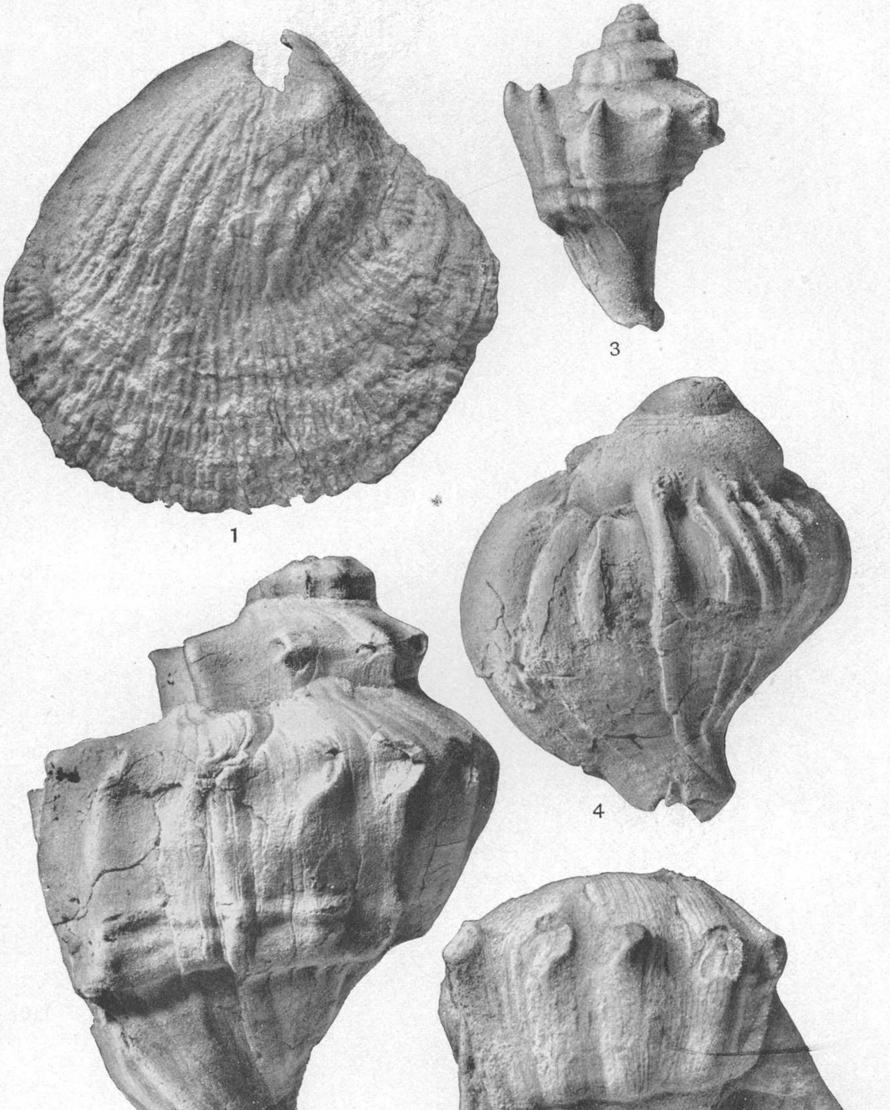
CHRYSODOMUS IMPERIALIS Dall.

Figure 4. Back of nearly perfect specimen, longitude 57 mm., natural size. Catalogue No. 165582, U.S.N.M. Upper Jacalitos formation; locality 4767. This species, which is characterized by its broad outline and peculiar reflexed varices, is believed to be characteristic of the upper Miocene. It is found in Oregon, in Santa Cruz County, Cal., and at one or two localities in the Coalinga district 110

TROPHON (FORRERIA) PONDEROSUM Gabb.

Figure 5. Side of imperfect specimen, altitude 86 mm., natural size. Catalogue No. 165562, U.S.N.M. Jacalitos formation; locality 4784.. 110

6. Front of imperfect specimen, altitude 72 mm., natural size. Catalogue No. 165555, U.S.N.M. Jacalitos formation; locality 4765.. 110



JACALITOS FOSSILS.

PLATE XXXVII.

PLATE XXXVII.

JACALITOS (UPPER MIOCENE) FOSSILS.

PANOPEA ESTRELLANA Conrad.

Page.

Figure 1. Exterior of imperfect right valve, longitude 80 mm., natural size. Catalogue No. 165568, U.S.N.M. Jacalitos formation; locality 4765 110

CHIONE SECURIS Shumard.

Figure 2. Exterior of slightly imperfect left valve, longitude 87 mm., natural size. Catalogue No. 165599, U.S.N.M. Jacalitos formation; locality 4763. This species, which is more inequilateral than *Chione temblorensis* F. M. Anderson, is believed to be characteristic of the upper Miocene 110

MACOMA sp. *a*.

Figure 3. Exterior of left valve, altitude 29 mm., natural size. Catalogue No. 165588, U.S.N.M. Jacalitos formation; locality 4763 110

THAIS KETTLEMANENSIS Arnold.

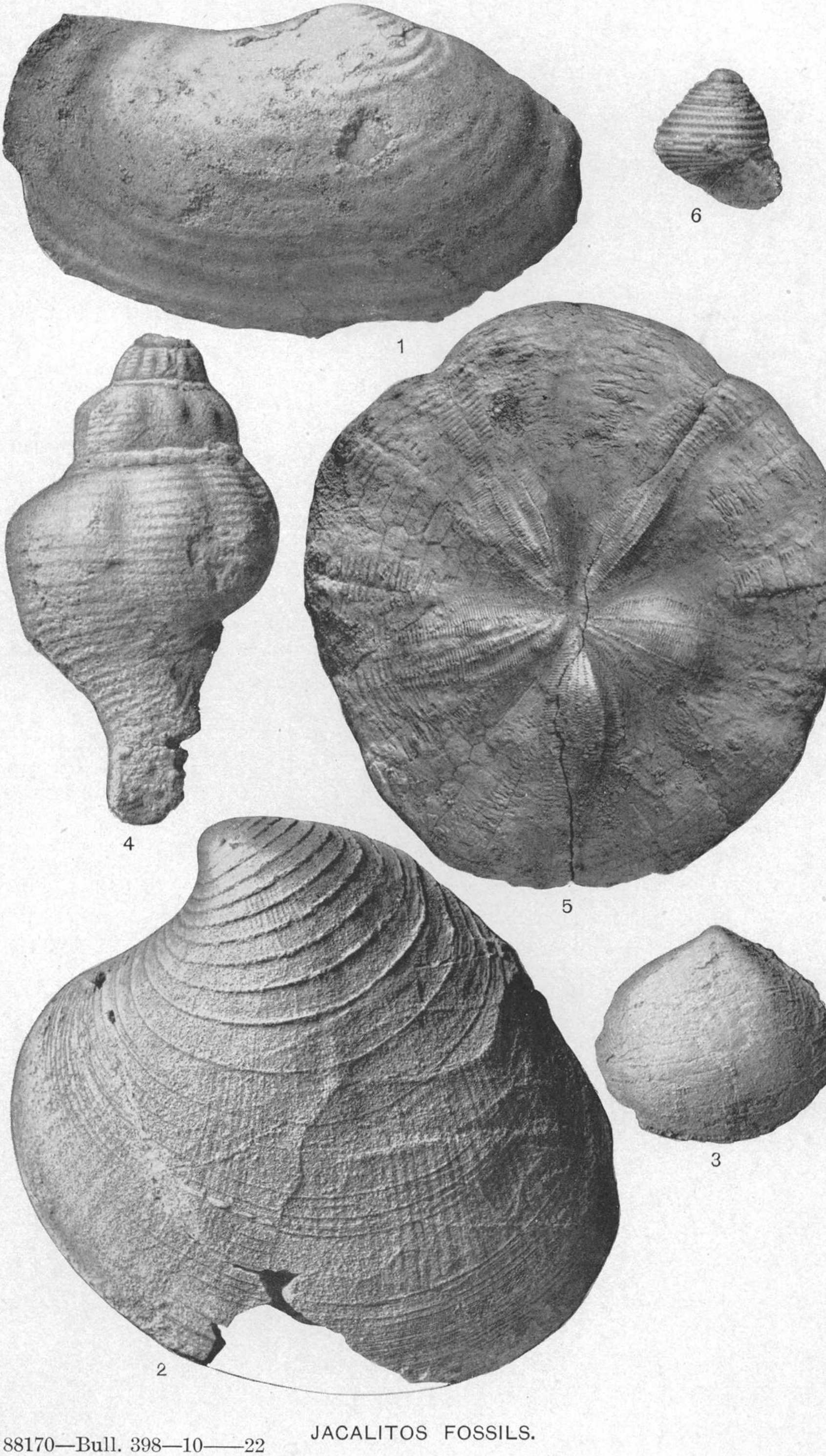
Figure 4. Back of a décolleté and otherwise imperfect specimen, longitude 53 mm., natural size. Paratype, catalogue No. 165614, U.S.N.M. Jacalitos formation; locality 4763. This genus was formerly known as *Purpura* 110

ASTRODAPSIS JACALITOSENSIS Arnold.

Figure 5. Top, longitude 79 mm., natural size. Type, catalogue No. 165610, U.S.N.M. Jacalitos formation; locality 4745 110

MARGARITA JOHNSONI Arnold.

Figure 6. Front, altitude 6 mm., × 3. Type, catalogue No. 165663, U.S.N.M. Jacalitos formation; locality 4765 110



JACALITOS FOSSILS.

PLATE XXXVIII.

PLATE XXXVIII.

JACALITOS (UPPER MIOCENE) PELECYPODA.

MACOMA VANVLECKI Arnold.

Page.

Figure 1. Exterior of left valve, longitude 54 mm. Type, catalogue No. 165576, U.S.N.M. Jacalitos formation; locality 4763. (See Pl. XXXIV, fig. 2) 110

MACOMA JACALITOSANA Arnold.

Figure 2. Exterior of right valve, longitude 70 mm., natural size. Type, catalogue No. 165613, U.S.N.M. Jacalitos formation; locality 4765.. 110

PAPHIA JACALITOSENSIS Arnold.

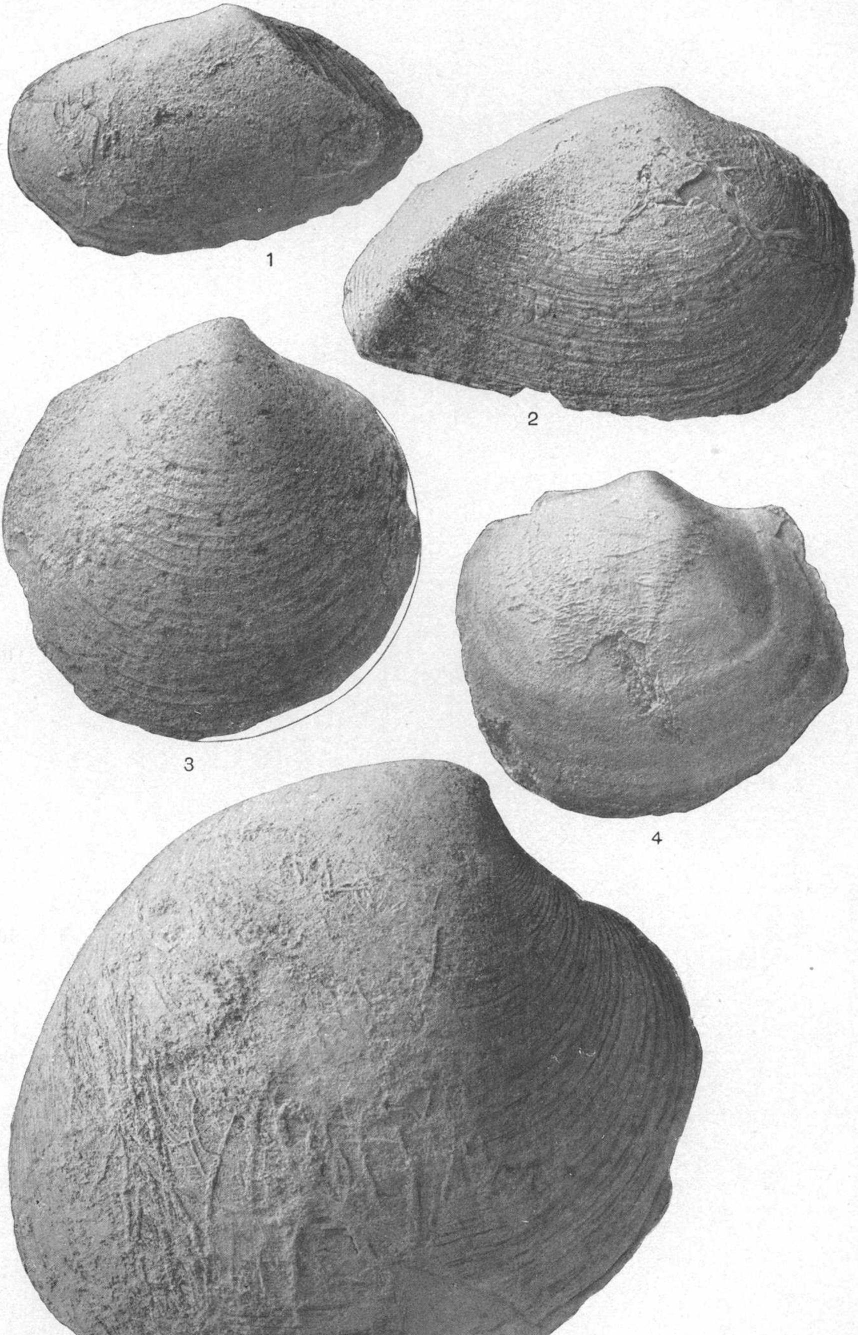
Figure 3. Exterior of right valve, altitude 57 mm., natural size. Type, catalogue No. 165587, U.S.N.M. Jacalitos formation; locality 4765. 110

THRACIA JACALITOSANA Arnold.

Figure 4. Exterior of cast of left valve, longitude 51 mm., natural size. Type, catalogue No. 165579, U.S.N.M. Jacalitos formation; locality 4763 110

DOSINIA JACALITOSANA Arnold.

Figure 5. Exterior of right valve, longitude 95 mm., natural size. Type, catalogue No. 165575, U.S.N.M. Jacalitos formation; locality 4763. 110



JACALITOS PELECYPODA.

PLATE XXXIX.

PLATE XXXIX.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

Ostrea atwoodi Gabb.

Page.

Figure 1. Exterior of left valve, longitude 59 mm., natural size. Catalogue No. 165531, U.S.N.M. Lower Etchegoin formation; locality 4678. This species is believed to be characteristic of the upper Jacalitos and lower Etchegoin formations, or middle portion of upper Miocene 126

2. Exterior of right valve, longitude 48 mm. Same locality.

Mulinia densata Conrad.

Figure 3. Exterior of right valve, longitude 65 mm., natural size. Catalogue No. 165559, U.S.N.M. Lower Etchegoin formation; locality 4682. This species ranges throughout the Miocene, but is more commonly found in the upper Miocene. It is sometimes known as *Pseudocardium gabbi* Rémond 125

4. Interior of left valve, longitude 75 mm., natural size. Catalogue No. 165559, U.S.N.M. Lower Etchegoin formation; locality 4679... 125

Diplodonta parilis Conrad.

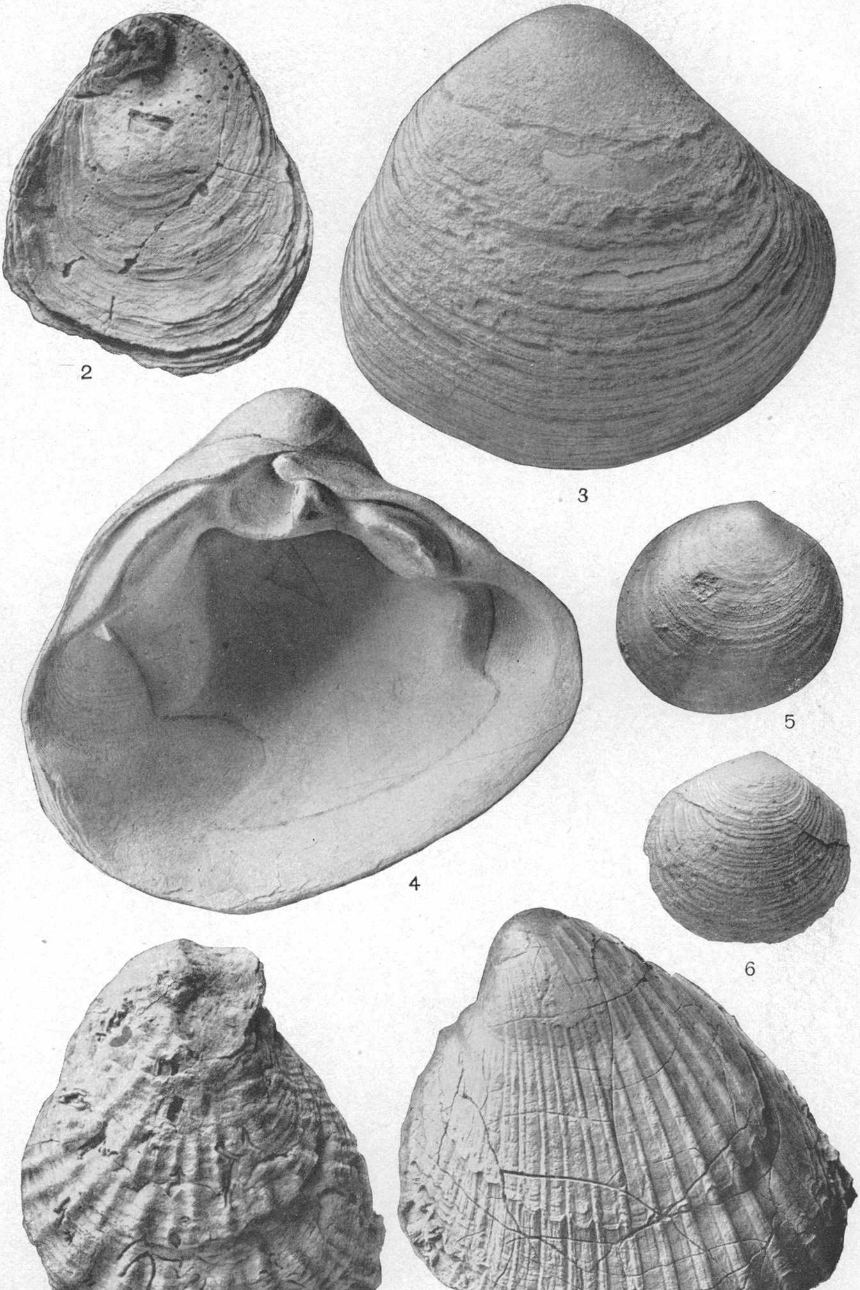
Figure 5. Exterior of right valve, longitude 31 mm., natural size. Catalogue No. 165484, U.S.N.M. Lower Etchegoin formation; locality 4806. This species is believed to be characteristic of the upper Miocene. It is also known from Oregon 131

Diplodonta harfordi F. M. Anderson.

Figure 6. Exterior of right valve, longitude 28 mm., natural size. Catalogue No. 165485, U.S.N.M. Lower Etchegoin formation; locality 4806. This species is believed to be characteristic of the upper Miocene and has so far been recognized only in the Coalinga district 131

Cardium meekianum Gabb.

Figure 7. Exterior of decorticated left valve, altitude 70 mm., natural size. Catalogue No. 165542, U.S.N.M. Lower Etchegoin formation; locality 4806. The external surface of this fossil is almost always gone. It is an abundant species in one or two of the layers of the lower Etchegoin, but has a range elsewhere from the upper Miocene to the lower Pliocene 131



ETCHEGOIN FOSSILS.

PLATE XL.

PLATE XL.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

ARCA TRILINEATA Conrad.

Page.

Figure 1. Exterior of left valve, longitude 61 mm., natural size. Catalogue No. 165534, U.S.N.M. Lower Etchegoin formation; locality 4665. This species, which is variable both in outline and number and sculpture of ribs, ranges from the upper Miocene to the Pliocene. It is abundant in the upper Miocene and later marine faunas in the Coalinga district.................... 125

1a. Umbones of same specimen.

THAIS ETCHEGOINENSIS Arnold.

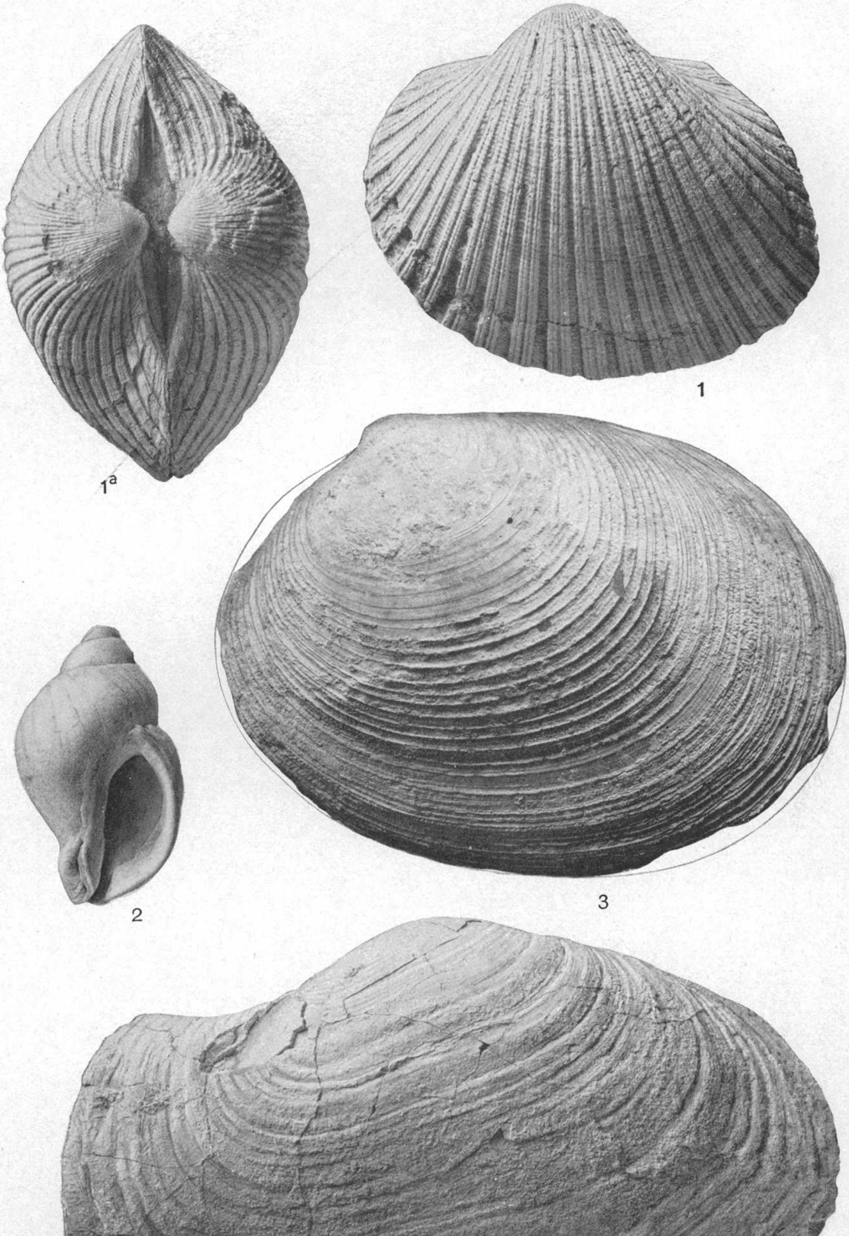
Figure 2. Front of slightly décolleté specimen, longitude 38 mm., natural size. Type, catalogue No. 165533, U.S.N.M. Lower Etchegoin formation; locality No. 4697. The genus *Thais* was formerly known as *Purpura*.. 130

PAPHIA TENERRIMA Carpenter.

Figure 3. Exterior of left valve, longitude 83 mm., natural size. Catalogue No. 165544, U.S.N.M. Middle Etchegoin formation; locality 4664. This species is abundant in the middle Etchegoin beds on White Creek and Anticline Ridge. It ranges from the upper Miocene to the Recent fauna.................................. 126

PANOPEA GENEROSA Gould.

Figure 4. Exterior of right valve, longitude 104 mm., natural size. Catalogue No. 165556, U.S.N.M. Upper Etchegoin formation; locality 4658. This species ranges from the lower Miocene to the Recent fauna.. 126



ETCHEGOIN FOSSILS.

PLATE XLI.

PLATE XLI.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

ECHINARACHNIUS GIBBSII Rémond var. ASHLEYI Arnold.

Page.

Figure 1. Top, longitude 60 mm., natural size. Catalogue No. 165548, U.S.N.M. Upper Jacalitos formation; locality 4767. An abundant form at this locality; also abundant in the Santa Maria district...... 110

ECHINARACHNIUS GIBBSII Rémond.

Figure 2. Top, longitude 54 mm. Catalogue No. 165547, U.S.N.M. Locality 4661. A relatively narrower specimen than that shown in Plate XLII, figure 7.. 125

GLYCYMERIS COALINGENSIS Arnold.

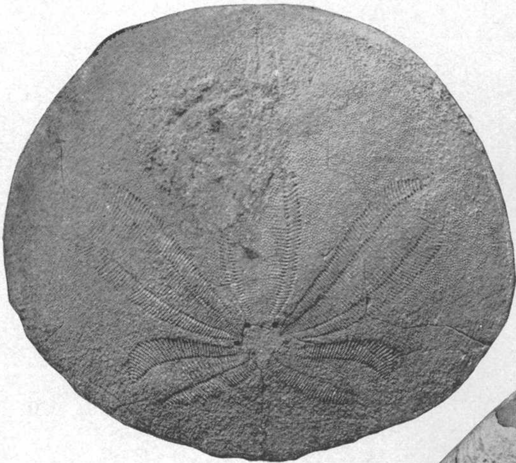
Figure 3. Exterior of decorticated right valve, longitude 42 mm., natural size. Type, catalogue No. 165526, U.S.N.M. Lower Etchegoin formation; locality 4806. This genus was formerly known as *Pectunculus*... 131

MACTRA ALBARIA Conrad.

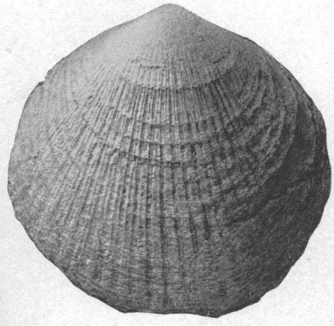
Figure 4. Exterior of an imperfect right valve from which a portion of the anterior extremity has been eroded; altitude 63 mm., natural size. Catalogue No. 165552, U.S.N.M. Lower Etchegoin formation; locality 4665. This species, which is believed to be characteristic of the upper Miocene, is found abundantly in Oregon, but only a few specimens were obtained in the Coalinga district... 125

MYTILUS (MYTILOCONCHA) COALINGENSIS Arnold.

Figure 5. Exterior of imperfect left valve, altitude 100 mm., natural size. Paratype, catalogue No. 165557, U.S.N.M. Lower Etchegoin formation; locality 4658... 125



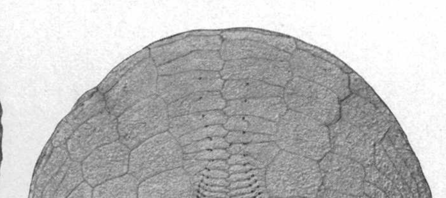
1



3

4

5



2

ETCHEGOIN FOSSILS.

88170—Bull. 398—10——23

PLATE XLII.

PLATE XLII.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

MACOMA SECTA Conrad.

Page.

Figure 1. Exterior of left valve, longitude 75 mm., natural size. Catalogue No. 165592, U.S.N.M. Etchegoin formation; locality 4806. This species ranges from the upper Miocene to the Recent fauna. 131

NEVERITA RECLUZIANA Petit.

Figure 2. Front view of decorticated and slightly imperfect specimen, altitude 36 mm., natural size. Catalogue No. 165486, U.S.N.M. Upper Etchegoin formation; locality 4710. This species ranges from the upper Miocene to the Recent fauna.................. 130

GLYCYMERIS SEPTENTRIONALIS Middendorf.

Figure 3. Exterior of left valve, longitude 24 mm. Catalogue No. 165527, U.S.N.M. Lower part of the Etchegoin formation; locality 4806. This genus was formerly known as *Pectunculus*.......... 131

3a. Interior view of same specimen.

MODIOLUS RECTUS Conrad.

Figure 4. Exterior of right valve from which the outer surface of the shell has been removed, longitude 86 mm., natural size. Catalogue No. 165535, U.S.N.M. Lower Etchegoin formation; locality 4698. This species ranges from the upper Miocene to the Recent and is characterized by its angular posterior outline.................. 128

NEVERITA RECLUZIANA Petit var. ALTA Dall.

Figure 5. Front of slightly imperfect specimen, altitude 28 mm., natural size. Catalogue No. 165489, U.S.N.M. Upper Etchegoin formation; locality 4709. This variety ranges from the upper Miocene to the Recent fauna.. 130

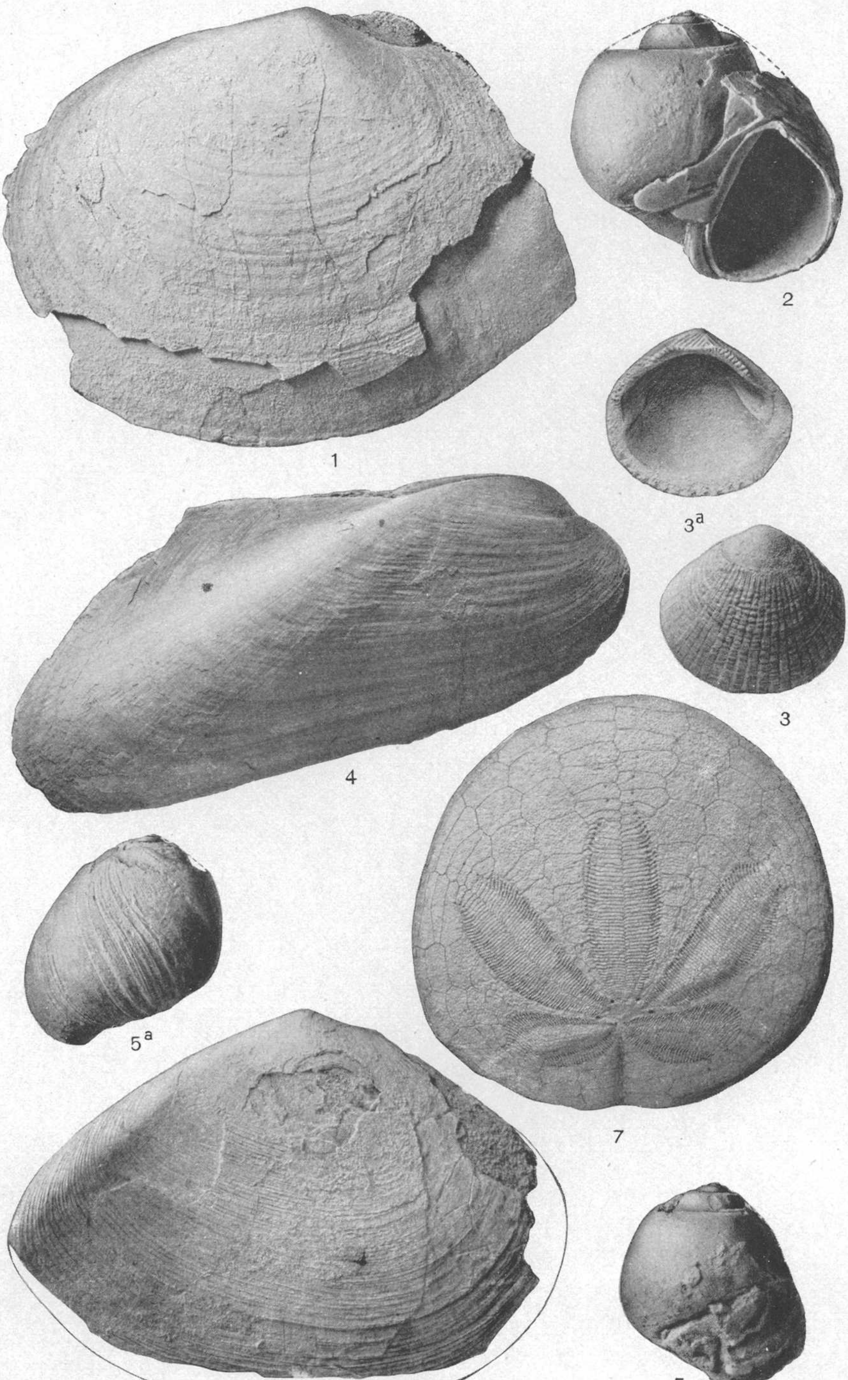
5a. Back of same specimen.

MACOMA NASUTA Conrad.

Figure 6. Exterior of slightly imperfect right valve, longitude 70 mm., natural size. Catalogue No. 165514, U.S.N.M. Lower part of the Etchegoin formation; locality 4756. This species ranges from the lower Miocene to the Recent fauna........................ 131

ECHINARACHNIUS GIBBSII Rémond.

Figure 7. Top, longitude 61 mm., natural size. Catalogue No. 165547, U.S.N.M. Lower Etchegoin formation; locality 4661. This figure illustrates a typical undistorted specimen. The specimens found in this district are usually more or less distorted. The species ranges through the Jacalitos and Etchegoin formations. (See Pl. XLI, fig. 2).. 125



ETCHEGOIN FOSSILS.

PLATE XLIII.

PLATE XLIII.

JACALITOS (EARLY UPPER MIOCENE) AND ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

THAIS KETTLEMANENSIS Arnold.

Page.

Figure 1. Front of decorticated and slightly imperfect specimen, altitude 82 mm., natural size. Type, catalogue No. 165585, U.S.N.M. Jacalitos formation; locality 4763 110

1a. Back of same specimen.

CRYPTOMYA QUADRATA Arnold.

Figure 2. Exterior of right valve, longitude 35 mm., natural size. Type, catalogue No. 165525, U.S.N.M. Lower Etchegoin formation; locality 4665 125

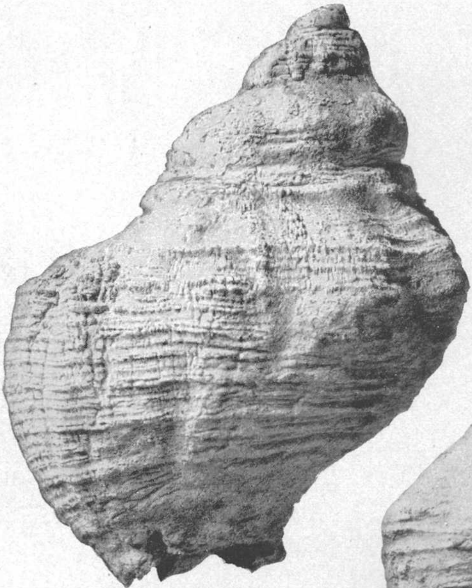
2a. Exterior of left valve of same specimen.

MULINIA DENSATA Conrad.

Figure 3. Front of both valves, altitude 50 mm., natural size. Catalogue No. 165554, U.S.N.M. Lower Etchegoin formation; locality 4754. This species is usually confined to the upper Miocene, although it is known to extend down into the Vaqueros. This species is sometimes listed as *Pseudocardium gabbi* Rémond 131

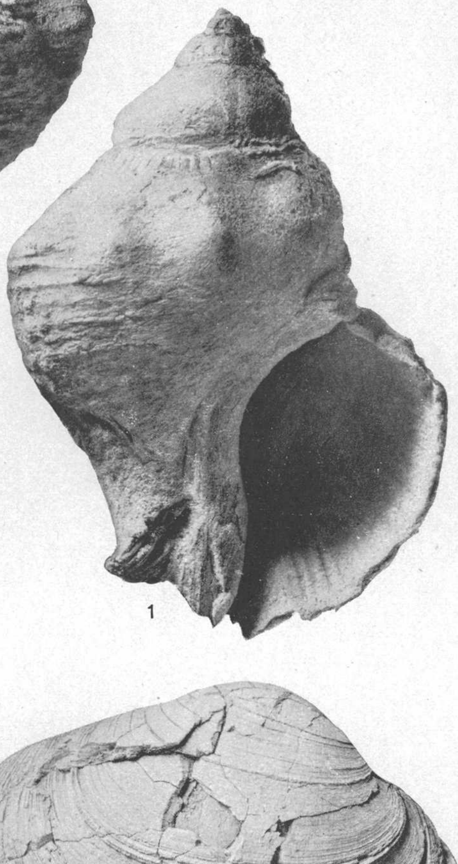
SAXIDOMUS NUTTALLI Conrad.

Figure 4. Exterior of right valve 105 mm., two-thirds natural size. Catalogue No. 165529, U.S.N.M. Upper part of Jacalitos formation; locality 4656. This species ranges from the upper Miocene to the Recent fauna 126

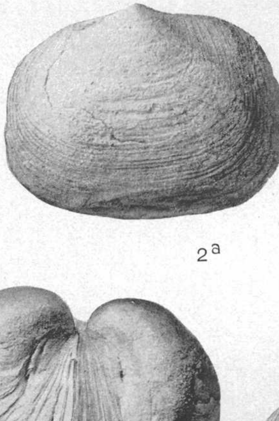


1[a]

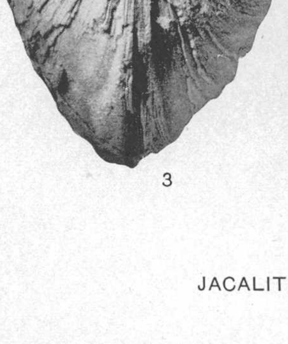
2



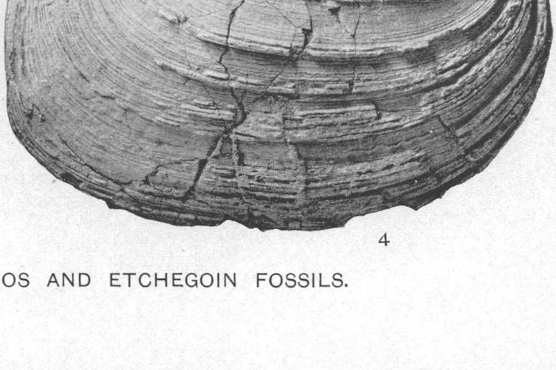
1



2[a]



3



4

JACALITOS AND ETCHEGOIN FOSSILS.

PLATE XLIV.

PLATE XLIV.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: LOWER HORIZON.

Lunatia lewisii Gould.

Page.

Figure 1. Front of slightly imperfect internal cast which, however, shows the general outline of the shell; altitude 90 mm., natural size. Catalogue No. 165541, U.S.N.M. Upper Etchegoin formation; locality 4665. This species ranges from the upper Miocene to the Recent fauna.. 127

Pleurotoma coalingensis Arnold.

Figure 2. Front, longitude 20 mm., × 2. Type, catalogue No. 165509, U.S.N.M. Upper Etchegoin formation; locality 4806........................ 133

Turritella vanvlecki Arnold.

Figure 3. Back of décolleté and otherwise somewhat imperfect specimen; longitude 57 mm., natural size. Type, catalogue No. 165496, U.S.N.M. Middle Etchegoin formation; locality 4658.......... 127

Trophon (Forreria) coalingense Arnold.

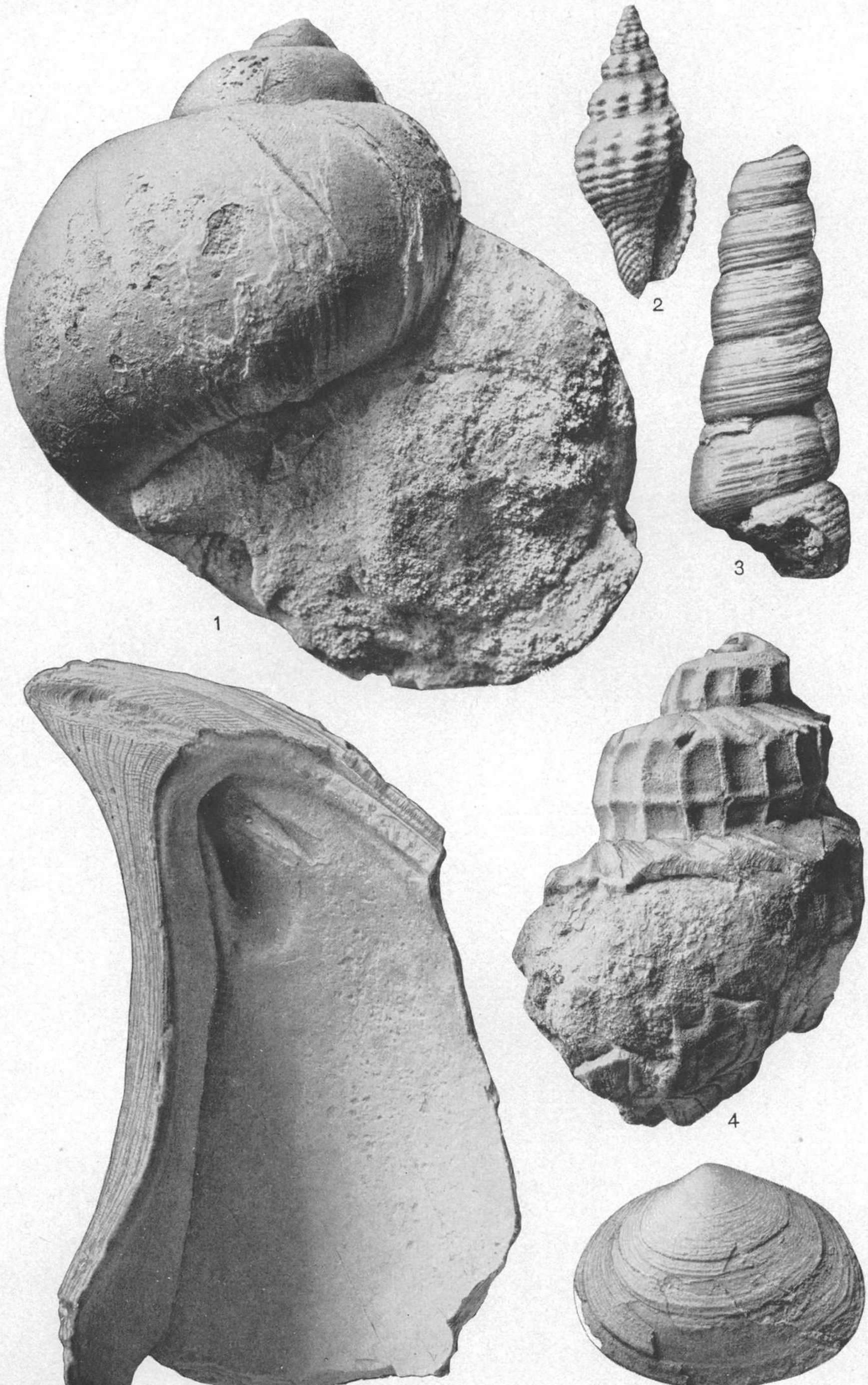
Figure 4. Back of imperfect specimen, longitude 65 mm., natural size. Type catalogue No. 165540, U.S.N.M. Upper Etchegoin formation; locality 4857.. 133

Cryptomya ovalis Conrad.

Figure 5. Exterior of left valve, longitude 37 mm., natural size. Catalogue No. 165589, U.S.N.M. Etchegoin formation; locality 4758. This specimen appears to be intermediate between the typical *Cryptomya ovalis* Conrad and *Cryptomya quadrata* Arnold........ 131

Mytilus (Mytiloconcha) coalingensis Arnold.

Figure 6. Exterior of umbonal region of a moderate-sized right valve, longitude 105 mm., natural size. Type, catalogue No. 165551, U.S.N.M. Lower Etchegoin formation; locality 4656.......... 125



ETCHEGOIN FOSSILS.

PLATE XLV.

PLATE XLV.

ETCHEGOIN (UPPER MIOCENE) FOSSILS.

PECTEN (PATINOPECTEN) OWENI Arnold.

Page.

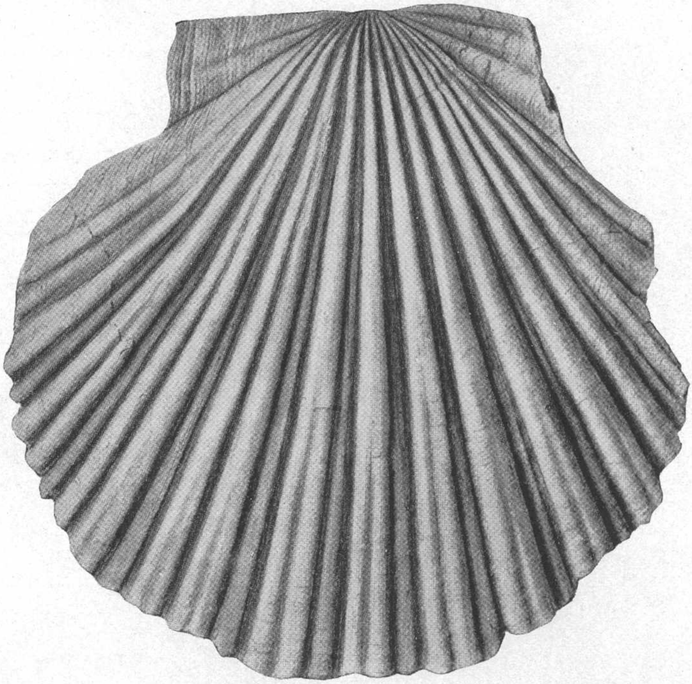
Figure 1. Exterior of right valve, anterior ear slightly broken, altitude 85 mm., slightly reduced. Type; Coll. Univ. California. Foxin's ranch, Santa Barbara County. A characteristic species in the upper Miocene.

CREPIDULA PRINCEPS Conrad.

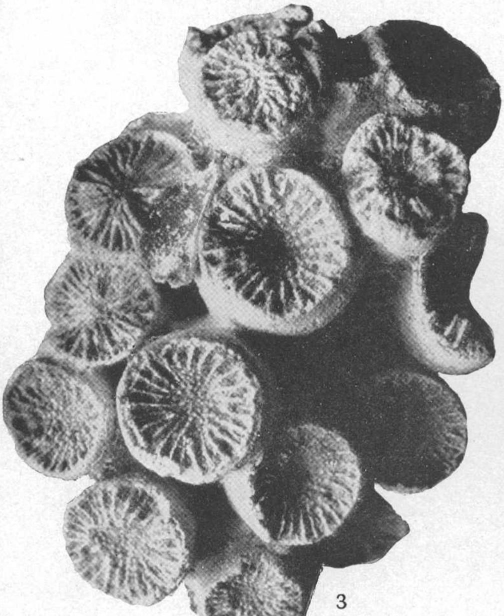
Figure 2. View of interior; longitude 106 mm., slightly reduced. Catalogue No. 165315, U.S.N.M. Packard's Hill, Santa Barbara. Found throughout the Miocene and Pliocene in California.

ASTRANGIA COALINGENSIS Vaughan.

Figure 3. View of top of group of specimens, maximum altitude 20 mm., × 3. Type, catalogue No. 165666, U.S.N.M. Upper Etchegoin formation; locality 4710. This species is believed to be characteristic of the upper Miocene.................................. 128



1



3

2

ETCHEGOIN FOSSILS.

PLATE XLVI.

PLATE XLVI.

ETCHEGOIN UPPER MIOCENE) FOSSILS: UPPER HORIZON.

SIGARETUS SCOPULOSUS Conrad.

Page.

Figure 1. Top, maximum diameter 36 mm., natural size. Catalogue No. 165524, U.S.N.M. Upper Etchegoin formation; locality 4662. This species ranges from the Oligocene to the lower Pliocene.... 127

PLACUNANOMIA CALIFORNICA Arnold.

Figure 2. Exterior of right valve, altitude 66 mm., natural size. Type, catalogue No. 165546, U.S.N.M. Upper Etchegoin formation; locality 4715.. 129

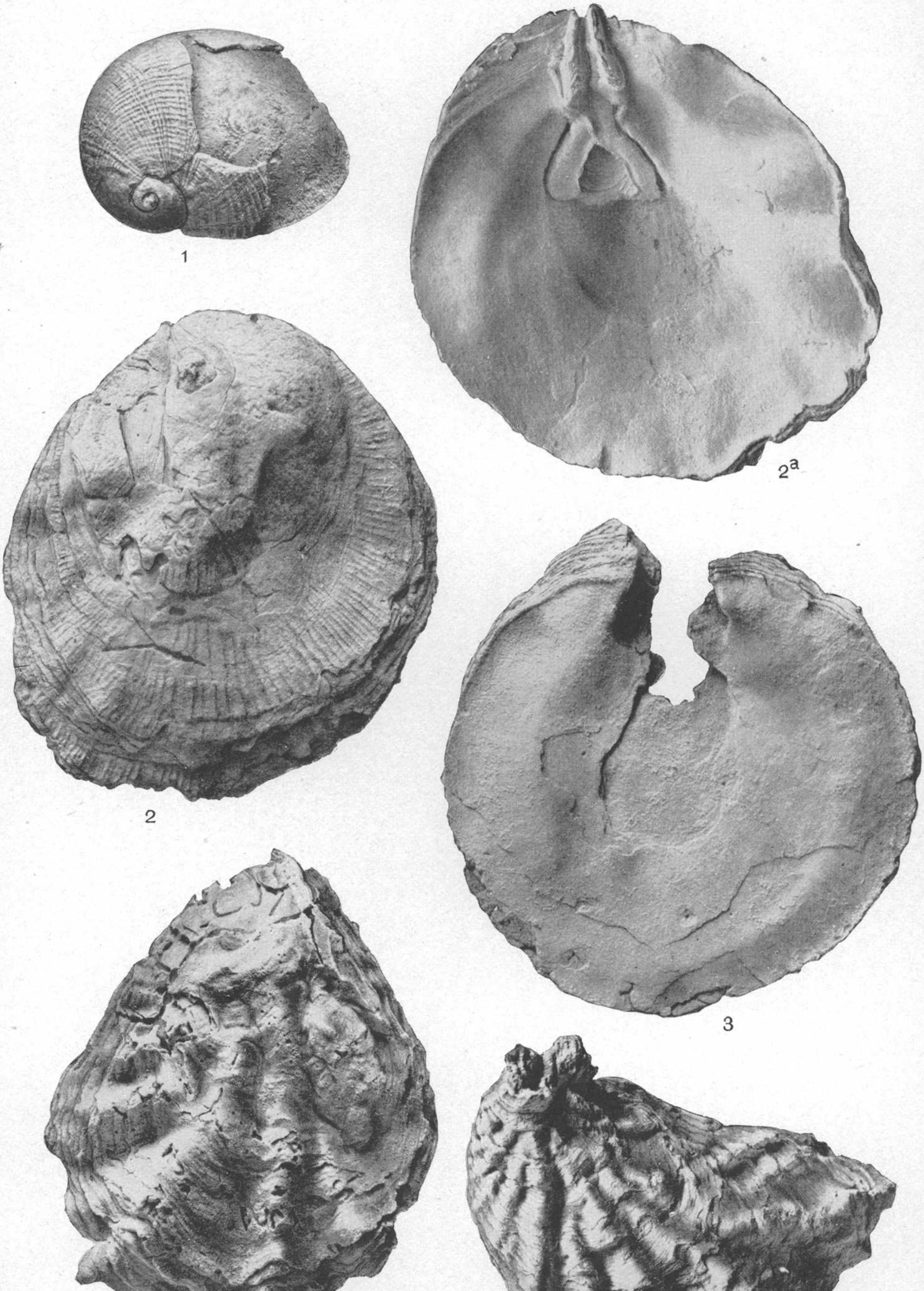
2a. Interior of same specimen.

3. Interior of left valve, paratype, altitude 67 mm., natural size.

OSTREA VESPERTINA Conrad.

Figure 4. Exterior of left valve, longitude 57 mm., natural size. Catalogue No. 165536, U.S.N.M. Upper Etchegoin formation; locality 4715.. 129

5. Right valve, longitude 67 mm. Same locality.



ETCHEGOIN FOSSILS.

PLATE XLVII.

PLATE XLVII.

ETCHEGOIN (UPPER MIOCENE) FOSSILS, UPPER HORIZON, AND TULARE (FRESH-WATER PLIOCENE) FOSSILS.

Astyris richthofeni Gabb.

Page.

Figure 1. Front of a rather poorly preserved specimen, altitude 11 mm., × 2. Catalogue No. 165510, U.S.N.M. Upper Etchegoin formation; locality 4806. This species ranges from the upper Miocene to the Pliocene 132

Trophon (Boreotrophon) stuarti Smith.

Figure 2. Back of body whorl and portion of penultimate whorl, longitude 25 mm., natural size. Catalogue No. 165492, U.S.N.M. Upper Etchegoin formation; locality 4712. This species ranges from the upper Miocene to the Recent and is a boreal type......... 130

Semele rubropicta Dall.

Figure 3. Slightly imperfect right valve, longitude 31 mm., natural size. Catalogue No. 165517, U.S.N.M. Upper Etchegoin formation; locality 4758. This species ranges from the upper Miocene to the Recent fauna.. 132

Mactra coalingensis Arnold.

Figure 4. Exterior of imperfect left valve, altitude 52 mm., natural size. Type, catalogue No. 165513, U.S.N.M. Upper Etchegoin formation; locality 4806.. 131

Macoma nasuta Conrad.

Figure 5. Imperfect left valve, longitude 69 mm., natural size. Catalogue No. 165515, U.S.N.M. Upper Etchegoin formation; locality 4758.. 131

Bulbous Growth on Fish Skeleton.

Figure 6. Top, longitude 52 mm., natural size. Catalogue No. 165495, U.S.N.M. Upper Etchegoin formation; locality 4740..................... 153

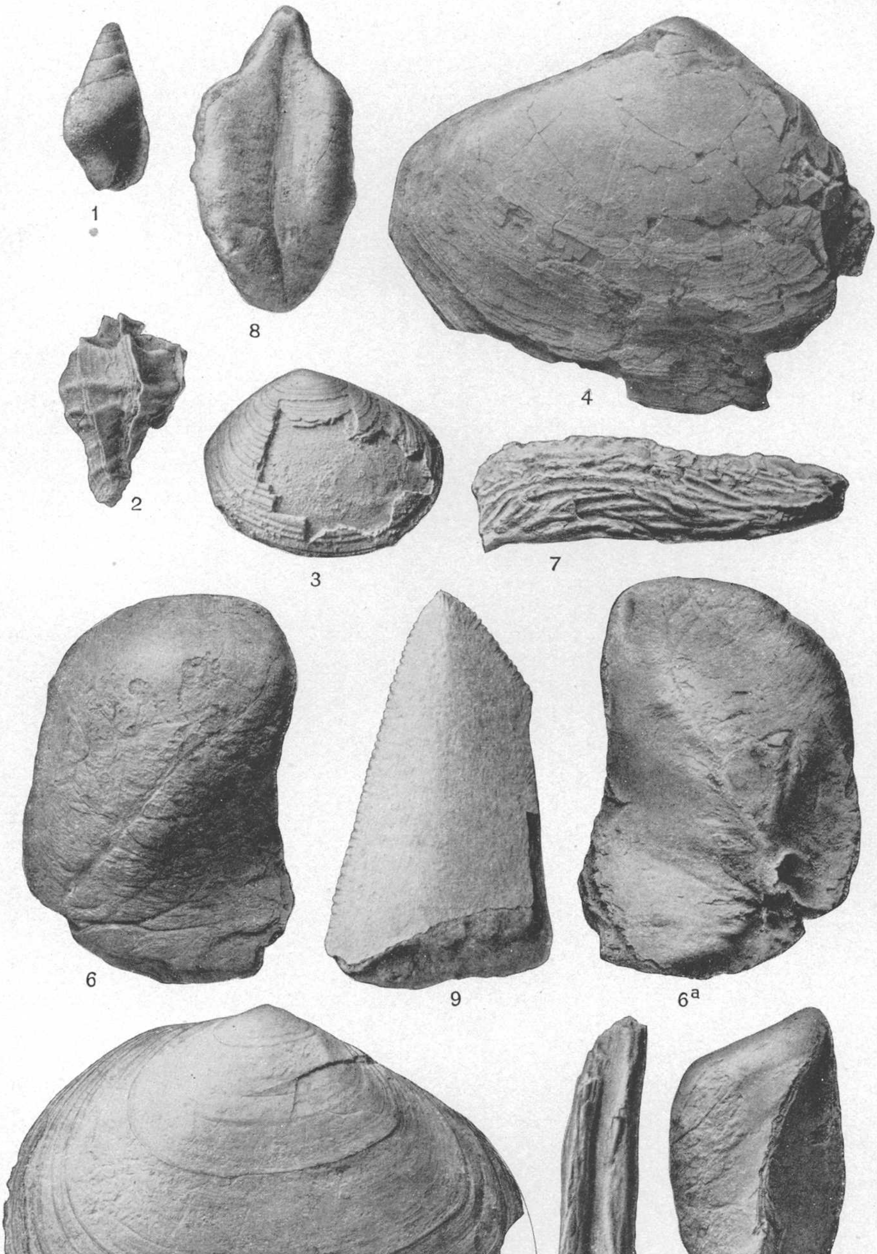
6a. Bottom of same specimen.

6b. Side of same specimen.

Fish Spine.

Figure 7. Side, longitude 49 mm., natural size. Catalogue No. 165493, U.S.N.M. Tulare formation; locality 4740................................ 153

7a. Base of same specimen.



ETCHEGOIN AND TULARE FOSSILS.

BULBOUS GROWTH ON FISH SKELETON.

Page.

Figure 8. Grooved base, longitude 40 mm., natural size. Catalogue No. 165494, U.S.N.M. Tulare formation; locality 4731............ 153

CARCHARODON ARNOLDI Jordan.

Figure 9. Back, longitude 50 mm., natural size. Catalogue No. 165488, U.S.N.M. Upper Etchegoin formation; locality 4709. This extinct species of shark is believed to be characteristic of the upper Miocene and lower Pliocene.. 130

PLATE XLVIII.

PLATE XLVIII.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: UPPER HORIZON.

PECTEN COALINGAENSIS Arnold.

Page.

Figure 1. Exterior of right valve, longitude 58 mm., natural size. Catalogue No. 165530, U.S.N.M. Upper part of Etchegoin formation; locality 4710. This species is believed to be characteristic of the upper part of the Etchegoin formation at the top of the Miocene...... 132

2. Left valve, longitude 55 mm., natural size. Same locality.

PECTEN (PLAGIOCTENIUM) DESERTI Conrad.

Figure 3. Exterior of right valve, altitude 43 mm., natural size. Catalogue No. 165518, U.S.N.M. Upper Etchegoin formation; locality 4715.. 132

4. Exterior of left valve, longitude 37 mm., natural size. Same locality.

CHAMA PELLUCIDA Sowerby.

Figure 5. Exterior of left valve, altitude 42 mm., natural size. Catalogue No. 165482 U.S.N.M. Upper Etchegoin formation; locality 4710. This species ranges from the upper Miocene to Recent, but is found in the Coalinga district only in the upper Etchegoin..... 131

6. Exterior of right valve; altitude 24 mm., natural size. Catalogue No. 165482, U.S.N.M. Locality same as last.

TRANSENNELLA CALIFORNICA Arnold.

Figure 7. Exterior of right valve, longitude 5.5 mm., × 5. Type, catalogue No. 165553, U.S.N.M. Upper Etchegoin formation; locality 4715.. 132

7a. Interior of same specimen.

PAPHIA STALEYI? Gabb.

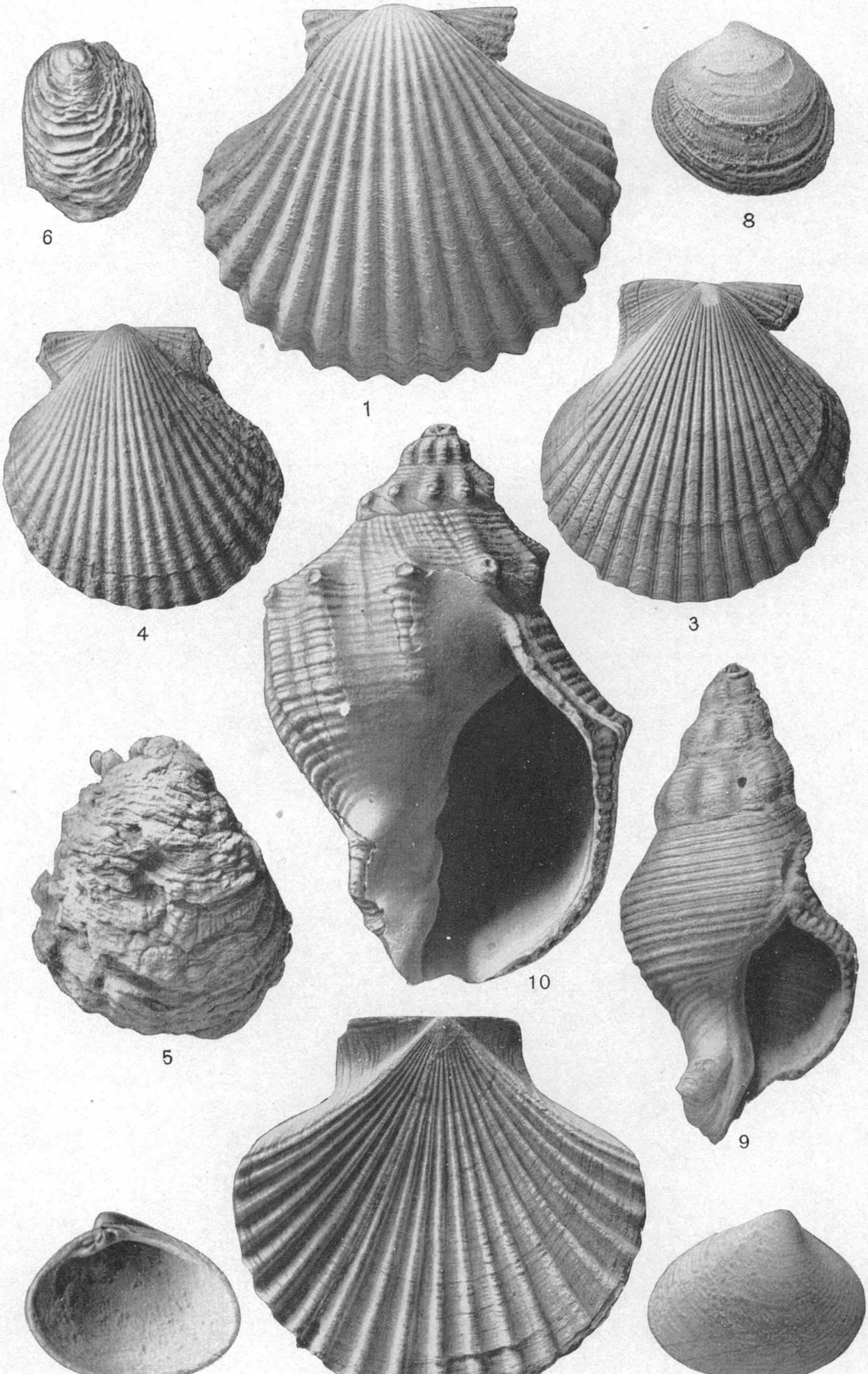
Figure 8. Right valve of young specimen, longitude 8.5 mm., × 3. Catalogue No. 165516, U.S.N.M. Upper Etchegoin formation; locality 4715. This species is believed to be characteristic of the upper Miocene and Pliocene. Formerly called *Tapes staleyi*......... 132

CHRYSODOMUS PORTOLAENSIS Arnold.

Figure 9. Front, longitude 64 mm., natural size. Type, catalogue No. 165473, U.S.N.M. Etchegoin formation; locality 4665. This species is believed to be characteristic of the upper Miocene, and is found abundantly in the lower Purisima formation near Portola in San Mateo County and in several localities farther south 126

CANCELLARIA TRITONIDEA Gabb.

Figure 10. Front, longitude 78 mm., natural size. Catalogue No. 165561, U.S.N.M. Upper San Pedro formation, San Pedro, California. This species is believed to range from the upper Miocene to the Pleistocene. The specimen figured is from the type locality.



ETCHEGOIN FOSSILS.

PLATE XLIX.

88170—Bull. 398—10——25

PLATE XLIX.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: UPPER HORIZON.

PECTEN (CHLAMYS) WATTSI Arnold.

		Page.
Figure 1.	Exterior of right valve, altitude 61 mm., natural size. Catalogue No. 165550, U.S.N.M. Upper Etchegoin formation; locality 4712. This specimen is also from the type locality. The species ranges from the upper Miocene to the lower Pliocene and is found in the Coalinga district only in the upper Etchegoin	132
2.	Exterior of left valve, altitude 76 mm., natural size. Same locality.	

PECTEN NUTTERI Arnold.

Figure 3.	Exterior of right valve, altitude 67 mm., natural size. Catalogue No. 165549, U.S.N.M. Upper Etchegoin formation; locality 4712. This specimen is from the type locality of the species, where it is moderately abundant. It is believed to be characteristic of the upper Miocene and possibly lower Pliocene	132
4.	Exterior of left valve, altitude 63 mm. Same locality.	

TEREBRATALIA SMITHI Arnold.

Figure 5.	Exterior of dorsal valve showing beak of ventral valve, altitude of former 22 mm., natural size. Catalogue No. 165512, U.S.N.M. Upper Etchegoin formation; locality 4758. This brachiopod is very abundant in the *Pecten coalingaensis* horizon	131
5a.	Ventral valve of same specimen. Longitude 27.5 mm., natural size.	

CALLIOSTOMA KERRI Arnold.

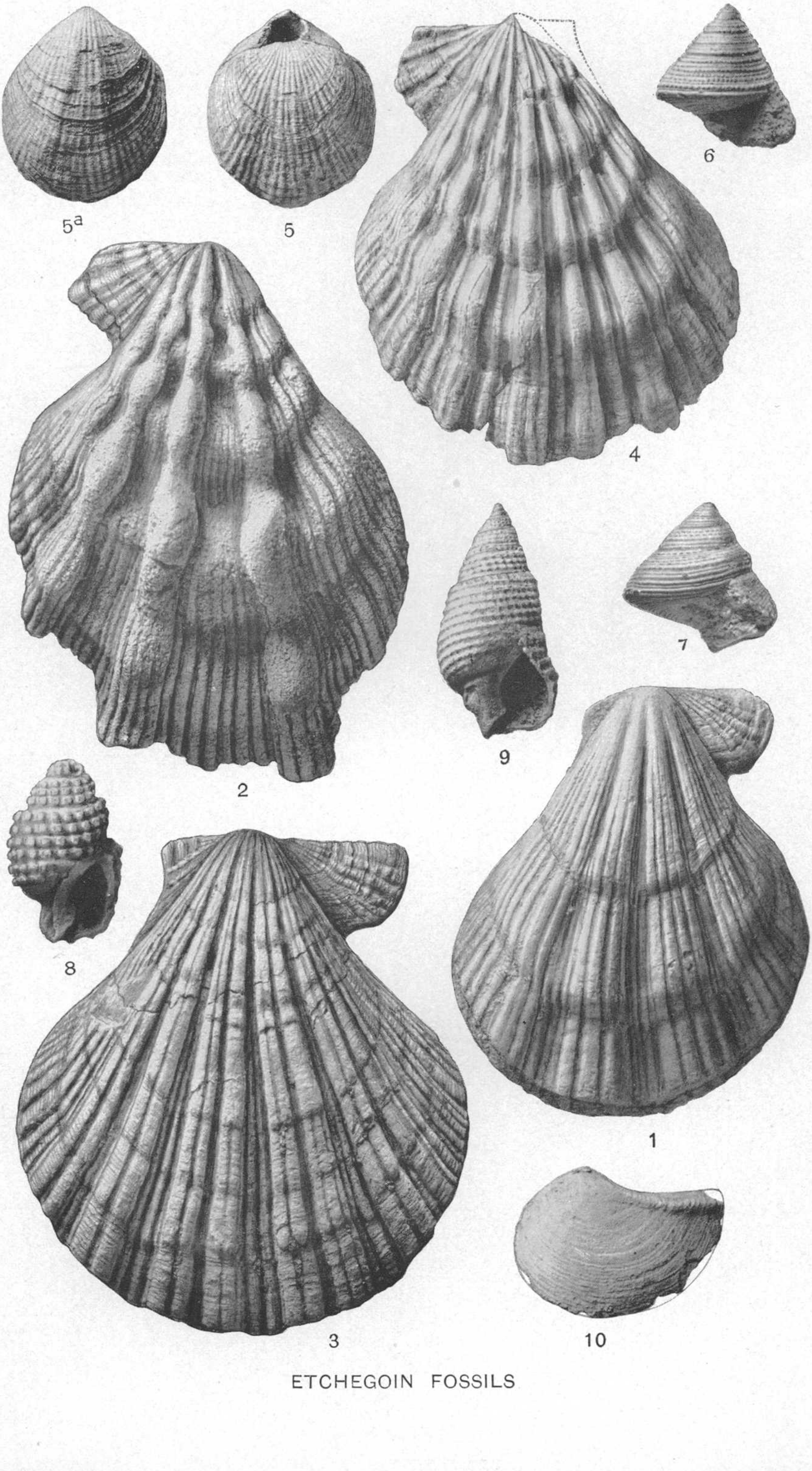
Figure 6.	Front of slightly distorted specimen, altitude 18.5 mm., natural size. Type, catalogue No. 165500, U.S.N.M. Upper Etchegoin formation; locality 4758	132

CALLIOSTOMA COALINGENSIS Arnold.

Figure 7.	Front view of slightly distorted specimen, altitude 21 mm., natural size. Type, catalogue No. 165499, U.S.N.M. Upper Etchegoin formation; locality 4758	132

NASSA CALIFORNIANA Conrad.

Figure 8.	Front of a slightly imperfect young and unusually nodose specimen, altitude 13.5 mm., × 2. Catalogue No. 165508, U.S.N.M. Upper Etchegoin formation; locality 4806. This species ranges from the upper Miocene to the Pleistocene and may possibly have living representatives. This nodose form is apparently characteristic of the upper Miocene	133



ETCHEGOIN FOSSILS

NASSA CALIFORNIANA Conrad var. COALINGENSIS Arnold.

Page.

Figure 9. Front, altitude 32 mm., natural size. Type, catalogue No. 165511, U.S.N.M. Upper Etchegoin formation; locality 4758.......... 133

CLIDIOPHORA PUNCTATA Conrad.

Figure 10. Exterior of left valve, longitude 28 mm., natural size. Catalogue No. 165497, U.S.N.M. Upper Etchegoin formation; locality 4806. This species, in which the right valve is somewhat flatter than the left, ranges from the upper Miocene to Recent fauna.... 131

PLATE L.

PLATE L.

ETCHEGOIN (UPPER MIOCENE) ECHINODERMATA: UPPER HORIZON.

SCUTELLA PERRINI Weaver.

Page.

Figure 1. Top, longitude 46 mm., natural size. Catalogue No. 165560, U.S.N.M. Upper Etchegoin formation; locality 4712. This species is believed to be characteristic of the uppermost Miocene and possibly lower Pliocene.. 128

2. Bottom, longitude 45 mm., natural size. Catalogue No. 165560, U.S.N.M. Same locality.

ASTRODAPSIS? sp. *a*.

Figure 3. Top, longitude 28 mm., × 2. Catalogue No. 165701, U.S.N.M. Upper Etchegoin formation; locality 4712. A common form at this horizon.. 128

3a. Bottom of same specimen.

ECHINARACHNIUS GIBBSII Rémond.

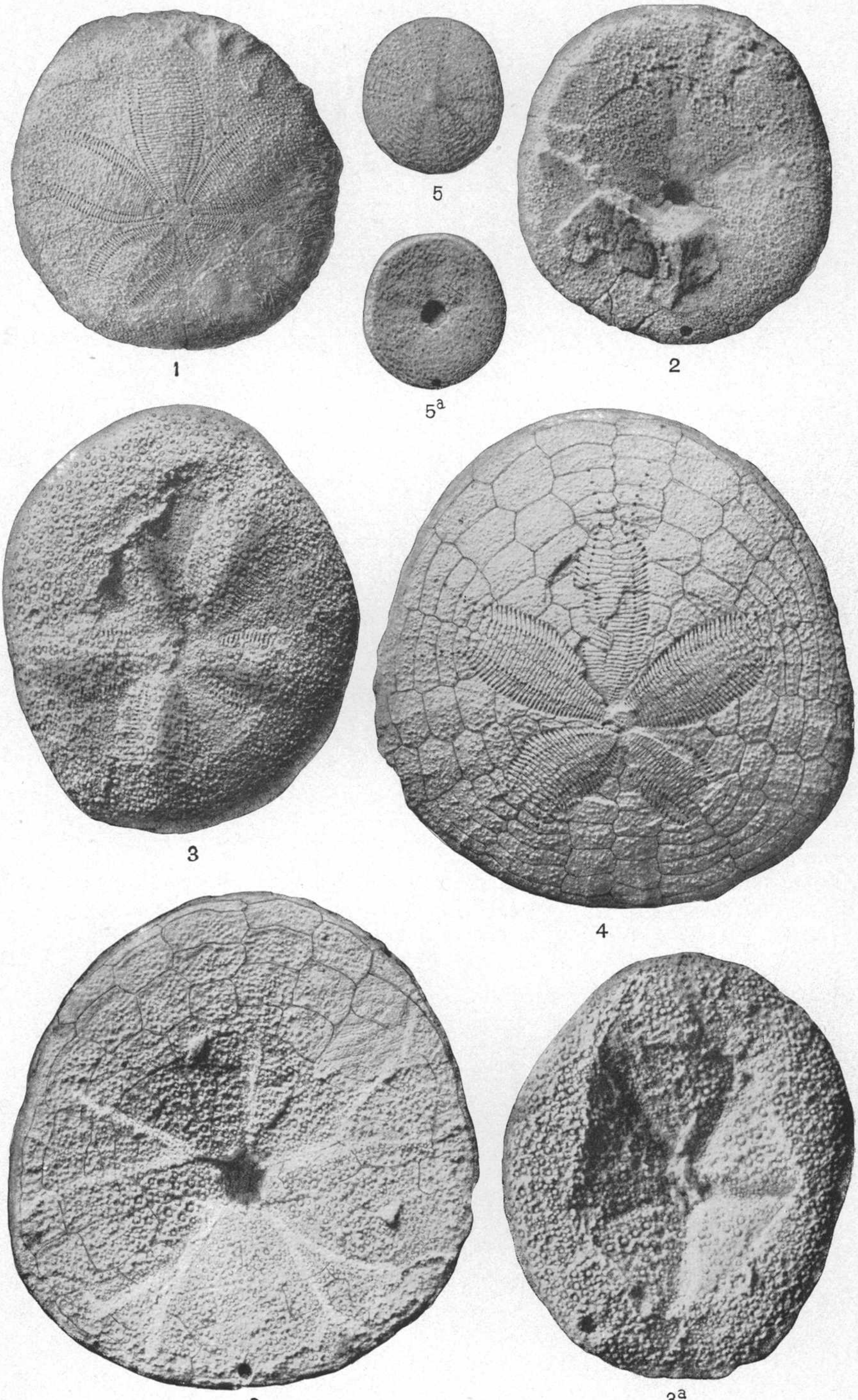
Figure 4. Top of young specimen, longitude 33 mm., × 2. Catalogue No. 165537, U.S.N.M. Upper Etchegoin formation; locality 4710. This is the most abundant sand dollar in the district and is found throughout the Jacalitos and Etchegoin formations....... 128

4a. Bottom of same specimen.

ASTRODAPSIS sp. indet.

Figure 5. Top of young specimen, longitude 10.5 mm., × 2. Catalogue No. 165538, U.S.N.M. Upper Etchegoin formation; locality 4708. 128

5a. Bottom of same specimen.



ETCHEGOIN ECHINODERMATA.

PLATE LI.

PLATE LI.

ETCHEGOIN (UPPER MIOCENE) FOSSILS: UPPERMOST FOSSIL BED.

LITTORINA MARIANA Arnold.

Page.

Figure 1. Front, longitude 14.5 mm., × 2. Type, catalogue No. 165481, U.S.N.M. Upper Etchegoin formation; locality 4718.......... 129

LITTORINA MARIANA var. ALTA Arnold.

Figure 2. Front, longitude 17 mm., × 2. Type, catalogue No. 165487, U.S.N.M. Upper Etchegoin formation; locality 4730.......... 129

MACOMA INQUINATA Deshayes.

Figure 3. Exterior of left valve, longitude 46 mm., natural size. Catalogue No. 165483, U.S.N.M. Upper Etchegoin formation; locality 4736. This species ranges from the upper Miocene to the Recent fauna.. 131

SOLEN SICARIUS Gould.

Figure 4. Exterior of imperfect left valve, longitude 45 mm., natural size. Catalogue No. 165491, U.S.N.M. Upper Etchegoin formation; locality 4728. This species ranges from the Miocene to the Recent fauna, and is particularly abundant in the Coalinga district in the upper *Mya* zone.................................. 132

OSTREA VESPERTINA Conrad var. SEQUENS Arnold.

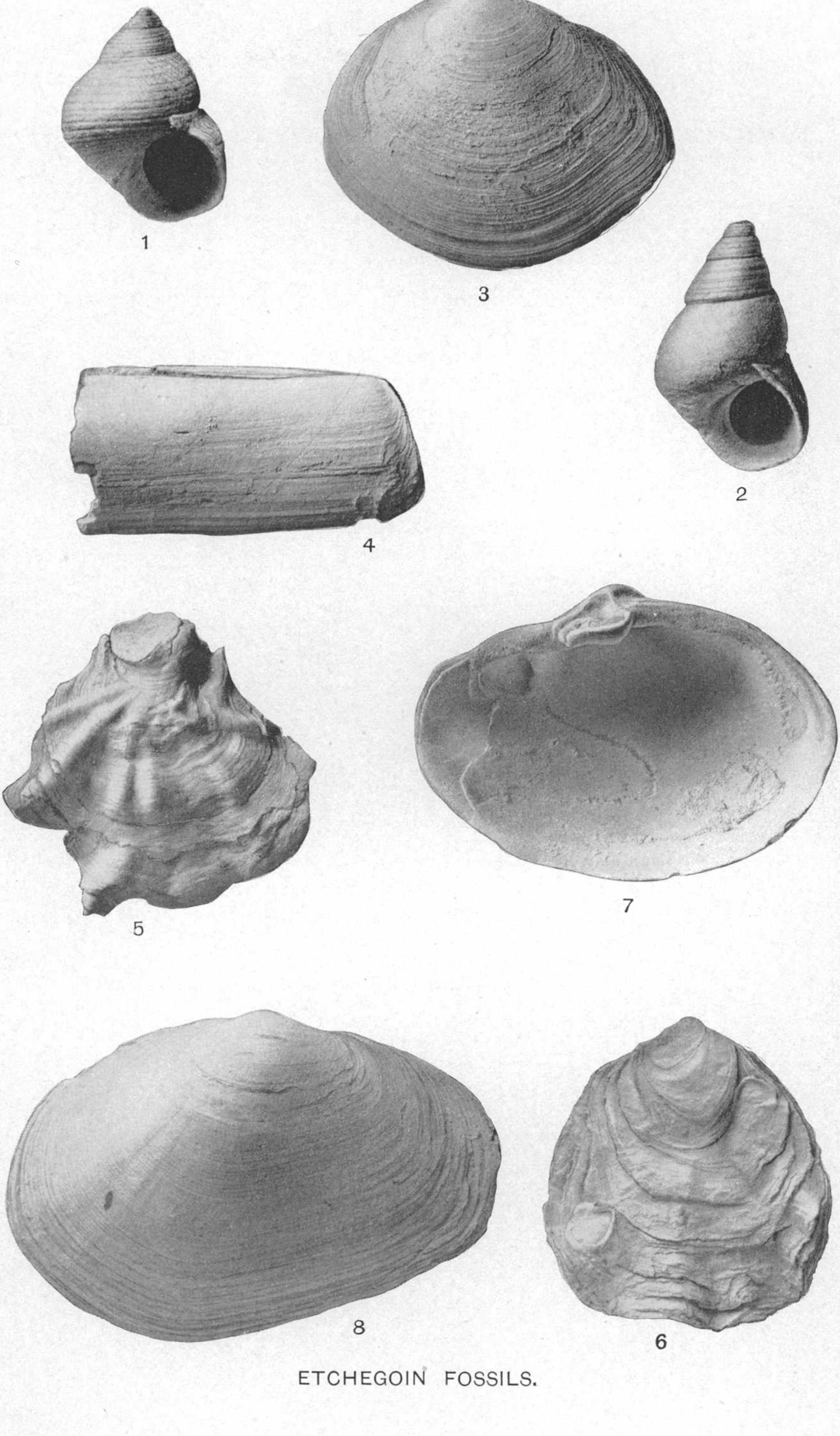
Figure 5. Exterior of left valve, longitude 42 mm., natural size. Type, catalogue No. 165545, U.S.N.M. Uppermost Etchegoin formation; locality 4728.. 132

6. Exterior of right valve, longitude 41 mm. Same locality.

MYA JAPONICA Jay.

Figure 7. Interior of left valve, longitude 56 mm., natural size. Catalogue No. 165479, U.S.N.M. (Perry's voyage). Upper Etchegoin formation; locality 4736. This species is intermediate between *M. truncata* Linn. and *M. arenaria* Linn. and extends from the upper Miocene to the Recent fauna; it is a cold-water form.......... 131

8. Exterior of left valve, longitude 66 mm., natural size. Catalogue No. 165480, U.S.N.M. Upper Etchegoin formation; same locality.



ETCHEGOIN FOSSILS.

PLATE LII.

PLATE LII.

TULARE (FRESH AND BRACKISH WATER PLIOCENE) FOSSILS.

Sphærium kettlemanensis Arnold.

Page.

Figure 1. Exterior of left valve; longitude 8 mm., × 4. Type, catalogue No. 165519. Tulare formation; locality 4731 153

1a. Interior of same specimen.

Sphærium cooperi Arnold.

Figure 2. Exterior of right valve; longitude 9.5 mm., × 2. Type, catalogue No. 165528, U.S.N.M. Tulare formation; locality 4732 153

2a. Interior of same specimen.

Carinifex marshalli Arnold.

Figure 3. Front, maximum diameter 3.7 mm., × 5. Type, catalogue No. 165507, U.S.N.M. Tulare formation; locality 4732 153

3a. Top of same specimen.

3b. Bottom of same specimen.

Planorbis vanvlecki Arnold.

Figure 4. Top, maximum diameter 4.5 mm., × 5. Type, catalogue No. 165506, U.S.N.M. Tulare formation; locality 4731 153

4a. Bottom of same specimen.

Physa humerosa Gould.

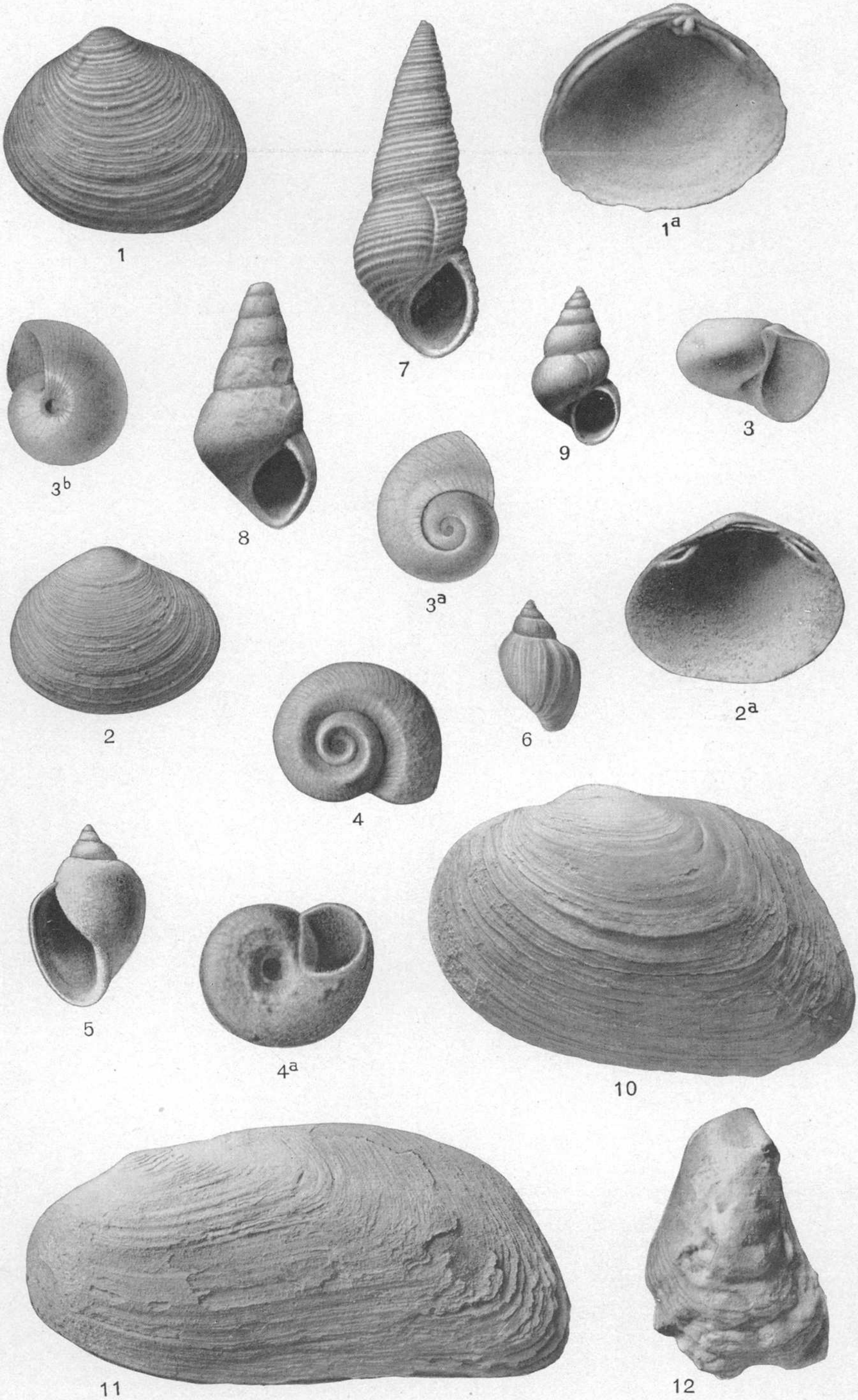
Figure 5. Front, longitude 8.5 mm., × 3. Catalogue No. 165502, U.S.N.M. Tulare formation; locality 4732. This species ranges from the Pliocene to the Recent fauna 153

Physa wattsi Arnold.

Figure 6. Back, longitude 6 mm., × 3. Type, catalogue No. 165503, U.S.N.M. Tulare formation; locality 4732 153

Goniobasis kettlemanensis Arnold.

Figure 7. Front of a rather large specimen, altitude 22.5 mm., × 2. Type, catalogue No. 165501, U.S.N.M. Tulare formation; locality 4715. Also found in the Etchegoin formation 153



TULARE FOSSILS.

GONIOBASIS NIGRINA? Lea.

Page.

Figure 8. Front of somewhat imperfect specimen, longitude 6 mm., × 5. Catalogue No. 165504, U.S.N.M. Tulare formation; locality 4732. This species is rather rare in the Tulare. It extends to the Recent fauna 153

AMNICOLA ANDERSONI Arnold.

Figure 9. Front, longitude 4 mm., × 5. Type, catalogue No. 165505, U.S.N.M. Tulare formation; locality 4732 153

ANODONTA KETTLEMANENSIS Arnold.

Figure 10. Exterior of left valve, longitude 59 mm., natural size. Type, catalogue No. 165522, U.S.N.M. Tulare formation; locality 4731.. 153

GONIDEA COALINGENSIS Arnold.

Figure 11. Exterior of left valve, longitude 73 mm., natural size. Type, catalogue No. 165521, U.S.N.M. Tulare formation; locality 4739.. 153

OSTREA LURIDA Carpenter.

Figure 12. Exterior of left valve, altitude 36.5 mm., natural size. Catalogue No. 165520, U.S.N.M. Tulare formation; locality 4743. This species, which is much less prominently corrugated than *Ostrea vespertina* Conrad, ranges from the uppermost Etchegoin (upper Miocene) to the Recent fauna 153

GENERAL INDEX.

INDEX OF FOSSILS.

[Figures in *italic* denote position of illustrations.]