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PETROLEUM RESOURCES
OF
CALIFORNIA

WITH SPECIAL REFERENCE TO UNPROVED AREAS

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PETROLEUM RESOURCES OF CALIFORNIA

With Special Reference to Unproved Areas

BY

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CALIFORNIA STATE PRINTING OFFICE
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To His Excellency, the Honorable William D. Stephens,
Governor of the State of California.

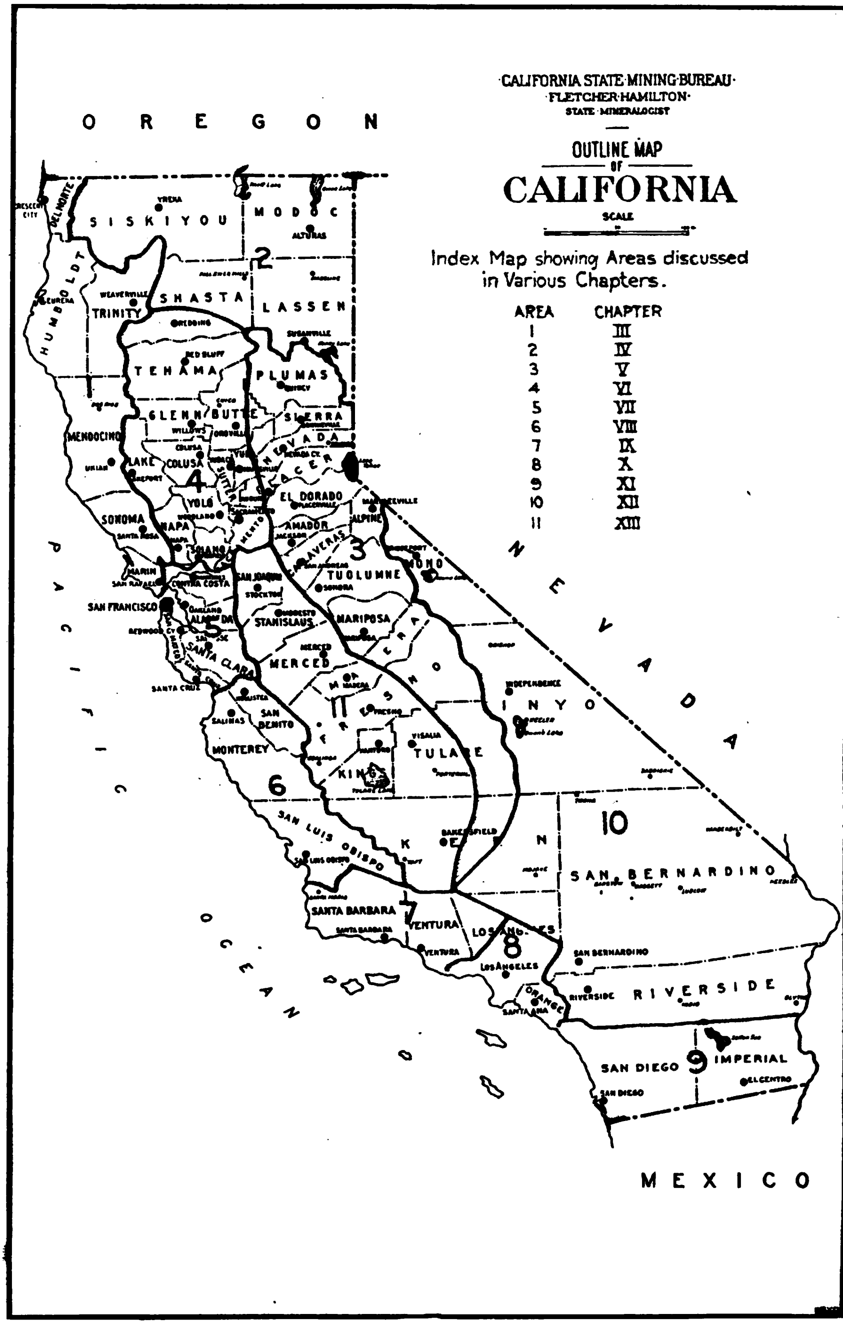
Sir:—I have the honor to herewith transmit Bulletin No. 89 of the State Mining Bureau, relating to the Petroleum Resources of California.

The increasing demand for petroleum and its products, and the inability of production to keep pace with requirements, for several years, have resulted in widespread prospecting throughout the world for possible new oil fields. In California, 'wild-cat' wells are being drilled in many localities, some of them in places where even a cursory inspection of the geology would tell of the futility of looking for oil. For this reason, the report herein aims to furnish information as to the unfavorable as well as to the favorable areas for development of additional petroleum resources in California.

Respectfully submitted.

Fletcher Hamilton,
State Mineralogist.

July 21, 1921.


CALIFORNIA STATE MINING BUREAU
FLETCHER HAMILTON
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INTRODUCTION.

Purpose and Extent of the Report.

The purpose of this report is to briefly take stock of the oil resources of the state and in particular to determine, if possible, the opportunity that exists for extending the productive area into districts that have hitherto been regarded as unfavorable. In line with this policy the greater portion of the writer's time was spent in investigating the so-called unproven areas, particularly in the northern portion of the state.

In the time allotted for the work it was found impossible to give a detailed description of any one area and it is only intended that the report should block out those areas which may be regarded as distinctly unfavorable and those which may be considered as worthy of further investigation. While a greater length of time would have been preferable it was recognized that briefness was essential, if the report was to be of any value in the present campaign of exploration. A total of six months was spent in field work and a distance of fifteen thousand miles was covered. A second six months was spent in writing the report and assembling data. In a portion of the field work in Northern California, the writer was assisted by Mr. E. Huguenin, engineer of the Bureau.

A brief description only has been given of the proven fields. The possibility of their extension has been noted in a general way. Readers who are interested in the details of these areas are referred to the numerous publications of the United States Geological Survey and the State Mining Bureau, a list of these being included in the report.

Chapter I has been devoted to describing the general geological facts that govern the origin and accumulation of petroleum in California based upon the actual conditions that exist in the proven fields. A knowledge of these conditions is absolutely necessary for successful exploration work. Chapter II describes the rock formations of the state which are directly, or indirectly, connected with the petroleum deposits. The character, thickness, where found, relationship to the oil measures and relative productiveness are briefly discussed.

The general principles laid down in these two chapters have then been applied to the various areas which are described in the remainder of the report. In determining what chapter contains the description of any certain district, the index map (frontispiece) showing the area covered by each, will be found helpful.

Plate I, a map of the state, showing in color the possibilities of the different areas, is intended only as a generalized summing up and the reader is referred to the text for the exact possibilities of the different areas.

Acknowledgments.

In the preparation of the report the writer has used freely all publications available upon the subject. Especially have the reports of the United States Geological Survey, the Bulletins of the Department of Geology of the University of California and publications of the State Mining Bureau been used.

To various members of the staff of the Bureau the writer wishes to acknowledge his thanks. In particular to Mr. R. E. Collom, State Oil and Gas Supervisor, for general advice on the report. To Mr. Walter W. Bradley, Statistician, for assistance in preparing the manuscript, and to Mr. Emil Huguenin, engineer, for assistance in the field work in Northern California.

To Prof. B. L. Clark of the University of California the writer is indebted for assistance in preparing the correlation table of the oil-bearing formations.

To the following, acknowledgement is due for information regarding the various areas: Mr. C. L. Decius, geologist of the Pacific Oil Company; Mr. F. Tickell, geologist of the Southern Pacific Company; Mr. R. N. Ferguson, petroleum geologist of Bakersfield; Mr. C. C. Thoms, deputy supervisor of the Department of Oil and Gas, Taft; Mr. Tom O'Neal of Pt. Arena; Mr. R. C. McDonald, engineer of Williams; Mr. Don McKinney of Esparto; Mr. W. E. Schumacher of the Standard Oil Company; Mr. A. Folger, geologist of the Standard Oil Company; Mr. Irving V. Augur, geologist, Los Angeles; Mr. C. G. Bullis, Los Angeles.

GENERAL SUMMARY OF CONCLUSIONS.

In the table below, the production figures for the year 1900 and again in 1920 are shown. It will be noted that during this twenty-year interval no addition to the principal producing counties has been made.

TABLE.*

County	1900		1920	
	Production. bbl.	Percentage of total	Production. bbl.	Percentage of total
Fresno	547,960	12.6	15,464,198	14.7
Kern	919,275	21.3	52,120,532	49.3
Los Angeles	1,722,887	39.9	14,206,000	13.4
Orange	254,397	5.9	15,800,000	14.9
Santa Barbara	183,486	4.3	5,962,970	5.7
Ventura	443,000	10.3	2,122,000	2.0
Miscellaneous	248,915	5.7	25,610	----------
	4,319,950		105,720,310	

* From the Sixth Annual Report of the State Oil and Gas Supervisor. Vol. 6. No. 7. Jan., 1921.

Exploration has opened up new fields within these districts, increasing the production of the state twenty-four fold, yet it has failed to add a single noteworthy field outside their boundaries.

The principal conclusion to be drawn from this report is similar to that shown by the table. An examination of the state indicates that no field of any appreciable size will be discovered outside the two present general areas of production.

These two districts are the San Joaquin Valley and the Coast from the Santa Maria River south to the Santa Ana River.

In the San Joaquin the most promising territory for development lies along the west side of the valley. In the Coast area it consists of that portion of Los Angeles and Orange counties lying between Santa Monica and Newport and south of the San Gabriel Valley.

It is also evident that oil in appreciable quantities is confined to porous sedimentary rocks of the Tertiary period, which are associated with bodies of organic shale of marine origin. The greater portion of the yield comes from beds of Miocene and Pliocene age.

The Cretaceous, which is the principal sedimentary formation exposed in northern California, shows numerous seepages. It is believed, however, that it will not produce sufficient oil to be of any great commercial importance.

Those fields which were plainly visible to the geologist and prospector have now been opened up to development work. New fields in the future will only be found by detailed study of the geology and topography of the state.

Statistics for 1920.

Total production (barrels)	105,720,310
Total proven acreage (acres)	91,319
Total number of wells producing	9,642
Average production, per day, per well (barrels)	35

CHAPTER I.

General Theory of the Origin and Accumulation of Oil in California.

Organic Theory of Origin.

The generally accepted theory among geologists as to the origin of petroleum in California, is that which assigns to it an organic source. According to this theory petroleum is the result of the slow decomposition and distillation of animal and vegetal matter at a low temperature, without a sufficient supply of oxygen. The result of this chemical reaction is the formation of liquid hydrocarbons, known as petroleum, or mineral oil.

Assuming that the above theory as to origin is correct, it follows that oil in California must necessarily have been formed in sedimentary rocks and in particular in those sedimentary rocks which contained organic material in appreciable quantities.

An investigation of the geological formations of the state indicates that such deposits of organic material are present in remarkable quantities; ranging in the geological column from the Cretaceous to the Pliocene and commonly known as 'organic shales.'

Further, it can be definitely stated that all *known* deposits of petroleum *in California* are found *in close association with these organic shales, either in or above them.*

Organic Shales.

The organic shales were originally marine deposits of fine silt, mingled with the remains of diatoms, foraminifera and various other forms of sea life.

Diatoms are a low, minute form of plant life or algæ, having a framework of silica. Under the microscope they appear as round dots in the shale and vary in size from 0.1 mn. to 1 mn. and apparently form the bulk of the shale. An analysis of various samples of California oil shale shows that they vary from 65 per cent to 85 per cent silica. In view of these facts it has been assumed that these diatoms are the chief source of the California oil.

After the diatoms, the next most abundant organisms are foraminifera, an animal organism, with a hard calcareous shell, generally about 2 mn. in length. In addition the shales contain numerous sponge spicules, fish scales and impressions of seaweed.

The diatom and foraminifera lived at the surface of warm inland seas, such as were present in what is now the great valley and coast regions of California, during the various geological ages from the Cretaceous to the present. These organisms dying, dropped to the bottom of the seas and together with other plant and animal matter formed an ooze or organic mud. Then, due to the low temperature and absence of oxygen in quantities, a very slow decomposition, or putrification of the organic parts, took place. It is, however, believed that no great quantity of liquid hydrocarbons were formed at this stage. These are believed to have been formed when, due to earth movements, the mud or ooze was uplifted above the surface of the sea and by reason of the heat and pressure due to these movements and possibly aided by the action of saline waters, distillation of the shale took place, which resulted in the formation of petroleum.

In general these organic shales are fine grained and compact in texture; light in weight; ranging in color from chocolate-brown, purple and maroon to light gray and white. They vary from the pure soft earthy, 'chalky' variety, to hard flinty porcelaneous varieties.

Migration and Accumulation.

The petroleum thus formed in the organic shales was probably present at first in minute quantities throughout the shale. It is next necessary to account for its concentration and accumulation in pools such as now exist in the California fields. To explain these concentrations in pools it will be necessary to assume that the oil migrated from the shales in which it formed to the porous reservoirs where it is now found, these reservoirs in practically all cases being porous sands either in the shales or directly above them. Whereas the origin of the petroleum from the organic shale may be readily explained, the force that caused the migration and accumulation of the oil is not as yet clearly understood. All that is certain is that the oil has migrated and accumulated in pools along certain geological structures, and while no oil in commercial quantities has been found except along these structures, no facts that will fit all existing conditions have been found to explain the reason for the accumulation.

Before giving a review of some of the theories for accumulation it would be well to describe briefly the typical geological structure wherein the oil in California is found.

The contraction of the earth's surface has caused folding in the rocks that form its crust. There are several different kinds of folds. (See Fig. 1, page 15.) When the strata are domed up in an arch the structure is known as an anticline. The trough corresponding to this arch is known as a syncline. When the strata have been tilted in one direction only the structure is known as a monocline. When the apex of an anticline or cyncline ceases to be horizontal it is said to plunge, and similarly when the axis is inclined from the vertical the fold is said to be assymetrical. When forces of compression have caused the strata to break and slip along a definite line, faulting takes place. When a later formation is deposited upon the tilted or eroded surface of an earlier formation, this is called an unconformity.

Theories as to Accumulation.

(1) Anticlinal Theory. This theory assumes that oil being of a less specific gravity than water rises above the water present in the porous rocks and collects in the highest possible point in an upward fold. The factors necessary for this hypothesis are, (a) saturation of the sand with oil, gas and water; (b) folding; (c) porous beds between impervious beds. Oil accumulating in this manner must overcome the friction of the grains of the porous rocks and the molecular repulsion of oil and water. The forces in favor would be difference in gravity of the oil and water and the inclination or dip of the strata.

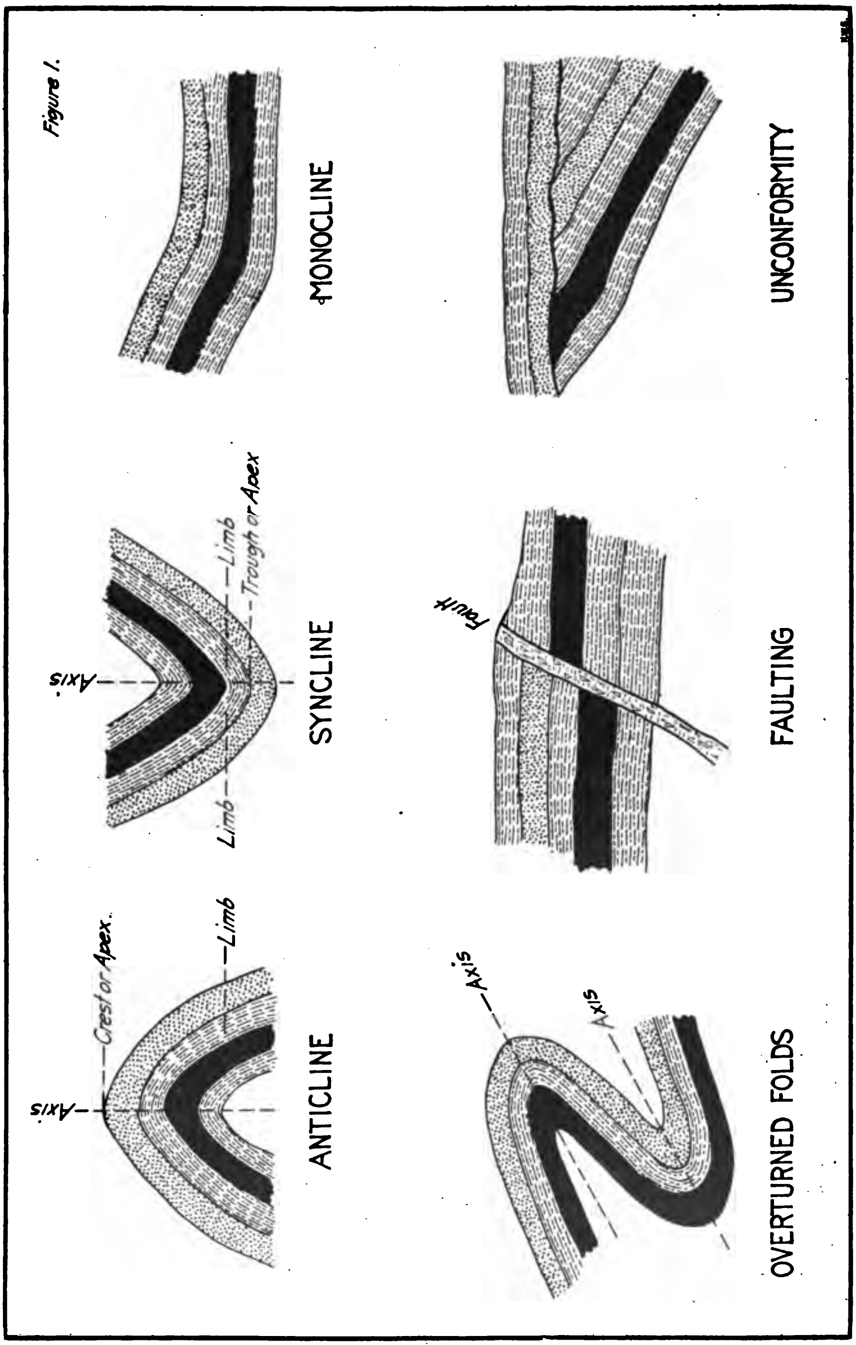

FIG. 1. Different Types of Structure Common to the Oil Fields.

(2) A second theory is that moving waters were the direct agent for the accumulation. That is, that the force that caused the migration was due either to hydraulic or capillary pressure.

Neither of the above theories, however, is sufficient to explain the enormous gas pressure which is found in California fields and which in nearly all cases is greater than that which could be developed by any hydrostatic pressure.

Nor do they explain why, when the forces that caused the original migration are no longer active, the oil does not move back over the path it once traveled.

(3) A theory which has recently been advanced by Marcel Daly[1] called the "diastrophic theory," attributes the migration to lateral pressure caused by the deformation of the earth crust. The forces of compression due to earth movements, he believes, have transferred their effects not only to the solid material of the earth's crust but to the liquids contained in the porous beds as well.

It is very probable that all of the above theories contain some element of truth, and the forces that contributed to the migration may possibly be a combination of all of these forces. That is, a liquid composed in parts of oil and water, due both to hydrostatic pressure and compression from earth movements, was forced to migrate along planes of fracture and unconformities till it was trapped in the highest parts of anticlinal folds. Having once entered the fold a gradual separation of the oil, gas and water took place due to the difference in specific gravity of these substances. The pressure over and above that which is due to hydrostatic forces may be due to a combination of further earth movements which compressed the strata in which the oil was trapped, and to chemical reactions between the hydrocarbons and saline waters, which liberated new gases. It is necessary also to further assume that once the oil entered the fold that the various points of entrance gradually became sealed due to the cementation of the porous sand by mineral bearing waters and tar.

However, regardless of what may have been the forces that caused accumulation, it can be definitely stated that all oil in commercial quantities in California is found in one or the other of the following geological structures:

(1) Along the crests of anticlinal folds and domes, such as are typified by the Buena Vista Hills and Elk Hills in the Midway, and the Montebello Hills and Coyote Hills in Southern California.

(2) In the upper part of plunging synclines, which are closely associated with productive anticlines. The Coalinga syncline is a type of this kind of a pool.

(3) Along the upper portions of monoclines and truncated anticlines lying along the foothills, which are under the influence of anticlinal domes farther out in the valley. This type of accumulation has examples in the West Side field at Coalinga, the west portion of the Midway field, and possibly the Kern River field.

(4) Along the zone of fracture and in upward folds influenced by faulting. Portions of the Salt Lake field near Los Angeles and some portions of the Puente Hills field are examples of this type. (See Fig 2, page 17.)

[1] Daly, Marcel. The Diastrophic Theory. Am. Inst. Min. Eng. Bull. 115.

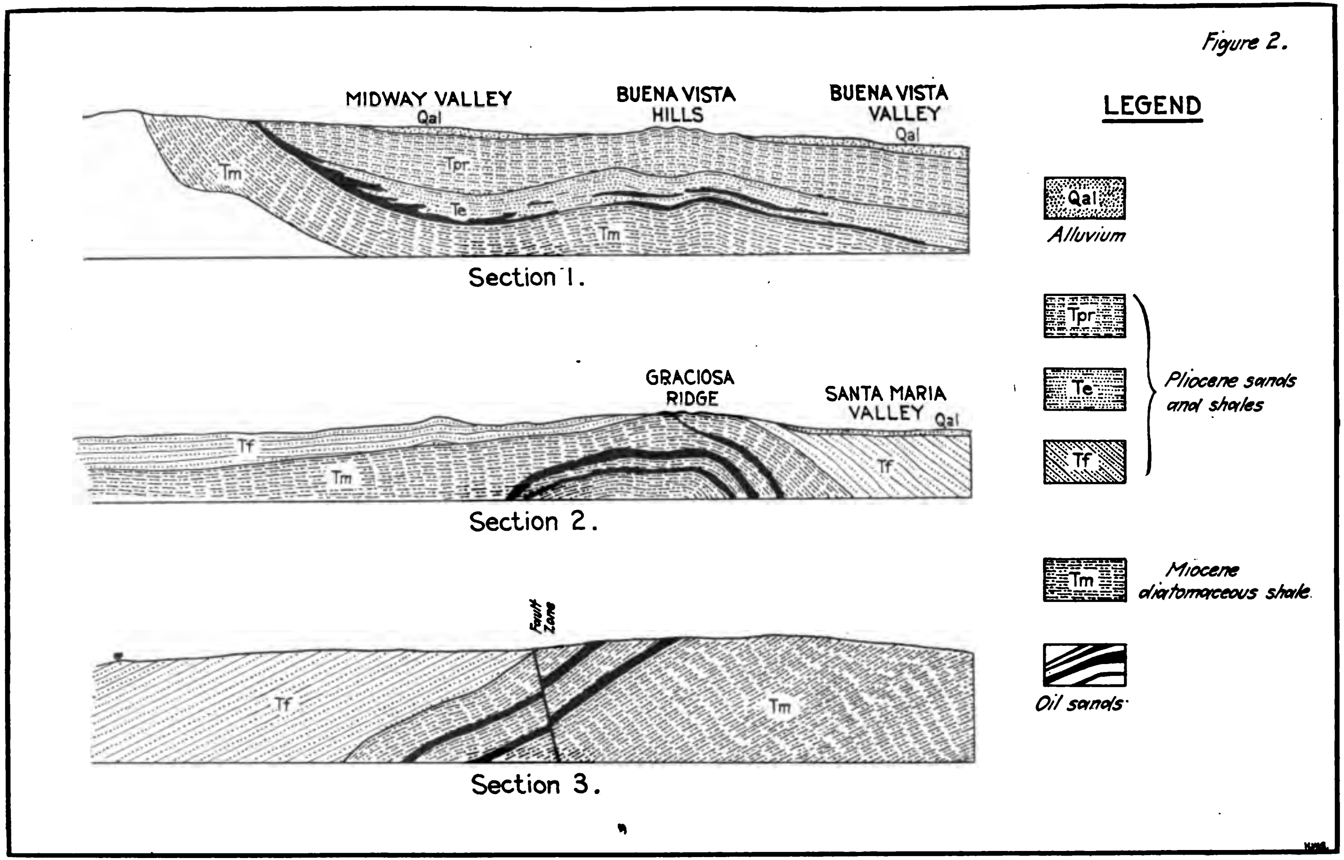

FIG. 2. Methods of accumulation in various types of structures found in the California fields.
Section 1. East-west section across the Midway District, Kern County, showing accumulation on a monocline, syncline and anticline (adapted from the U. S. G. S. Prof. Paper 116).
Section 2. Shows accumulation on an anticlinal fold in the Santa Maria Field, Santa Barbara County (adapted from the U. S. G. S. Bull. 322).
Section 3. North-south section across Salt Lake Field, Los Angeles County, showing accumulation along a fault zone (adapted from the U. S. G. S. Bull. 309).

In general those fields along the crests of anticlines or domes have produced the largest wells while those along fault zones the smallest. Fields situated along low-dipping monoclines are the longest lived and show the least rate of decline.

It has been assumed that oil travels laterally and vertically—never downward—and the locations of all known pools in California appear to bear out this assumption: except in possibly the uppermost sandstone of the formation directly below an organic shale bed, no oil has been found in formations stratigraphically below a known bed of organic shale. In certain cases oil has been found in formations which are geologically older than the organic shale which is present in that locality, but in such cases its presence may be readily explained by the fact that faulting has brought the older formation into a stratigraphic position above the organic shale—a reversal of their normal position.

The reason for the failure of the oil to migrate downward has been attributed to the facts that the porous sedimentary rocks of the oil field are saturated with water, and the difference in specific gravity of the oil and water has forced the oil upward. Similarly should the porous rocks not contain water, the oil by reason of gravity should migrate downward.

Lateral migration has probably taken place along planes of unconformities, and porous beds; and vertical migration, along faults, cracks or fractures and porous beds.

Reservoirs.

Reservoirs are the series of beds in which the oil collects along various geological structures described in the preceding paragraphs.

As previously stated these beds are either in the organic shale formation, or directly above it. When found in the shales, the reservoir beds are either very fine grained sands, or hard, flinty beds of shale which have become fractured and broken, allowing the oil to collect in the voids between the fractured particles of the silicious shale. These two cases are typified by the fine sands in the so-called 'brown shale' of the Belridge and Lost Hills fields, and in the fractured flinty zone, near the base of the diatomaceous shale in the Santa Maria field.

In the majority of cases, however, the oil has collected in the sandstone beds overlying the organic shale. The lithology of these beds is a very important consideration in the accumulation of the oil.

First, the beds must be porous enough to absorb the oil in appreciable quantities. The porosity is not dependent upon the size of the grains, but rather on the shape; regularity in size; and arrangement. A fine-grained sand composed of spherical grains all of one size and arranged in a regular manner, will have greater porosity, than a coarse-grained sand in which the grains are irregular and flat, so that they may be fitted tightly together, thus reducing the porosity. The size of the grains affect the character of the oil. In general, fine-grained sands contain the light oil, while coarse sands contain the heavy viscous oil. This difference in the character of the oil is due to the fact that the light oil will move readily through and collect in the fine-grained sand, whereas the thick viscous oils are too tarry to move freely except in coarse sands. The so-called shale oil zone on Twenty-five Hill, west of Taft, and the deep 'shale oil zones' of the Belridge field are examples of this differentiation due to the size of the grains.

Second, there must be a difference of porosity in the different beds that make up the reservoir. There must be a porous bed between two impervious beds. Otherwise the oil would not tend to concentrate in certain beds, but would be disseminated throughout the reservoir, in such a lean saturation that extraction in commercial quantities by means of wells would be impossible.

The Arroyo Grande field is a good example of lean saturation. In this case, the oil has collected in the Pismo formation, which in this particular locality contains no impervious shale beds, but is entirely made up of sand. The result is that the oil has disseminated throughout the entire 1000 feet or more of the Pismo formation, in such lean saturation, that it is difficult to obtain wells that are commercial producers, although there is enough oil present if concentrated in smaller beds to produce oil in commercial quantities.

Third, the relationship in geological time between the source and the reservoir has an important bearing upon the accumulation. If there is too great a time interval between the age of the beds in which the oil formed and those which make up the reservoir, one can not expect the reservoir to contain oil, although all other conditions may be favorable. The reason for this is obvious. If there was an opportunity for the organic shales to be uplifted and eroded before the deposition of the reservoir formation, the oil content of the organic shale would run out and be lost, before an opportunity was afforded for the collection of the oil in the reservoir.

In some cases after the reservoir formation has been deposited and the oil collected therein, there has been an erosive time interval, in which the reservoir and its oil content were eroded away. Subsequently the organic shales were again lowered beneath the surface of the sea and a second reservoir formation was deposited. This in time was uplifted and folded. In this case there would be little or no oil in the second reservoir, as the greater part of the oil content of the organic shales had collected in the first reservoir and was lost in the erosive time interval. An example of this is found in the Pleyto district on the west side of the Salinas Valley. Here the Monterey shale (Lower Miocene) and the Paso Robles sands (Upper Pliocene) are folded in an anticline, yet there is no appreciable amount of oil in the Paso Robles, although the general conditions for accumulation are favorable. It is probable that this failure is due to the great time interval between the Monterey shale and the Paso Robles formation.

Saturation and Recovery.

The capacity of oil sands and the amount of oil recoverable are two important considerations in determining the value of a prospective field. It has been estimated by J. O. Lewis[1] that the average porosity for California sands is about 25 per cent of their volume, provided they are completely saturated. Using this porosity, Lewis has estimated

[1] Lewis, J. O. Bull. 148. U. S. Bureau of Mines.

that a sand one foot thick covering a square acre in extent will be capable of containing 1940 barrels of oil, which is probably a very conservative estimate.

The amount of oil recovered, however, is a very small percentage of that which is contained in the sand. It is generally agreed that not more than 20 to 30 per cent is extracted by means of wells.

It has been assumed by operators that when a well ceases to produce, the oil sands in the vicinity have been exhausted. This is not the case. In all probabilities as much as 70 per cent of the oil is still present in the sand, and the reason for the decline of the well is due to the exhaustion of the gas, rather than the oil.

The main force which drives the oil from the sand into the well is the expanding energy of the gas dissolved in the oil. It has been shown that California oils will absorb about 15 per cent of their volume in natural gas. This gas is absorbed in the oil in the same manner as soda water is charged with carbon dioxide. When a well is drilled into an oil sand, the pressure is suddenly reduced at this point and consequently the liquefied gas expands and becomes a true gas. This expansion forces the oil from the sands into the well, much in the same manner as when the cork is removed from a bottle of soda water and the dissolved carbon dioxide gas forces the liquid out of the mouth of the bottle. The expansion of the liquefied gas from the oil takes place more readily in light oil than in heavy viscous oils. In the preceding paragraphs it was stated that fields along the crest of sealed anticlines produced the largest wells, while wells located on low dipping monoclines were the longest lived and showed the slowest rate of decline. This can be explained on the assumption that along the crest of anticlines the oil for the most part is of a comparatively light gravity and the liquefied gas expands readily, forcing in its first rush to freedom large quantities of oil into the well, and consequently giving a large initial production. This easy expansion allows a great portion of the gas to escape without doing its full share of moving the oil, which results in a rapid decline in the well and a large percentage of the oil is left in the sands without any force to drive it into the well. On the other hand in low dipping monoclines, such as the Kern River field, the oil is heavy and viscous and the liquefied gas cannot slip out of the oil readily and must, to escape, move the oil with it. This probably explains the slow rate of decline in fields of this character.

Areas of Accumulation.

In order to have a productive field there must not only be present beds of organic shale, but these beds must be of considerable thickness and must cover a large area in extent. It frequently happens that wells located on opposite sides of the apex of an anticline differ greatly in their productiveness. In most cases of this kind, an examination of the field will show that on the side of the largest well the organic shales underlie the country over a considerable area, while on the opposite side, where the small producer is found, the shales are present only in a limited area.

SUMMARY OF THE CONDITIONS NECESSARY FOR THE ACCUMULATION OF OIL IN COMMERCIAL QUANTITIES IN CALIFORNIA.

(1) There must be present in close association with the prospective field, thick beds of organic shale to serve as a source for the oil.

(2) There must be present either in, or above, the organic shale, porous beds, between impervious beds to act as a reservoir for the oil.

(3) The reservoir beds must be folded in a favorable structure, so as to cause the oil to accumulate.

(4) There must be a large area of accumulation.

(5) There must not be too great an interval in geological time between the organic shales and the formations composing the reservoir.

Surface Indications of Oil.

The best surface indication that a district contains oil is, of course, an actual seepage or flow of oil *somewhere* in that area. While all known productive fields of California do not always contain seepages, notably in the cases of closed or buried fields, nevertheless if the underlying formations of these fields are followed to where they outcrop, in every case actual seepages are found.

In the Tertiary formations which contain the asphaltic oil, seepages can be readily found as the evaporation of the lighter constituents leave behind a heavy tarry residuum, which is noticeable long after the seepage has ceased to flow.

In the case of the light oil of the Cretaceous formation, this evaporates entirely upon coming to the surface and leaves behind no residuum and unless the seepage is actually flowing, it is not likely to be found.

In general, seepages occur along faults, cracks, and where the upturned edges of the formations outcrop.

'Gas Blows' and burnt shale areas are also good indications of oil. True 'gas blows' are found along faults, cracks and on the outcrops of formations where petroleum gas has in past times, or is at the present, escaping into the air. In almost every case this gas has by accident caught fire, which has resulted in the burning to a more or less slaggy condition of the formations in that vicinity. The burning has changed the color of the beds to either a vivid red or purple, or a dull white, depending upon whether or not the beds contained iron compounds.

Frequently in wild-cat districts it has been claimed that 'gas blows' are present, and for evidence long narrow black and brown colored fragments of sandstone have been presented. It is the opinion of the writer that these so-called 'gas blows' are in no way connected with petroleum gas, but merely represent a concentration of iron compounds along cracks by means of moving waters, with a resulting discoloration of the formation to black and brown.

Notable gas blows are found in the Buena Vista Hills near Taft and in the McKittrick district.

'Burnt Shale Areas' are composed of shale or sandstone which at one time or another contained seepages of oil and which by accident caught fire and burned, leaving the shale or sandstone in a condition that resembles a brick yard, the vivid red and purple colors of the rocks being particularly noticeable in these areas. 'Burnt shale areas' are found in numerous places in the Santa Maria and McKittrick Districts.

Seepages, gas blows, and burnt shale areas do not of themselves mean that the district in which they are found is going to produce oil in commercial quantities. There must also be present suitable structure, reservoir beds and a sufficiently wide area of accumulation and origin.

CHAPTER II.

Description of the Oil-Bearing Formations of California.

General Geology and Structure of the State.

In discussing the general geology of California, the state may be divided into five provinces:

(1) The Coast Ranges. (2) The Great Central Valley. (3) The Lava Beds of the Northeastern Region. (4) The Sierra Nevada Mountains. (5) The Desert Region of the Southeast.

(1) THE COAST RANGES.

In the extreme northwestern portion of the state, in the counties of Del Norte, Trinity and Siskiyou, the Coast Ranges are known as the Siskiyou or Klamath Mountains. These mountains in general rise to an elevation of about 5000 feet and are extremely rugged. The principal rivers in this district are the Klamath and the Trinity rivers. The geological formations consist of slates, schists and limestone, of Paleozoic age, together with a younger series of altered sands and shales, probably of Jurassic age. In addition, there are numerous areas of granitic rocks and gneisses, the age of which is uncertain. The Jurassic sediments contain large intrusive masses of serpentine and basaltic rocks. All of these sediments have been sharply folded and their structure is intricate and complex.

South of the Klamath Mountains and north of the Bay of San Francisco, the Coast Ranges are composed of a series of long, narrow, parallel ranges and valleys. These ranges have an elevation in general of about 2100 feet, and present to a marked degree a sameness in elevation. When viewed from a high point this region appears like a huge dissected plateau. A. C. Lawson[1] has stated that this dissected plateau represents an ancient peneplain, which has been uplifted from a nearly base level condition to its present altitude, this uplift being marked by at least six marine terraces. The principal river valleys consist of the Eel River in the north; the Russian River in the central portion and the Napa and Sonoma valleys in the south. In the greater portion of this area, the rocks exposed consist of cherts, sandstone, crystalline schists and serpentine of the Franciscan formation (Jurassic?). Along the coast there is a narrow strip of Cretaceous, together with small areas of rocks of Tertiary age. On the great valley side of the mountains a great thickness of Cretaceous sediments is exposed together with small isolated patches of rocks of Tertiary age.

South of the Bay of San Francisco, the Coast Ranges in general trend nearly parallel to the Coast. The average elevation is from 2000 to 3000 feet, except south of Los Angeles, where the San Gabriel, San Bernardino and San Jacinto Ranges reach altitudes from 10,000 to 11,000 feet. The most prominent topographic feature is the series of rather broad interior valleys which separate the different ranges between San Francisco and Los Angeles. South of Los Angeles, these valleys are conspicuous by their absence and the general trend of the small valleys,

[1] Lawson, A. C. Univ. of Calif. Bull. Dept. of Geology, Vol. 1, No. 8. The Geomorphogeny of the Coast of Northern California.

that are present, is at right angles to the Coast. Beginning at the north these interior valleys consist of the Santa Clara Valley in Santa Clara County; the San Benito and Tres Pinos valleys in San Benito County; the Salinas Valley in Monterey County and northern San Luis Obispo County; the Cuyama and Santa Ynez valleys in Santa Barbara County; the Simi Valley and the Valley of the Santa Clara River in Ventura County; the San Gabriel and San Fernando valleys of Los Angeles County; and lastly, the Valley of the Santa Ana River in Orange County.

The principal ranges consist of the Santa Cruz Mountains, which lie along the boundary between Santa Clara and Santa Cruz counties; the Diablo Range, which forms the eastern edge of the Coast Ranges from Suisun Bay to Coalinga; the Gabilan Range, which lies between San Benito and Monterey counties; the Santa Lucia Range, which forms a mountainous region along the coast of Monterey and San Luis Obispo counties; the Temblor Range, which lies in eastern San Luis Obispo and western Kern counties; in Santa Barbara are the San Rafael and Santa Ynez ranges, which have a northwest direction; the Topatopa Mountains in Ventura County and the Santa Monica Mountains in western Los Angeles County, trending almost due east and west. The San Gabriel Mountains in Los Angeles County, the San Bernardino Range in San Bernardino County, the San Jacinto Range in Riverside County, and the Peninsula Range, which extends southward through San Diego County into Lower California separate the desert region from the Coastal Plane of Southern California. These ranges, both in topography and geology, bear a marked resemblance to the Sierra Nevada and may be regarded as a southward extension of this system. The Santa Ana Mountains in Orange County may be regarded as the most southward range of the true Coast Range type.

For the most part the Coast Ranges, between San Francisco Bay and the Santa Ana Mountains, are composed of unaltered sediments of Cretaceous and Tertiary age. Exceptions to this condition are found in the central portion of the Diablo Range, where large areas of the Franciscan (Jurassic?) are exposed and in the Santa Lucia and Gabilan ranges which consist almost wholly of highly altered sediments of Paleozoic age, together with granite rocks and gneisses. It is in the Tertiary sediments which lie along the eastern and western flank of the middle Coast Ranges, that the principal oil fields of California are found. South of the Santa Ana River, the sedimentary rocks are limited to a narrow strip along the Coastal Plane and a few isolated patches in eastern Riverside County. The San Gabriel, the San Bernardino, the San Jacinto and the Peninsula Range are composed of granitic rocks.

(2) THE GREAT CENTRAL VALLEY.

The Great Central Valley of California comprises an area of about 16,000 square miles and includes the Sacramento Valley in the north and the San Joaquin Valley in the south. The north end of the Sacramento Valley is at Redding, Shasta County, where it has an elevation of 600 feet and a width of about ten miles. Extending southward, its width increases to 20 miles at Red Bluff, 40 miles at Willows, and 45 miles at Suisun Bay, into which the Sacramento River discharges. The San Joaquin has a width of about 30 miles at its northern extremity near Stockton, thence it increases in width as it extends southward, till it reaches a maximum of 60 miles near Hanford, Kings County. At the base of the Tehachapi Mountains, in Kern County, where the valley ends, it has a width of about 36 miles and an elevation of about 1000 feet.

The valley's surface is almost entirely covered by alluvium, but undoubtedly formations of Cretaceous and Tertiary age are present beneath the surface. The only notable interruption in the surface continuity is formed by the Marysville Buttes, a volcanic mass in the central part of the Sacramento Valley.

Between Red Bluff and Suisun Bay, the alluvium of the valley floor rests, on its western edge, against rocks of Cretaceous age, exposed in the foothills of the Coast Ranges. South of San Francisco Bay, the valley floor is terminated on its western side by rocks of Tertiary age, exposed in low-rounded hills that jut out into the valley's floor. The large producing oil fields of the San Joaquin Valley are found in these low hills. On the eastern edge, or Sierra side, the alluvium of the valley floor rests for the most part against the metamorphic and crystalline rocks of the Sierra Nevada and except for an area of Miocene around Bakersfield and a small thickness of Tejon between the Mariposa and the American rivers, sedimentary rocks of Tertiary age are conspicuous by their absence. In the extreme northeastern part of the Sacramento Valley, there is a large area of volcanic tuff and lava exposed.

(3) THE LAVA BEDS OF THE NORTHEASTERN REGION.

This lava covered region forms an extensive area in the northeastern portion of the state and includes the counties of Modoc, Lassen and the eastern parts of Siskiyou, Shasta and Tehama counties. The central and northern portions of this area form a plateau which is between 4000 and 5000 feet in elevation. In the northeast the Warner Mountains reach an altitude of 8000 feet. In the south the Lassen Peak Range reaches an altitude of more than 10,000 feet, and on the west, Mount Shasta towers at an altitude of 14,380 feet.

Practically all this region is covered with lava, probably of late Tertiary age. In a few places there are lake bed deposits of loose sands and clays and fresh water diatomaceous shale.

(4) SIERRA NEVADA.

The Sierra Nevada is the dominating physical feature of the state. It forms a great single range that extends from the base of the Lassen Peak Range southward to Tejon Pass in northern Los Angeles County. On the western side it slopes gently up from the great valley to its crest and thence drops off abruptly to the desert on its eastern edge. In its northern portions it reaches an altitude of from 9000 to 10,000 feet and southward it rises to its greatest height in Mount Whitney, an elevation of 14,501 feet. In its northern and western parts there are large areas of altered sedimentary and igneous rocks which are highly mineralized. In the south and east the range is almost entirely composed of granitic rocks.

(5) THE SOUTHEASTERN DESERT REGION.

This district consists of a number of detached mountain ranges which are separated by arid valleys and flat stretches of the desert.

The principal ranges are the White Mountains in Mono County; the Coso Range, southeast of Owens Lake; the Panamint Range along the western border of Death Valley; the Amargosa Range in eastern Inyo County; the Kingston Range in northeastern San Bernardino County, and the Hathaway, Chuckawalla and Chocolate mountains on the eastern border of the Imperial Valley. These ranges vary in altitude from 3000 to 11,000 feet.

Among the valley areas are the Colorado Desert in the southeastern part, the Imperial Valley in the extreme south and the Mojave Desert and the Death Valley regions in the north.

The mountain ranges for the most part consist of altered sediments of Paleozoic age, together with granitic rocks and lava flows. In eastern San Bernardino County there are lake bed deposits of Miocene and Pliocene age. In the Imperial Valley, there are exposures of fine silts and clays of Miocene age.

Faults.

The two major lines of faulting are (1) the San Andreas fault, which lies in the Coast Ranges and extends from Cape Mendocino, in Humboldt County, to the Colorado Desert, a distance of 600 miles. It is marked throughout the greater part of this distance by narrow troughlike valleys and steep mountain slopes. (2) The great fault marking the eastern base of the Sierra Nevada, along which the great Sierra Range was uplifted.

Non-Oil-Bearing Formations.

A little less than one-half of the state's surface is made up of crystalline rocks. The term crystalline rocks will be used in this report to designate rocks of igneous and metamorphic origin. These rocks, by the very nature of their being, can not be expected to contain petroleum, as they are the result of intense heat and pressure, and in addition contain no organic material which might form petroleum. Occasionally small quantities of oil have been found in crystalline rocks, namely in a crystalline schist at Placerita Canyon, Los Angeles County, and in serpentine rocks on Bear Creek, Colusa County. Neither of these deposits have much commercial value and are interesting only for their uniqueness. The collection of oil in both cases, is undoubtedly due to the fact that organic shales at one time overlaid the crystalline rocks and a small portion of their oil content, filtered down into the fractures and crevices of the underlying crystalline formation.

It will, therefore, be assumed in this report that crystalline rocks in general are not capable of containing oil in commercial quantities in

California and, discussing the different districts in detail, such areas as contain these rocks will be dismissed from consideration.

The second type of rocks that will be considered as nonoil-bearing in California are those sedimentary rocks of pre-Cretaceous age. The reason for this assumption is based upon the following facts: (1) These rocks for the most part have been highly altered and deformed and any possible oil content has been destroyed by metamorphism. (2) There are no bodies of diatomaceous shale present, (3) although limestone beds, which are oil bearing in other states, occur in considerable thickness from the Cambrian to the Triassic in California, great mountain making movements have so shattered and altered these beds, that they are practically crystalline rocks and contain no structure that would be favorable for the accumulation of oil. (4) There is no authentic record of any occurrence of petroleum in California in sedimentary formations older than the Cretaceous. It is, therefore, the opinion of the writer, that no oil in commercial quantities will be found in California in formations older than the Cretaceous.

OIL-BEARING FORMATIONS.

As stated in Chapter I, all known occurrences of oil in California are found in close formation with beds of organic shale, commonly known as diatomaceous shale. These beds range in age from the Cretaceous to the Pliocene. Therefore, in this report, the only formations which will be considered as potential sources of petroleum will be sedimentary formations from the lower Cretaceous to the upper Pliocene.

Cretaceous.

For the purpose of this report the Cretaceous will be considered as having two major units only, the lowermost beds known as the Knoxville, and the upper beds known as the Chico. (The Horsetown beds will be regarded as upper Knoxville.)

The Knoxville formation consists as a whole of dark, fine-grained, thinly-bedded, more or less carbonaceous shales. Alternating with the shale beds are thin lenses of fine-grained sandstone. A few lenses of pebbly conglomerate occur near the top of the formation. In general, the Knoxville is characterized by a predominance of shale. It occurs in the following areas (1) along the west side of the Sacramento Valley from Redding to Suisun Bay, (2) along the west side of the San Joaquin Valley from Suisun Bay to a point just south of Coalinga, (3) in a narrow strip in northeast Humboldt County and southwest Trinity county, (4) in small patches along the Coast from San Francisco as far south as San Luis Obispo. It is best developed along the west side of the Sacramento Valley, where it reaches a maximum of about 25,000 feet. In the San Joaquin Valley it has an average thickness of about 4000 feet. The most characteristic fossils are the *Aucella piochi* and the *Aucella crassicollis*. No oil in commercial quantities has as yet been obtained in the Knoxville. Seepages of light green and dark amber-oil, of a paraffine base occur in the Knoxville shales of Colusa County, (a discussion of the possibilities of this region is given in

Chapter VI). It is the opinion of the writer that no great production of oil can be expected from the Knoxville formation.

The Chico formation consists in general of massive medium coarse blue-gray and greenish sandstone, which turns to a tawny brown on weathering. Interbedded with the sandstone are thin beds of dark gray shale. In the Sacramento Valley, near the bottom of the formation, are several beds of conglomerate, made up of pebbles of crystalline rocks. In Solano and Yolo counties, the Chico contains several beds of dark carbonaceous shale ranging in thickness from 100 to 500 feet. Along the west side of the San Joaquin Valley from Coalinga to Livermore pass, the uppermost Chico is called the Moreno formation and consists of almost 2000 feet of diatomaceous and foraminiferal shale, this shale being the original source of the Cretaceous oil found in the Oil City field.

In general the Chico is characterized by a predominance of sandstone. It occurs in the following areas (1) along the west side of the Sacramento and San Joaquin valleys; (2) along the east side of the Sacramento Valley north of Oroville; (3) along the coast of northern California from the mouth of the Russian River to Cape Mendocino; (4) in the southern Coast Ranges particularly in the Santa Ana and Santa Monica mountains. Over the entire state it has a maximum thickness of about 8000 feet.

The only oil in commercial quantities which has been obtained from the Chico is at Coalinga, in the old Oil City field, where a total of twelve wells produced on an average 135 barrels per day, for the year 1920. There are seepages of light green oil in the Chico of Humboldt County and in Yolo and Solano counties it has been reported that there are seepages of light green oil in the Chico shales.

In general the Cretaceous oil varies in color from amber and light green to white. It is of a paraffine base and averages about 52° Baumé in gravity.

It is extremely doubtful in the opinion of the writer, that a large production can ever be expected from the Cretaceous formation, or that it will produce in commercial quantities except in the Coalinga district, where it contains thick beds of diatomaceous shale and is folded in a favorable structure.

Eocene.

The Eocene in this report will be considered as having three divisions, the lower or Martinez, the middle or Meganos and the upper, or Tejon.

The Martinez formation consists of thick-bedded, medium coarse-grained, greenish-gray sandstone. It contains some minor beds of shale and conglomerate. The maximum thickness is about 4000 feet. It occurs in the following areas: (1) Santa Ana Mountains. (2) Santa Monica Mountains. (3) Ventura County. (4) San Francisco Bay region. (5) Lake County. (6) Probably certain sands and shales along the valley of the Eel River in Humboldt County.

Characteristic fossils are *Cucullæa mathewsoni* and *Turritella pachecoensis.* There is no production of oil in commercial quantities from the Martinez.

The Meganos formation consists mainly of marine shales with some sandstone and conglomerate. In the Simi Valley the shales are apparently carbonaceous. They vary in color from purple to grey and are thin-bedded and rather fine-grained in texture. In the vicinity of San Diego the Meganos consists of fine clay shales, and near Suisun-Fairfield, and in the Mount Diablo region it consists of pink diatomaceous shales.

The best known outcrops occur as follows: (1) San Diego County. (2) Santa Monica Mountains. (3) Simi Valley. (4) San Emigdio Mountains. (4) Mount Diablo. Characteristic fossils are *Turritella andersoni* and *Natica hannibali.*

The Meganos shales are probably the source of the oil found in the Tejon sandstone of the Simi Valley and the Sespe district of Ventura County.

The Tejon consists of a hard coarse-grained light yellow and gray sandstone. The basal sands in the San Joaquin Valley and Southern California are frequently of a reddish color due to iron oxide. On the east side of the Sacramento Valley, the Tejon is known as the Ione and consists of about 1000 feet of fine clays and some sandstone. The maximum thickness over the entire state is about 5000 feet. Beds of lignite and red and yellow pottery clays are characteristic of the Tejon. In Ventura County the Topa-Topa formation may be considered as being of Tejon age.

The Tejon occurs in the following areas: (1) San Diego County. (2) Santa Ana Mountains. (3) Ventura County. (4) Santa Ynez Mountains. (5) West side of the San Joaquin Valley. (6) East side of the Sacramento Valley. (7) Isolated areas in the northern Coast Ranges.

Characteristic fossils are the *Venericardia planicosta* and *Turritella uvasana.*

In the Simi and Sespe regions of Ventura County, the Tejon is the principal oil-bearing formation and yields a greenish-black oil of about 40° Baumé gravity, which has accumulated in the Tejon sands from the underlying Meganos shales. In the Coalinga field, the Tejon contains some oil which has migrated from the Moreno shales. In the Kreyenhagen Hills of Kings County, the Tejon sands yield small amounts of green oil.

Oligocene.

The Oligocene has been definitely recognized in the following areas: (1) Ventura County where it is known as the Sespe formation. (2) West side of the San Joaquin Valley from the Coalinga district to Livermore Pass, where it is known as the Kreyenhagen shales. (3) Santa Cruz Mountains, where it is known as the San Lorenzo series.

The Kreyenhagen shales may be regarded as lower Oligocene and consist of pink and chocolate colored diatomaceous and foraminiferal shales; clay shales; and a little sandstone. They have a maximum thickness of about 1500 feet, and are the original source of the main body of petroleum in the Coalinga field, which has undoubtedly migrated from these shales into the overlying Vaqueros sandstone.

The characteristic fossils are *Leda lincolnensis* and *Fusinus lincolnensis.*

The Sespe formation is found in Ventura County and consists of about 3500 feet of white, red and brown sandstone, interbedded with beds of purple and red clays. In the Simi Valley, this formation contains several prominent beds of conglomerate. There are no known fossils in this formation and it probably in part represents a continental deposit. In the Sespe and South Mountain districts of Ventura County, it is the principal oil-bearing formation, the oil having collected in the Sespe from the underlying Eocene shales. The oil is black and averages about 32° Baumé gravity. The Sespe may be regarded as upper Oligocene.

The San Lorenzo formation is found in the Santa Cruz Mountains and consists of about 3000 feet of fine-grained sandstone and shale. Characteristic fossils are *Cardium lorenzanum* and *Acila dalli.* The San Lorenzo formation is not regarded as an oil-bearing formation. However, at Moody Gulch in the Santa Cruz Mountains it contains a small amount of light-gravity oil, which has migrated along a fault plane from the Monterey shale into the San Lorenzo.

Approximately 1,300,000 barrels of oil were produced from beds of Oligocene age during the year 1920, which is about 1.3 per cent of the entire production of the state.

Miocene.

The Miocene may be regarded as having two main divisions, the lower Miocene which contains the so-called Monterey Series and the upper Miocene, which contains the San Pablo Series in the San Francisco Bay region and the Santa Margarita Series of middle California.

The Monterey Series is a name which has been recently applied by the U. S. Geological Survey to the lower portion of the Miocene in California and covers what was formerly recognized as two separate formations, viz: (1) The Monterey shale (called in various reports of the U. S. Geological Survey, Puente shale, Monterey shale, the Modelo formation, Salinas shale and Maricopa shale). (2) The Vaqueros sandstone.

Inasmuch as the terms Monterey shale and Vaqueros sandstone have become fixed by long usage among the oil men of California to designate two of the most important oil horizons of the state, it is the opinion of the writer that this terminology should remain in discussing oil field geology.

For the purpose of this report, while the term Monterey Series will be regarded as designating the lower Miocene, the term Monterey shale will be continued in use to designate the upper portion of the series, which is mainly shale, and Vaqueros sandstone will be used for the lower portion.[1]

[1]NOTE. Prof. B. L. Clark of the University of California has recently proposed the name of Temblor to designate the upper portion of the Monterey Series and the writer has used this name in the correlation tables (Plate II) as the standard name for the upper portion of the Monterey Series.

The lower portion of the Monterey Series, which is mainly sandstone consists of hard yellowish-gray sandstones and conglomerates. It has a maximum thickness of about 5000 feet. The Vaqueros outcrops in the following areas: (1) Santa Cruz Mountains. (2) East side of the Santa Lucia Range and in the Salinas Valley district. (3) Santa Ynez Mountains and Santa Maria district. (4) West side of the San Joaquin Valley. (5) Santa Monica and Santa Ana mountains. It is not known north of the Bay of San Francisco or east of the Coast Ranges. Characteristic fossils are *Pecten magnolia* and *Turritella inezana.*

The Vaqueros has been found productive in the following regions: [1]Coalinga district where it is the principal oil-bearing formation, the oil having migrated and collected in the Vaqueros sands from the underlying Kreyenhagen shales. (2) In the Santa Maria field, the third oil zone is believed to be in the Vaqueros, the oil having migrated from the Monterey shales, probably along a fault plane into the uppermost Vaqueros beds. (3) At Moody's Gulch in the Santa Cruz Mountains, the Vaqueros sands contain a small quantity of light oil, where they have been brought in contact by faulting with the Monterey shales. The Vaqueros formation yielded in 1920 about 16,000,000 barrels of oil or 16 per cent of the yield of the entire state.

The Monterey shale formation in this report includes, the Puente shale, the Modelo formation, the Salinas shale and the lower portion of the Maricopa shale. It consists mainly of diatomaceous shale with some interbedded sandstone and volcanic ash. The diatomaceous shales vary from the fine, soft, white, chalky form to the hard, brittle, flinty variety, which has been altered to this form by silica-bearing waters. In general the soft chalky form is thick-bedded and breaks up into small thin flakes, while the flinty form is found in narrow ribbon-like beds about 2″ in width. The microscope shows that all varieties contain abundant organic remains and a chemical examination shows they are composed chiefly of silica. The color varies from white to brown. The shales are on the whole, rather brittle and fracture and fold easily, giving rise to many small minor folds in the formation, which often complicates and confuses the nature of the real structure. Characteristic fossils are *Turritella ocoyana* and *Pecten peckhami.*

The Monterey shale formation is very widespread in the Coast Ranges, occuring as far north as Point Arena, Mendocino County, and as far south as the Orange and San Diego County line.

The principal localities are (1) Point Arena and Point Reyes. Those two localities are the only known occurrences north of the Bay of San Francisco. (2) Berkeley Hills. (3) Santa Cruz Mountains. (4) Vicinity of Monterey. (5) Salinas Valley, where it has been called the Salinas shale. (6) San Luis Obispo and Santa Barbara counties. (7) Ventura County, where it has been called the Modelo formation. (8) Los Angeles County where it has been called the Puente shale. (9) Orange County. (10) Kern County where it has been called the Maricopa shale.

[1]NOTE.—Recent paleontological work has shown that these so-called Vaqueros sandstones probably belong to the upper portion of the Monterey series and can be classified as belonging to the Temblor formation.

The Monterey shale is the original source of the oil and underlies the reservoir beds in the following fields: (1) Midway-Sunset field. (2) Kern River. (3) Los Angeles and Orange County fields. (4) The Ojai, the Piru, the Santa Paula and Ventura Avenue fields of Ventura County: (5) The Arroyo Grande field.

In the Santa Maria district the oil has collected directly in the Monterey shale, a fractured flinty zone near the base of the formation acting as the reservoir.

The oil is black and of an asphaltic base ranging in gravity from 9° Baumé in the Casmalia field to 36° Baumé in the Midway.

It is probable that over 65 per cent of the 105,000,000 barrels of oil produced in California in 1920 had its origin in the Monterey shale formation. Most of this, however, has migrated to the overlying formations and the Monterey actually yielded only about 6,000,000 barrels or 6 per cent of the entire yield of the state.

The Santa Margarita formation (upper Miocene) consists of a hard compact sandy diatomaceous shale and a white granitic sandstone member.

In the Salinas Valley area the white sandstone is best developed and the diatomaceous shale is only about 400 feet thick. In the San Joaquin Valley the diatomaceous shale is well developed and consists of about 2000 feet of hard compact blue shale, somewhat more sandy than the Monterey diatomaceous shale. It is found only in the Middle Coast Ranges between the Salinas Valley and the San Joaquin Valley. The characteristic fossils are *Pecten crassicardo* and *Ostrea titan.*

The Santa Margarita is oil-bearing in the following areas. (1) Small seepages near San Ardo in the Salinas Valley. (2) Small seepages in the Park field and Lonoak districts of Monterey County. (3) Along the west side of the San Joaquin Valley from Sunset to Devil's Den, where it overlies the Monterey shale and probably contributes to the oil in the McKittrick beds which form the principal reservoir beds of the west-side fields. In the Belridge and Lost Hills fields oil has collected directly in certain sandy beds of the Santa Margarita shale. This oil is rather light, averaging almost 38° Baumé and is commonly known as brown shale oil.

It is roughly estimated that the Santa Margarita yielded in the San Joaquin Valley almost 2,000,000 barrels in 1920 or almost 2 per cent of the state's production.

The San Pablo formation consists of about 1500 feet of a rather coarse, blue-gray sandstone, found principally in the vicinity of San Francisco Bay. Characteristic fossils are *Pecten crassicardo* and *Pecten raymondi.* The San Pablo is not known to contain oil, in any appreciable amounts.

Pliocene.

Formations of Pliocene age are the most prolific source of oil in the state. This is due to the fact that they overlie the diatomaceous shale of the Monterey. The lower portion of the Pliocene may be considered as being represented by the Fernando Series in Southern California, the McKittrick group in the San Joaquin Valley and middle Coast Range, and the Merced Series in Northern California.

The upper Pliocene may be called the Saugus in Southern California and the Paso Robles in Central and Northern California.

The Fernando is found south of the Tehachapi mountains and the Santa Maria River. It consists of soft blue shales and medium coarse gray and white sands. Near the top there are beds of gravel made up of well rounded crystalline pebbles. It has a maximum thickness of about 8000 feet. It is best known in the following localities: (1) Puente Hills. (2) Vicinity of Los Angeles. (3) Southwestern Ventura County. (4) Santa Maria district.

In the following fields its beds are the principal sources of oil. (1) Los Angeles and Orange county fields. (2) The Ojai, Piru, Santa Paula and Ventura Avenue fields of Ventura County. (3) The Summerland field.

Characteristic fossils of the lower Pliocene are *Pecten oweni* and *Pecten healeyi.*

During the year 1920 beds of Fernando age produced 30,500,000 barrels of oil or 30.5 per cent of the entire state's production.

In the San Joaquin Valley beds equivalent to the Fernando are called McKittrick and consist of loose gray sands and fine blue shales. The maximum thickness is about 4000 feet. The McKittrick overlies the Monterey and Santa Margarita shales in the Midway-Sunset, McKittrick, Elk Hills, Belridge, Lost Hills and Kern River fields and contains the principal oil sands of these fields. During the year 1920 these beds produced 43,800,000 barrels of oil or 43.8 per cent of the total state production. The oil is black and averages about 26° Baumé.

In the Middle Coast Ranges, beds equivalent to the McKittrick and Fernando formations have been called Etchegoin and Jacalitos and consist of loose sands, gravels and blue shales. They contain no oil in commercial quantities.

In Northern California the lower Pliocene is called the Merced and consists in general of white and gray sandstone, conglomerate and muddy shales. It has a maximum thickness of about 3000 feet. It is best developed on the San Francisco Peninsula and in the Santa Cruz Mountains, where it overlies the Monterey shale and contains oil in small quantities along the coast side of the mountains between Santa Cruz and Halfmoon Bay. In this region it is known as the Purisima.

In Southern California the uppermost Pliocene may be called the Saugus and consists of soft sands and gravels. It contains no oil in commercial quantities. The division between the Fernando and Saugus is not noticeable except on detail work.

In central and northern California the loose sands and gravels of the upper Pliocene may be called the Paso Robles. These beds contain no oil in commercial quantities.

Characteristic fossils of the upper Pliocene are *Pecten bellus* and *Crepidula princeps.*

Plate II shows a correlation of the oil-bearing formations of California from the Cretaceous to the Pliocene. This table is not intended as a complete correlation table of all the Tertiary formations of the West Coast, but is intended to correlate in a rough manner for practical use those formations which have an influence upon the origin and accumulation of petroleum in California.[1] Formations from which oil has been produced in commercial quantities for an appreciable length of time have been printed in red.

Formations from which oil has been obtained in small quantities, but not on a commercial scale, or which contain authentic seepages of oil, have been printed in green.

Formations from which there has been no actual production of oil or which contain no authentic seepages of oil have been printed in black. These differentiations are based upon the actual facts known to date. It is not intended that this should condemn those formations which have been printed in black or green, as it is possible that future drilling might show that they contain oil in commercial quantities.

[1]In preparing this table the writer is indebted to Prof. B. L. Clark of the University of California for assistance and advice.

CHAPTER III.

POSSIBILITIES OF OIL IN THE COAST AREA NORTH OF THE BAY OF SAN FRANCISCO.

(Includes the counties of Marin, Sonoma, Mendocino, Humboldt, Trinity and Del Norte.)

The general geography and geology of this region has been discussed in Chapter II. As stated there, the major portion of this area is covered with crystalline rocks and therefore affords no possibility of being oil bearing. The oil possibilities are limited to small areas of sedimentary rocks in the Sonoma Valley and along the ocean edge from Bolinas Bay to the mouth of the Eel River.

As the county boundaries have been made to conform more or less to the topographical and geological districts of this area, it may best be discussed in detail by counties.

Marin County.

Marin County is a rather rugged mountain area of 529 square miles. Geologically it has been divided into two areas by the San Andreas Fault, which runs in a northwest direction from Bolinas Bay to Tomales Bay. The country lying east of the fault, which is the upthrow side, is called the Marin peninsula and comprises about three-quarters of the county. The rocks exposed are of the Franciscan formation of Jurassic age and consist of beds of massive gray-green sandstone and radiolarian chert which have been intruded by masses of serpentine and basalt. Both the character and age of these beds preclude their being oil bearing and this district may be dismissed as having no oil possibilities.

The country lying west of the San Andreas fault is called the Point Reyes peninsula and as a result of being on the downthrow side of the fault rocks of Miocene and Pliocene age are found exposed in this district.

These formations consist of bituminous shale of the Monterey formation and loose marine sands of the Merced formation (lower Pliocene.)

The Monterey shales cover about nine-tenths of the peninsula. In the northern portion near Inverness and Tomales Bay they rest directly on the granitic rocks. At Bolinas Point and Duxbury Reef the shales are distinctly bituminous and there are small seepages of heavy black oil at both of these localities. Due to the close proximity of the shales to the fault zone, they have been intensely folded and crushed, which obscures the true nature of the structure. However, there are at least two well defined anticlines on the peninsula as well as numerous minor folds. The axis of the most westerly fold may be seen along the beach one-half mile west of the town of Bolinas where it strikes N. 30° W. The axis of the second fold runs along the high ridge about one-half mile west of Pine Gulch and Olema Creek. This strikes in a general northwest direction. The total thickness of the Monterey in this area is about 4000 feet. The Merced sands occupy a small area in Paradise Valley, just north of the town of Bolinas. The total thickness of these sands is about 600 feet and the general dip is about 30° to the east. Ordinarily it would be expected that these sands would be petroliferous, as they overlie the bituminous shale: this is not the case, however, as they show no evidence of any oil content. This lack of oil is probably due to the great unconformity between these beds and the Monterey shale. Three wells have been drilled just west of the town of Bolinas on the Garzolia Ranch. Two of these were drilled about one-fourth of a mile west of the ranch house at the head of a small gully. These wells were drilled to a depth of about 1800 feet in the Monterey. The one nearest the ranch house encountered no oil, the one nearest the ocean had a small showing at 700 and 1200 feet. A third well was drilled on the sea cliff just back of Duxbury Reef. This well went into the Monterey for 2800 feet and encountered small showing at 200 and 2400 feet. These wells were drilled about 1905.

The possibility of obtaining oil in commercial quantities in this district is not very good. The upper Miocene sands which once probably overlayed the Monterey shale and in which the oil content of the shales probably collected have been removed by erosion. Such oil as remains is in small quantities in fractured zones in the shale and it is doubtful if anything more than a showing would be encountered in any well drilled in this area. Fig. 3 shows a generalized east and west section through a point about two miles north of Bolinas.

Sonoma County.

Sonoma County comprises an area of 1577 square miles. Three-fourths of this area is covered by rocks of Franciscan formation and therefore cannot be considered as having any oil possibilities.

One area of sedimentary rocks which might possibly contain oil, consists of a narrow strip of the Cretaceous formation which outcrops along the coast from the Russian River north to the Gualala River. This strip of Cretaceous is almost four miles wide and rests on its eastern edge on the Franciscan. These rocks, which are probably of Chico age, consist of massive fine-grained sandstone and pebbly sandstone interbedded with fine dark-colored muddy shales. The general dip is about 35°-40° to the west. On certain of the wave-cut terraces the Chico is covered by terrace deposits of fine brown sand. There are no known indications of oil in this area, and it cannot be considered as having any possibilities as it contains neither favorable structure nor organic shales.

A second area of sedimentaries is around the town of Valley Ford, where there are about six square miles of fine sands, clays and conglomerates, probably of the Merced formation (Lower Pliocene). These beds are lying directly on the eroded surface of the Franciscan. There is nothing to indicate that these beds contain oil and this area can be dismissed as having no possibilities.

A third area of sedimentaries in Sonoma County is in the Sonoma Valley. The east and west side of the valley is made up mainly of Franciscan formation and Pliocene lava flows. However, in the center of the valley there is a range of hills known as the Sonoma Mountains and which extend from Santa Rosa to San Pablo Bay. In these hills there are outcrops of sedimentary rocks of Tertiary age, which contain seepages of oil.

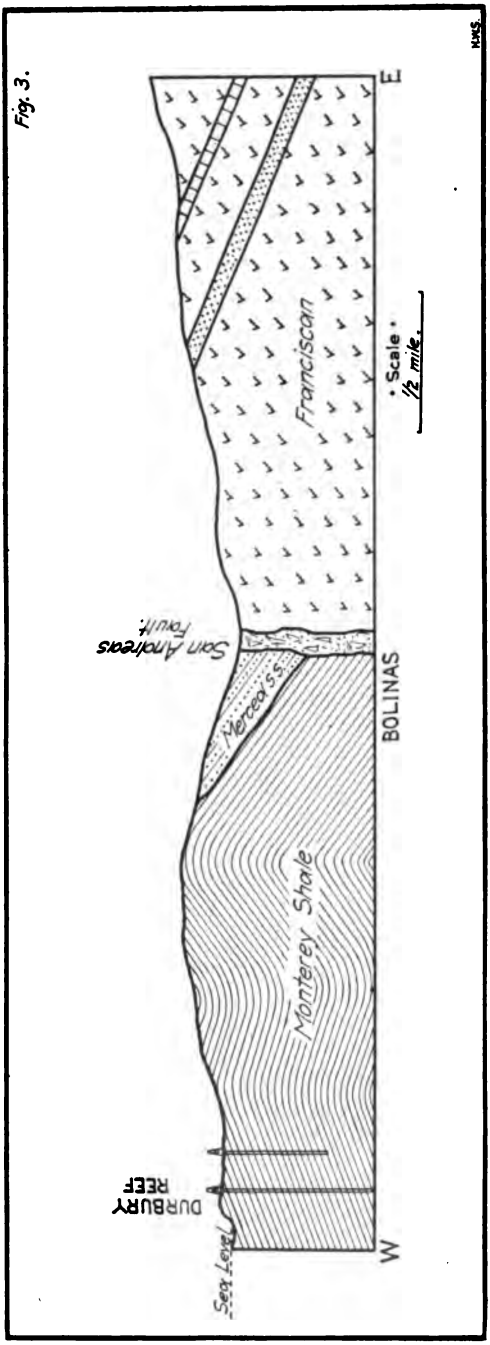

FIG. 3. East-west section across the Point Reyes Peninsula, about two miles north of Bolinas, Marin County.

At the upper end of these hills, near Santa Rosa, the formations consist of fine sands and clays of the Merced (Lower Pliocene) which are lying on the Sonoma tuff and Markwest andesite (Lower Pliocene). Beneath these lava flows there is a small thickness of San Pablo formation which, in turn, rests upon the Franciscan. There is nothing to indicate that this portion of the hills contains oil.

At the south end of the hills, between the towns of Petaluma and Sonoma, the formations consist of medium coarse blue sands and fine sandy shales, probably of the San Pablo formation, which are dipping at an angle of about 35° to the southeast; on their western edge these beds probably rest upon the Franciscan beneath Petaluma Creek. The contact, however, is obscured by overlying beds of Pliocene tuff and lava. The eastern edge of these San Pablo beds, near the town of Sonoma, is also covered by volcanics, which are dipping at about 20° to the east. On the hills east of the town of Sonoma, the dip changes and the Sonoma tuff and Markwest andesite are found dipping at an angle of about 30° to the west. Overlying these lavas is a small thickness of Merced sands and conglomerates. Near the Sonoma-Napa County boundary line, the San Pablo beds again appear, this time dipping 30° to the west, indicating that there is a syncline in the valley south of the town of Sonoma. East of the Sonoma-Napa boundary, the San Pablo beds rest unconformably upon a massive buff sandstone, probably of Tejon age, which is dipping at about 70° to the east.

Evidence as to petroleum is as follows: On the Ducker ranch, three and one-half miles east of Petaluma and one and one-half miles east of the old adobe fort, in the bottom of a small canyon, there are seepages of a heavy black asphaltic oil in the blue sands of the San Pablo formation. These beds are apparently dipping at an angle of about 40° to the southeast. About 1909, four wells were drilled on the mesa just above the seepages. The Ramona Oil Company drilled three of the wells and the Petaluma Home Oil Company, one well. These holes have now been abandoned. Well No. 1 of the Ramona Oil Company was drilled in blue clay and brown sand to a depth of 800 feet, where it is claimed that gas was struck, which had a pressure of 217 pounds and a flow of 690,000 cubic feet per 24 hours. The well, however, soon clogged up and the flow ceased.

Well No. 2 was drilled to a depth of 910 feet, logging oil sands at 335 to 400 feet. In none of these wells, however, was oil obtained in commercial quantities.

The origin of this oil which is found in the San Pablo beds is not clear. There are no known outcrops of Monterey shale in this district. South of San Pablo Bay, however, in Contra Costa County, there is quite an area of bituminous shale of the Monterey. It is possible that this shale is present beneath San Pablo Bay, and the San Pablo sandstone which is dipping to the southeast may be in contact with these bituminous shales, beneath the waters of the bay. In that case, the oil content of the shales would tend to move up the dip into the porous sands of the San Pablo formation and appear in seepages along the outcrop of this formation. It is the opinion of the writer that the structural conditions are not favorable for the accumulation of oil in appreciable amounts in this area.

Mendocino County.

Mendocino County has an area of 3453 square miles, the major portion of which is rugged and mountainous. The sedimentary rocks are confined to a strip along the ocean edge and small isolated areas in the valley of the Eel River. The remainder of the country is covered with metamorphic rocks of the Franciscan formation and can be listed as unfavorable for oil. The strip along the coast averages about eleven miles in width from east to west and covers the entire sixty miles of ocean frontage of the county in a north and south direction. The northern portion of this strip, from the Humboldt County line, as far south as the Garcia River, is composed of rocks of the Chico formation. These beds consist of massive gray sandstones and fine dark-colored shales. In some places these shales have a slatey appearance. The formations have been much deformed and crushed and good dips are difficult to obtain. In general the beds lie in a monocline, dipping about 35° to the west. There is no known indication of petroleum in this area of Chico and both structural conditions and the character of the rocks are unfavorable for the accumulation of oil.

In the vicinity of Point Arena, the Chico is overlayed by bituminous shales and some sandstone of what is probably the Monterey formation. This area of Monterey covers about 25 square miles. Its northern boundary is marked by Alder Creek, where the shales are lying unconformably upon the Chico. The eastern boundary is along the Garcia River, where the Monterey has been faulted against the Chico by the San Andreas fault. The southern boundary is found about 2½ miles south of the town of Point Arena, where there is apparently a fault contact between the Monterey and the underlying Chico sandstones. Plate III is a reconnaissance map of this area, showing structure and areal geology.

The Monterey formation is at least 5000 feet thick, the major portion of which consists of diatomaceous shale, of both the flinty and chalky varieties. In the upper 2000 feet there are numerous lenses of fine-grained sandstone. In the lower 1000 feet there are two well defined beds of medium coarse-grained sandstone. These beds are about 150 feet thick. The general trend of the formation is N. 45° W.

Three well defined folds are found within this area of Monterey. The most easterly is north of the Garcia River and runs through the town of Manchester. The sandstone beds of the lower portion of the Monterey are exposed along this fold.

The second fold is found running through the town of Point Arena. The third and last fold is found close to the beach, running N. 45° W., through the center of Sec. 10, T. 12 N., R. 17 W., M. D. B. and M. As this fold crosses a portion of the O'Neal Ranch, it will be designated as the O'Neal anticline. In general these folds are rather narrow and steep, the dips ranging from 20° to 60°.

Indications of petroleum are as follows: Along the sea cliffs, from the port of Point Arena as far north as the lighthouse, there are numerous seepages of dark asphaltic oil coming from fractured areas in the diatomaceous shale. Along the eastern flank of the syncline, corresponding to the O'Neal anticline and just southwest of the O'Neal ranch house, there is an outcrop of fine-grained bituminous sand about ten feet thick which can be followed in a northwest direction for 3½ miles, finally ending in the sea cliff, just east of the lighthouse. The sand is heavily bituminized and smells strongly of gasoline. It is possible that this deposit might be mined and distilled at a profit.

The following wells have been drilled in this district: The Mendocino Coast Oil Company drilled a well, called the Robbins well, at the northwest corner of Sec. 11, T. 12 N., R. 17 W. A depth of 2240 feet in Monterey shale was reached, and it is claimed that good showings were found. On the Hunter Ranch, near the center of Sec. 11, T. 12 N., R. 12 W., a well was drilled by a Fresno company and called the John D well. It reached a depth of 1700 feet. The Robbins well was drilled in 1905, and the John D. well in 1910. Both wells are located in a syncline and can not be considered as testing out this district. In 1918, Brandenstein and Silverberg drilled a well about 150 feet east and north of where the west line of section eleven runs into the ocean. This well was located on the axis of the O'Neal anticline. A depth of 780 feet was reached and tar sands were logged from 522–715. This hole was not drilled deep enough to be a fair test of this area.

The most favorable area for drilling in this district consists of about 400 acres in sections 10 and 11, T. 12 N., R. 17 W., M. D. B. and M. This area is on the axis of the O'Neal anticline. The structure is favorable and there is also the possibility of a drainage area from under the ocean. Seepages indicate that the fold contains some oil; but whether or not it is in commercial quantities can only be told by drilling.

The other areas of sedimentary rocks in Mendocino County are along the Eel River in the vicinity of Round Valley, Laytonville and Willits. These beds consist of shale and sandstone and are found in small isolated patches on the Franciscan. In general they vary from 100 to 500 feet in thickness and cover areas of not more than four or five square miles. Small seams of coal are found in these beds and the age is probably Eocene. There is nothing to indicate that they contain oil.

Humboldt County.

The only area in Humboldt County that is worthy of consideration as a possible oil field, consists of a body of sedimentary rock which lies along the coast from the Mendocino County line to a point about twelve miles north of Eureka. The east boundary is marked in the southeast by the south fork of Eel River and in the northeast by a line about six miles west of Mad River.

The remainder of the county is covered by the following formations: (1) An area of Franciscan sandstone, chert and serpentine lies east of the sedimentaries above mentioned and covers an area of about twelve miles in width, running in a northwest direction across the center of the county from the Mendocino County line to a point on the coast near Trinidad. (2) Immediately east of the Franciscan, and parallel to it, is an area of the Knoxville (Cretaceous) formation, occupying an area about four miles in width and stretching in a northwesterly direction from a point where the Van Dusen River crosses the Trinity County line to a point on the coast near Big Lagoon. (3) The northeastern portion of the county, east of the Knoxville area, consists of limestones, schists and slates of Paleozoic age, together with some granite.

None of the three above-mentioned areas contains any evidence of oil or offers any inducement for drilling from a geological standpoint.

In the sedimentary area along the coast between Eureka and the Mendocino County line, there are numerous indications that the formations contain oil, at least in a limited amount. This area will, therefore, be discussed somewhat in detail. For the purpose of discussion, it can best be divided into two districts.

First—That area lying at the mouth of Eel River and stretching approximately from Ferndale to McKinleyville, which may be considered as the flood-plane which the river has cut in the soft Pliocene beds which are found outcropping here. On the north flank of Bear River Ridge and just south of the town of Ferndale the best outcrops are found. Here there is a thickness of over 5000 feet of soft muddy-clay shales and fine-grained white sandstone, striking approximately a little north of west and dipping on an average of 20° to the northeast. These beds are known as the Wildcat Series and are believed to be of Pliocene age, although it is possible that the lower beds may be of Miocene or even Eocene age. They are resting unconformably upon the underlying massive Cretaceous sandstone. North of the Eel River the same beds are found dipping to the southwest and it is evident that, structurally, the valley of the Eel River at its mouth is a synclinal trough, the axis of which runs through the town of Fortuna, striking a little north of west. In the vicinity of Eureka, the Wildcat beds are apparently dipping to the west and it is possible that small folds are present in this vicinity. At various times oil and gas have been reported as being present in water wells drilled in this district. The writer, however, found no seepages or indications of petroleum gas.

The possibilities of this district as an oil field depend upon whether there are favorable folds, and the presence of organic shale at a reasonable depth beneath the Wildcat beds. Apparently both of these factors are lacking, although it is possible that a more detailed survey might find evidence of their presence.

Second—This district comprises that area lying approximately south and west of the Eel River. Indications of petroleum consist of a series of seepages of light oil running in a line from the town of Briceland to Capetown, a distance of nearly forty-five miles. The territory that can be considered as offering any possibilities consists of the country drained by the Bear and Mattole rivers and the district around Briceland.

The formations exposed consist of a lowermost member of massive blue-gray sandstone of medium-grained texture, interbedded with dark fine-grained slatey shales. Stratagraphically above this is found a body of about 2000 feet of dark, fine-grained greasy carbonaceous shales, in which are found the seepages of oil. Interbedded with the shale are beds of blue-gray sandstone. The last and uppermost member of the series consists of about 500 feet of massive, hard blue sandstone. This series of beds is probably of Chico (Cretaceous) age. They rest unconformably on their eastern edge along the valley of the Eel River on the eroded surface of the Franciscan. Overlying the Chico, are small areas of soft, fine, white sandstone and fine, blue muddy shales and some pebbly sandstone. These beds are found in the vicinity of Garberville, Briceland, and the mouth of the Bear River and are probably of Tertiary age.

The petroleum found probably originated in the carbonaceous shales of the Chico and has collected in the interbedded sandstone beds. Any production must come from this member of the Chico. The locations of the line of seepages and the wells drilled are shown on Plate IV. The oil is of a paraffine base, varying from light green to amber in color and from 30° Baumé to 50° Baumé in gravity.

The topography consists of a series of ridges and narrow valleys, having a trend of N. 45° W., the elevation of the ridges being about 2500 feet.

Faulting is common and the valley of the Mattole River is probably a structural valley formed by the San Andreas fault. The massive sandstone and the soft shales of the Chico do not contain well defined bedding planes and good dips are rare. No detailed mapping was made of the structure, but in general there are a number of anticlinal and synclinal folds striking in a northwest-southeast direction, the axis of the anticlines being marked by the narrow valleys and the synclines by the ridges. Along all the anticlinal axes erosion has cut down to the lowermost sandstone member of the Chico and in no case was a fold found which contained on its axis the oil bearing shale member of the Chico. Hence any well which would penetrate the oil sands must be located down the flanks of the folds, a location which is not generally considered favorable.

Following is a list of the wells drilled, with the reported results. (Located on Plate IV; map of southwestern Humboldt County.)

Year 1865.

Three wells were drilled on Oil Creek, marked on Plate IV as 1-2-3. Depth of these wells is unknown; it is reported that gas was found. Well 1 is in Sec. 35, T. 2 N., R. 3 W. Well 2 is in Sec. 1, T. 1 N., R. 3 W. Well 3 is in Sec. 6, T. 1 N., R. 2 W.

Two wells on Bear Creek, marked 4-5. Depth unknown; encountered gas and a little oil. Well 4 is in Sec. 24, T. 1 N., R. 3 W. Well 5 is in Sec. 20, T. 1 N., R. 2 W.

McNutt Gulch well, located in Sec. 30, T 1 S., R. 2 W. Depth 300 feet; a little oil found; is still seeping. Marked 6 on Plate IV.

Union well on the north fork of the Mattole, in Sec. 30, T. 1 S., R. 1 W., marked 7. Depth 500 feet; reported as a fifteen-barrel well.

Brown and Knowles well, in Sec. 25, T. 1 S., R. 2 W., marked 8. Depth 300 feet; oil reported at 150 feet.

The Joel Flat well, known as the Henderson well, in Sec. 15, T. 1 S., R. 2 W., marked 9. Depth 500 feet; reported as a ten-barrel well, and 300 barrels of oil are reported as being sold.

Year 1891.

Well on Buckeye Creek, in Sec. 5, T. 2 S., R. 1 W., marked 10. Depth 800 feet. Five-barrel well reported at 500 feet. This well drilled by Far West Company and known as the Burrows well.

Well on Buckeye Creek, known as the Humboldt well, in Sec. 6, T. 2 S., R. 1 W., marked 11. Depth 1900 feet; little oil.

Davis Creek well, in Sec. 13, T. 1 S., R. 3 W., marked 12. Drilled by Far West Company; depth 800 feet; little oil.

YEARS 1901–1902.

McIntosh well on Zanona Ranch, in Sec. 29, T. 1 S., R. 2 W., marked 13. Depth 1700 feet. Reported as a fifteen-barrel well.

Wild Goose well, in Sec. 15, T. 1 S., R. 2 W., marked 14. Depth 1003 feet; oil encountered at 221, 420 and 775 feet; reported as a fifteen-barrel well.

Craig well on the North Fork of the Mattole, in Sec. 30, T. 1 S., R. 1 W., marked 15. Drilled to 800 feet; strong showing of oil and gas reported.

Hoaglin well in the upper Mattole, in Sec. 1, T. 3 S., R. 1 W., marked 16. Depth 1800 feet; showing of oil reported.

Well at Briceland, in Sec. 18, T. 4 S., R. 3 E., marked 17. Drilled to 780 feet; has been producing enough gas for 20 years to supply store and hotel.

YEAR 1908.

McWherter well on Bear Creek, Sec. 14, T. 1 N., R. 3 W., marked 18. Depth unknown; reported showing of oil and gas.

Briceland Oil and Land Co., Sec. 33, T. 4 S., R. 4 E., marked 19. Drilled to 2100 feet; little oil at 410, and granite encountered from 503 to 2100 feet.

YEARS 1920–1921.

Humboldt Oil Company now drilling in Sec. 20, T. 4 S., R. 3 E., marked 20.

Northern Counties Oil Company now drilling in Sec. 36, T. 2 S., R. 1 W., marked 21.

All townships and ranges refer to Humboldt Meridian.

In regard to the reported amount of oil produced at the various wells, as far as the writer was able to ascertain, these figures are not based upon any accurate guage, as none of the wells produced for any length of time and they merely represent a guess on the part of the operator and therefore can not be relied upon to any extent.

Possibilities.

While a large number of wells have been drilled in this district, the majority without any definite results and a few successful in a small way for a limited length of time, the results can not be taken as a fair test, as methods of drilling and producing have improved and changed since the last of these wells were bored.

The geological conditions in general and the structure in particular are not favorable for the accumulation of oil in large quantities. However, the district along the Bear and Mattole rivers and the area around Briceland appear worthy of further examination and testing, but any drilling undertaken should be with the understanding that the best possible return will be small.[a]

[a]A report on the oil possibilities of this portion of Humboldt County, by Mr. W. Stalder, can be found in Bulletin 69, California State Mining Bureau.

Del Norte County.

Del Norte County is almost entirely covered with crystalline and metamorphic rocks. The center of the county is occupied by crystalline limestones, slates and schists of Paleozoic age. Along the coast and also on the eastern border of the county there are outcrops of Franciscan sandstone, chert and serpentine. In the extreme northwest there is an area of granite, all of which are unfavorable for the presence of oil.

The only areas of sedimentary rocks of sufficient area to be mapped lie on the coast about three miles north of Crescent City. Here there is a thickness of about 700 feet of fine-grained, muddy, blue shales, occupying an area of about 10 square miles. On all sides the shales are lying on the eroded surface of the Franciscan. Fossil evidences indicate that the beds are of Pliocene age and probably belong to the Wildcat Series. Evidences of oil have been reported from time to time. The writer, however, could find nothing that indicated the presence of petroleum. In the middle of this area on Sec. 24, T. 16 N., R. 2 E., the North Coast Oil and Refining Company is drilling a well. All geological conditions are distinctly unfavorable for the presence of oil in Del Norte County.

Trinity County.

From a geological standpoint there is nothing to indicate that oil will ever be found in Trinity County. Formations exposed consist of highly metamorphozed sediments of Paleozoic age, some of which have been identified as belonging to the Carboniferous and Devonian periods. Beneath these are found crystalline schists and gneisses which may be pre-Cambrian. Large masses of granite are common. The only area of sedimentary rocks which has not been metamorphosed to a crystalline condition is a small strip of Knoxville shale in the southwestern portion of the county, a continuation of the Knoxville area in Humboldt County. There is no authentic record of any indication of petroleum in the county.

CHAPTER IV.

OIL POSSIBILITIES IN NORTHEASTERN CALIFORNIA.

(Consists of the Counties of Siskiyou, Modoc, Shasta and Lassen.)

The western portion of this region includes the district of the Siskiyou Mountains and the eastern portion, the district of the Lava Beds.

Topographically and geologically this territory lends itself to be discussed by counties.

Siskiyou County.

The main line of the Southern Pacific Railroad from San Francisco to Seattle divides the county into approximately two parts. West of the line of the railroad the county is extremely rugged and mountainous and is known as the region of the Siskiyou Mountains. The formations exposed are highly metamorphosed sediments of Paleozoic and possibly pre-Cambrian age, together with large masses of granite, all unfavorable for containing oil.

East of the line of the railroad is a great lava plateau, stretching eastward to the Modoc County line. From the plateau rise various volcanic peaks to heights of 5000 to 8000 feet and in the south-central portion, Mount Shasta towers at a height of 14,380 feet. This region, with some minor exceptions, which will be noted below, is entirely covered by lava flows, chiefly andesites and basalts. The age of the lava is thought to be Tertiary with some Quaternary flows near Mount Shasta. No oil can be expected from the lava beds. Whether or not they cover Tertiary formations which might contain oil can not be told from surface indications. In the upper valley of the Little Shasta River, about six miles southeast of Montague, there are some fresh-water springs in the lava beds from which bubbles of gas are coming. These so-called gas springs have caused considerable oil excitement in this region. An examination convinced the writer that the gas is in no way connected with petroleum deposits.

Unmetamorphosed sedimentary areas are found in the following localities: (1) A small area of Chico (Cretaceous) running from the vicinity of Round Mountain north through Hornbrook to the Oregon line at Hilts. The Chico consists of about 1500 feet of massive sandstones and thin-bedded dark shales. The beds have a dip of 15° to the east and strike N. 40° W. They contain no evidence of petroleum. Overlying the Chico on the east is a small area of fine-grained green sandstone and sandy shale containing seams of lignite, in the vicinity of Ager. This formation is probably of Eocene age. It occupies an area about 18 miles long and 10 miles wide and has a dip of 20° to the east, where it rests against the lava beds. Its exact relationship to the lavas is not clear. No evidences of oil were found in this formation. (2) A second area of sedimentaries is found just east of Dunsmuir, along the valley of the McCloud River. The formations consist of more or less altered shales, sandstone and limestone of Carboniferous, Devonian and Jurassic age. They contain no evidence of petroleum.

Modoc County.

Modoc County, lying in the extreme northeastern portion of the state, consists of a high plateau with an average elevation of nearly 5000 feet, from which detached mountain peaks and volcanic ranges rise to a height of 8000 and 9000 feet. Along the northern and eastern border there are large fresh-water lakes. The formations that outcrop consist, with some minor exceptions, of flat-lying lava beds, chiefly andesite and basalts, the age of which is probably Tertiary. There is no surface evidence as to what underlies the lavas, or what is their total thickness. A few miles south of Fall River Mills, Shasta County, the Pit River has cut its channel down 1800 feet in these flat-lying beds, and there is no evidence of any underlying formations.

Running from a point on the Pit River, about seven miles west of Canby and as far east as Alturas and as far north as Goose Lake, is a flat-lying bed of fresh water diatomaceous shale, varying from 25 to 50 feet in thickness. The shale is interbedded between two lava flows and has a small caping of muddy shale. The deposit probably represents a Pleistocene lake bed. The thickness of shale is too small to form any appreciable amount of petroleum and also there is lack of structure. Modoc County offers no inducements for drilling operations.

Shasta County.

Geologically, Shasta County may be divided into three districts: (1) The eastern half of the county, lying approximately east of the 122° meridian, is topographically similar to Modoc County. It is covered with the same lava flows and is likewise unfavorable for the development of petroleum. (2) The northwestern portion of the county, lying approximately west of 122° meridian and north of Redding, is a rugged, mountainous region. The formations consist of beds of limestone, chert, slate, sandstone and conglomerate, all more or less metamorphosed and belonging to the Devonian, Carboniferous, Triassic, and Jurassic periods. There are also masses of intrusive granite and serpentine. The county has been much deformed and crushed and the beds are steeply tilted. This area has been mapped in detail and the report published by the U. S. Geological Survey,[1] so no further description of the formations will be given here. While formations similar to the Devonian, Carboniferous, and Triassic limestone found outcropping in this area produce oil in other regions of the United States, no evidence of petroleum has been found in this area, nor is their structure favorable for its accumulation. (3) The extreme southwestern portion of the county and the area around the head of the Sacramento Valley are covered by beds of Cretaceous age, Tertiary lava flows and valley alluvium. Beneath these sediments are masses of granite, serpentine and metamorphic Paleozoic rocks. As this region has been described in detail in the Redding Folio, U. S. Geological Survey, no further description of the geology will be given here. It suffices to say that the district contains no evidences of petroleum and is unfavorable for its accumulation.

At the head of the Sacramento Valley, just north of Redding, along Buckeye Creek, there are a number of salt and sulphur springs in the

[1]Redding folio 138. U. S. Geological Survey.

Chico beds from which small quantities of gas are emanating. On the strength of these so-called gas springs, four wells were drilled, the deepest being 1000 feet. They were drilled in the Chico and probably penetrated to the lowermost beds of this formation. No oil was encountered and only a small quantity of gas. It is the opinion of the writer that the gas found is not connected with petroleum deposits.

Lassen County.

Lassen County is similar to Modoc and eastern Shasta in topography and geology. The formations exposed are practically flat-lying beds of lava, chiefly andesite and basalt. There is nothing to indicate their total thickness, or the character of the underlying formations, except on the south boundary of the county where they are lying on the eroded surface of the granites of the Sierra Nevada. South and east of Westwood there is a tongue-like mass of the Carboniferous formation coming in from Plumas County. There are no favorable indications of oil in Lassen County.

CHAPTER V.

AREA OF THE SIERRA NEVADA MOUNTAINS.

(Consists of the following Counties: Plumas, Sierra, Eastern Part of Butte County, Eastern Part of Yuba County, Nevada, Eastern Part of Placer, El Dorado, Amador, Alpine, Calaveras, Tuolumne, Mariposa, Eastern Part of Madera, Eastern Parts of Fresno and Tulare Counties and that Part of Kern County that lies in the Sierras.)

On the north this province may be considered as ending along the north line of Plumas County, where the granite peaks of the Sierra give way to the lava beds of Lassen County. The eastern edge is marked, from Plumas County as far south as Mono County, by the boundary line of California and Nevada and thence it follows the west line of Mono and Inyo counties, marked by the great Sierra fault line, through eastern Kern to Tejon Pass, where the Sierra proper ends. The western edge, in this report, will be considered as lying just east of the foothills of the Sacramento and San Joaquin valleys.

The Sierra Nevada structurally may be considered as a great fault block, which is being slowly tilted, the eastern edge, marked by the great fault scarp, going up and the western edge along the great central valley acting as the hinge. The result of this tilting has given a gentle western slope and a rather abrupt falling away on the east towards the desert of Nevada.

The rock exposed can be divided into two series: (1) The Bedrock series consists of granitic rocks, together with bodies of schists and slates, which have been produced by intense metamorphism of ancient sediments and igneous rocks. The main body of altered sediments is known as the Calaveras formation, consisting of slates, quartzites and limestones of Carboniferous age and the Mariposa slates of Jurassic age. (2) The Superjacent series, which overlies the Bedrock series, is made up of beds of auriferous gravel of Eocene and Miocene age, together with lava flows, chiefly andesite and rhyolite tuff, probably of Miocene age. Along the foothills there are sediments of Cretaceous and Tertiary ages. These, however, will be considered as belonging to the Sacramento and San Joaquin Valley areas and will be discussed in chapters relating to those districts.

The southern half of the Sierra Nevada, as far north as Madera County, is composed entirely of granitic rocks. The central and northern portions contain the altered sediments of the Bedrock series, together with their associated granites and the overlying gravels and lavas of the Superadjacent series. The total absence of any of the oil-bearing formations and the crystalline and metamorphic character of the rocks exposed, make the area of the Sierra Nevada an impossible one for the origin or accumulation of petroleum.

CHAPTER VI.

Area of the Sacramento Valley, Including the East Slope of the Coast Ranges and the Foothills of the Sierra Nevada.

(Consists of the counties of Tehama, Glenn, Western Butte and Yuba, Sutter, Colusa, Lake, Yolo, Napa, Solano, Western Placer, Sacramento.)

This area will be divided into three districts and each discussed in more or less detail.

(1) DISTRICT OF THE WEST SIDE OF THE VALLEY AND EAST SLOPE OF THE COAST RANGES.

TOPOGRAPHY.

Along the west side the flat-lying lands of the Valley floor rise first to a mass of rather low rugged foothills varying in elevation, as they extend westward, from 300 to 1500 feet. They occupy a belt about fifteen miles in width and extend from the southern boundary of Shasta County to Suisun Bay. These hills have been carved out along the upturned edges of the Cretaceous formation. The rather hard Chico sandstone which marks their eastern edge has given rise to a characteristic topography of innumerable small canyons and ridges, with a general east and west trend, while on the other hand, the underlying soft Knoxville shales which mark their western limits have given rise to a topography of rather broad valleys or basins, with a north and south trend. West of these foothills, the main peaks of the east slope of the Coast Ranges rise to a height of 3000 to 4000 feet and the topography of the country is extremely rugged, having been carved out of the hard resistant rocks of the Franciscan. In Lake County the rugged topography is somewhat broken by a broad level valley around Clear Lake, which drains into the Sacramento, and still further south the Napa Valley forms a broad, flat plain, draining into Carquinez Straits.

GEOLOGY.

The oldest rocks exposed are beds of altered sandstone, chert, schist and masses of intrusive serpentine, all of the Franciscan formation (Jurassic). This formation extends in a belt from southern Shasta County to northern Napa County and varies in width from about five miles at its northern end to 25 miles in southern Lake County. It covers the entire western portions of Tehama, Glenn and Colusa counties; about nine-tenths of Lake County; and is found outcropping in the northeast portion of Napa County and along the east side of the Napa Valley. Any area covered by this formation may be considered as unfavorable for oil.

Overlying the Franciscan is found the Cretaceous—the only formation within this area that offers any promise of containing oil. The lowermost Cretaceous, known as the Knoxville,[1] consists of dark thin-bedded, fine-grained carbonaceous shales. While the writer has no definite data on the proportion of carbonaceous matter in the shales,

[1]Includes the Horsetown.

it apparently is less than 1 per cent, and it is from this that any oil found in the Knoxville will necessarily come. Interbedded with the shales are thin beds of fine-grained sandstone—generally about three inches thick. The general aspect of the Knoxville is that of a shale formation.

Above the Knoxville is found the uppermost Cretaceous or Chico, which consists in this area of massive, medium coarse, blue-gray and greenish sandstone, which turns to a tawny brown on weathering. Interbedded with the sandstone are minor beds of dark, fine-grained shale. The contact between the Knoxville and Chico is marked generally by a thick bed of conglomerate, made up of crystalline pebbles. In Yolo and Solano counties, the uppermost Chico contains several beds of dark colored more or less carbonaceous shales, averaging in thickness about 150 feet, and it is from these beds that any oil in the Chico must come.

The main body of Cretaceous sediments within this area is found occupying the foothill belt which extends from southern Shasta County to Suisun Bay; and they cover, roughly, an area of about 15 miles in width across the centers of Tehama, Glenn and Colusa counties, the west half of Yolo County and the northeast corner of Napa and the northwest corner of Solano counties. The maximum thickness is nearly 30,000 feet, approximately the lower 22,000 being Knoxville and the upper 8000 feet, Chico. The general structure (with some exceptions which will be noted below) is that of a great monocline dipping at an angle of about 35° towards the Sacramento Valley. All known seepages of oil in the Sacramento Valley occur in this belt of Cretaceous.

Other districts in which the Cretaceous occurs are as follows: (a) A small area of Chico occupying a synclinal trough just south of the town of Lower Lake, Lake County. (b) A much-folded area of Knoxville shales about 1500 feet thick in the hills along the west side of the Napa Valley. (c) An area of Knoxville and Chico in the range of hills north of Vallejo and Benicia. None of these areas show any indication of oil.

Tertiary formations occur as follows: (a) In northern Tehama County in the foothills along the valley edge, just west of Redding, are outcrops of nearly flat-lying beds of loose sand, conglomerate and volcanic ash, known as the Tuscan Tuff formation, of Miocene age. The Tuff is lying unconformably upon the Chico and is best exposed along the south fork of Cottonwood Creek. In southern Tehama County in the hills west of Corning, beds of flat-lying Tuscan Tuff are found. (b) In northern Glenn County in the foot hills along the valley's edge, west of Orland, is a series of buttes. These buttes are formed of beds of Chico sandstone dipping at about 25° to the east and capped by beds of flat-lying lava, averaging 50 feet in thickness. The lavas are probably of late Pliocene age. (c) In southern Colusa County in the hills west of Williams and Arbuckle and occupying the lower courses of Cortina Creek, Sand Creek, Elk Creek and Petroleum Creek, are beds of conglomerate, blue sandstone and soft blue shales. The average thickness of these beds is about 1000 feet and the age is probably upper Pliocene. They are lying unconformably upon the Chico.

None of the above Tertiary beds show any evidence of oil.

(d) In Yolo County, around the Capay Valley, there is a Tertiary formation about 800 feet thick consisting mainly of beds of fine clay, intercalated with ash beds and containing, near the top and bottom, beds of conglomerate and yellow sand. It is probable that this formation is of Eocene age, as it bears a marked resemblance to the Ione (Tejon) of the east side of the Sacramento Valley. It is found in small patches along the floor of the Capay Valley, and in the hills just north of the town of Capay, known as Duncan's Bluffs, it forms the nose of a faulted anticline. Lying unconformably upon the Chico, along the valley's edge, it probably extends as far north as Buckeye Creek and as far south as Putah Creek. It has been reported that the clays, when boiled with ether, show a light amber oil. If so, this oil must have come from the underlying Chico, as the Ione beds contain nothing that would form oil. (e) In the vicinity of Vacaville, Yolo County, there are beds of diatomaceous shales, interbedded with muddy blue shales and overlayed with conglomerate beds. Total thickness of the formation is about 600 feet. The diatomaceous shale beds average about 75 feet in thickness. The age is probably middle Eocene (Meganos). This Meganos is found outcropping along the flanks of an anticline which runs along the Vaca Valley, east of Vacaville. It also outcrops in the range of hills between Vacaville and Winters, where it dips eastward beneath the alluvium of the Sacramento Valley at an angle of about 30°. (f) In the small range of hills about four miles southeast of Fairfield, known as the Potrero Hills, there are beds of pink diatomaceous shales averaging about 100 feet in thickness and interbedded with fine-grained white sandstone. The total thickness of this formation, as shown by the Honolulu Consolidated Well, is about 1100 feet. The age is probably middle Eocene (Meganos). Slight showing of oil has been reported in the shale. (g) Beginning just west of Fairfield and running south to Benicia and west to the Napa Valley is an area of Pliocene lava, which lies on the eroded surface of the Franciscan and Chico. These lava beds continue into the Napa Valley and are found capping the ridges on both sides and at the head of the valley. (h) A small amount of Tejon is found in the hills just southwest of Napa City and in the hills just east of Napa Junction. (i) In Lake County, south of the town of Lower Lake, there is about 5000 feet of Martinez and Tejon sediments, overlying the Chico in a synclinal trough. The total areal extent is about five square miles. (j) In southern Lake County there are numerous lava flows overlying the Franciscan.

INDICATIONS OF PETROLEUM.

Indications of petroleum on the west side of the Sacramento Valley and the east slope of the Coast Range are limited to the Cretaceous area in Glenn, Colusa, Yolo and Napa counties and possibly the Meganos area in the Potrero Hills. A reconnoissance map of this territory is shown on Plate V. The remainder of the district offers no inducement for drilling, and no further discussion of it will be given here.

Following are the localities in the above-mentioned counties in which there are authentic evidences of petroleum:

In Glenn County, there are no actual seepages of oil. In the hills west of Orland, however, there are numerous occurrences of gas in the Chico sandstone. In Colusa County, seepages of light-amber oil of a paraffine base, with a gravity of 20° Baumé occur in the Knoxville shales at the following places: (1) Along the west side of Bear Valley, near Wilbur Spring, there is a line of seepages beginning in, approximately Sec. 21, T. 14 N., R. 5 W., and continuing southward to Sec. 35, T. 14 N., R. 5 W. The majority of these seepages occur in calcareous springs at the contact of the Knoxville shales with the underlying Franciscan chert and serpentine. The maximum yield is about one gallon per day. In some cases, however, the seeps are actually in the chert and serpentine. In Sec. 35, T. 14 N., R. 5 W., a tunnel has been driven into the serpentine for a distance of about fifty feet, with the result that as much as a barrel of oil has been found in certain of the crevices in the serpentine. The occurrence of the oil in the serpentine and chert may be accounted for by the close proximity of the Knoxville shales, the oil apparently having migrated from the overlying compact shales into the fractures and crevices in the chert and serpentine and hence may be regarded as a freak occurrence of petroleum. Any tunnel or well sunk in the serpentine or chert with the expectation of encountering a pool of oil is doomed to failure. (2) A second series of seepages is found along the axis of a faulted anticline, running north and south through Venado (Mountain House). These occur in sandstone beds in the Knoxville, the most prominent seep being found in the SE¼ of Sec. 31, T. 15 N., R. 4 W. Wells drilled along this fault at various times still continue to show small amounts of gas. (3) A third series is found along the bottom of Sand Creek, in Sec. 8, T. 13 N., R. 3 W., where the creek cuts across the axis of a small fold. These seeps are probably in the Chico.

In Yolo County, along the axis of a fault in the Rumsey Hills, which mark the east side of the Capay Valley, there are numerous salt and sulphur springs from which it is claimed green oil seeps. The springs are in the middle Chico. At the time of the writer's visit, most of these springs had ceased to flow, so the report could not be verified. In the hills just south of Capay, it is claimed that in rainy weather there are numerous seepages of oil and gas from the clay of the Ione formation, and a sample of light amber oil distilled from the clay was shown to the writer at the time of his visit.

In the Berryessa Valley, Napa County, there are several notable seepages in the Knoxville shales. They are located as follows: in the SW¼ of Sec. 25, T. 9 N., R. 3 W.; on the J. W. Harris Ranch, about seven miles north of Monticello; on the Zem Zem Ranch in the SE¼ of Sec 34, T. 11 N., R. 4 W.; on the 300-foot level of the Knoxville mine.

In Solano County, about one mile southeast of Cannon, in Secs. 11 and 14, T. 5 N., R. 1 W., there are several well defined 'gas blows.' These gas blows occur along the axis of a fold, in the Chico sandstone, and in the vicinity of the 'blow' the rocks have been burnt to a brick-red slag.

In the Potrero Hills, east of Fairfield, there are numerous seepages of gas reported in the Meganos shales.

STRUCTURE.

Plate V shows the approximate locations of the major folds and faults within these counties. Fig. 4 shows two generalized sections across this area. The majority of these folds (with two exceptions which are noted below) are sharply compressed and faulted and apparently not the most favorable type of structure for the accumulation of oil in appreci-

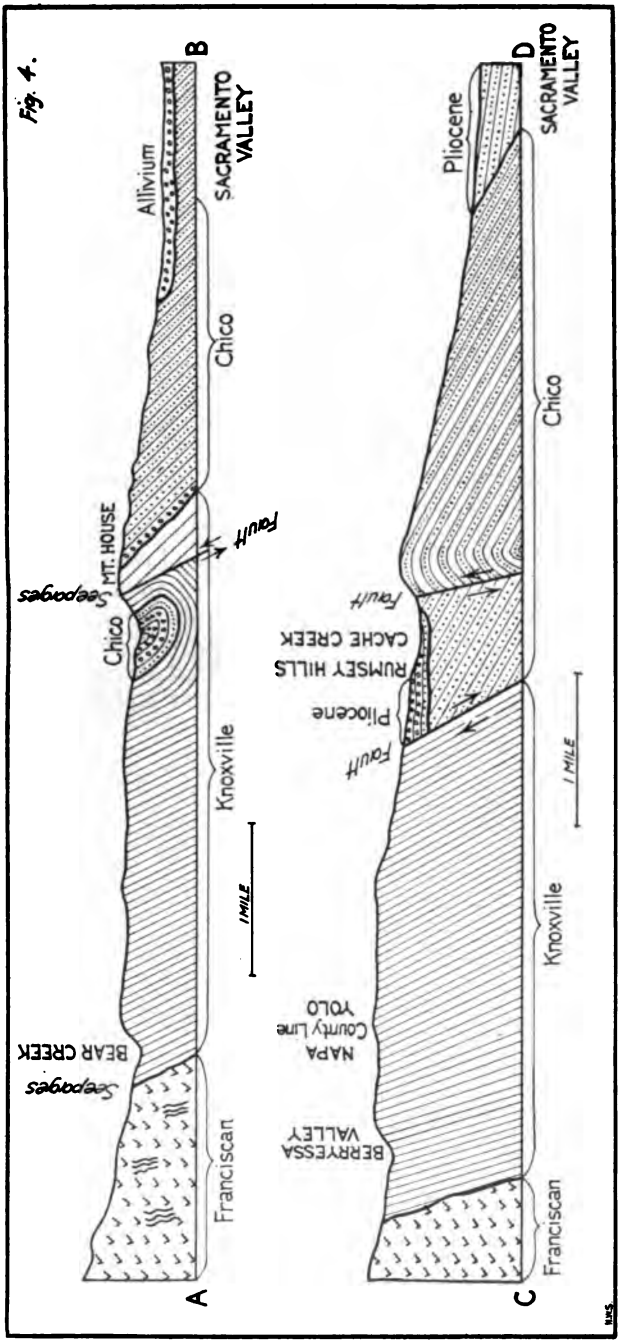

FIG. 4. East-west sections across western side of the Sacramento Valley (see Plate V for location).

able quantities. The two exceptions consist of (1) an anticline in the Chico sandstone running out from the foothills into the flat of the Sacramento Valley about three miles southeast of Vacaville. The axis of this fold, which strikes N. 45° W., may be followed from Sec. 3, T. 5 N., R. 1 W., to Sec. 30, T. 5 N., R. 1 E. The dips of the flanks vary from 15° to 40°. (2) The Potrero Hills, four miles east of Fairfield, form an elongated dome in the Meganos formations. The axis of the dome strikes approximately east and west and may be followed from Sec. 6 to Sec. 11, T. 4 N., R. 1 W. The dips on the flanks vary from 10° to 20° and the plunge at the east and west ends is approximately 35°. Both of these folds, from a structural standpoint, are favorable for the accumulation of oil.

POSSIBILITIES.

Factors favorable for the accumulation and production of oil in this area are as follows: (1) The presence of oil as shown by seepages. (2) The presence of structures more or less favorable for the accumulation of oil in small quantities. (3) In the case of the anticline south of Vacaville and the dome in the Potrero Hills, the structure is favorable for the accumulation in large quantities.

Factors unfavorable are as follows: (1) The character of the formation present (Cretaceous) is distinctly unfavorable for the formation of petroleum in an appreciable amount. (2) Faulting and tilting of the strata have caused a considerable percentage of whatever oil was originally present to run out and be lost. (3) The structure, due to sharp folding and faulting, is not favorable for the accumulation of oil in large quantities, except in the two cases above noted. Summing these factors up, it would appear that wells drilled along the axis of the anticlines and faults (shown on Plate 5) should obtain showing of oil and, possibly, under the most favorable conditions, obtain small quantities of oil. Whether these small quantities of oil which might be obtained would be of commercial value can only be determined by drilling. Due to the favorable structure and the large area of possible accumulation, the anticline southeast of Vacaville and the dome in the Potrero Hills may be considered as the most favorable locality to test out this district.[1]

Following is a list of wells, with the reported results.

TEHAMA COUNTY. Unnamed well in Sec. 30, T. 23 N., R. 4 W., drilled to a depth of 2020 in the Chico; showing of gas reported.

COLUSA COUNTY. (1) Unnamed well drilled in the NW¼ of Sec. 23, T. 20 N., R. 5 W., about the year 1902; depth 2900 feet; located in a syncline in the Chico; show of gas and oil reported. (2) Williams Oil Company 'Brim Well,' located in the SE¼ of Sec. 15, T. 15 N., R. 4 W.; drilled to a depth of 2540 in the Chico; considerable gas reported. (3) Williams Oil Company 'Granger Well,' located in the NE¼ of Sec. 18, T. 15 N., R. 4 W., on the axis of a faulted anticline; drilled to a depth of 600 feet in the Knoxville shales; good showing of oil reported from 75 to 600 feet. (4) Williams Oil Company well, located in the NE¼ of Sec 17, T. 15 N., R. 4 W.; drilled to a depth of 1400 feet in the Chico; showing of oil and gas reported. (5) Williams Oil Company 'Mountain House Well,' located in the SE¼ of Sec 18, T. 5 N., R. 4 W.,

[1]These two areas are now being tested by the Honolulu Consolidated Oil Co.

on the axis of a faulted anticline; drilled to a depth of 1300 feet in the Knoxville; good showing of gas reported at 1042 feet; well still shows a small flow of gas. These wells of the Williams Oil Company were drilled between 1901–1909. (6) At the present time (April, 1921) the Mountain House Standard Oil Company is drilling a well in the NE¼ of Sec. 18, T. 15 N., R. 4 W. A depth of 715 feet has been reached and a good showing of light oil is reported. (7) Unnamed well in NW¼ of Sec. 32, T. 15 N., R. 4 W.; shallow; still shows small amount of gas. (8) Three wells are reported as having been drilled on Sand Creek, in Secs. 7 and 8, T. 13 N., R. 3 W.; reported depths were from 1000 to 1500 feet and showings of gas and oil were said to have been encountered, one well still showing a small amount of gas. These wells are located approximately on the axis of an anticline in the uppermost Chico. (9) On the west side of Bear Creek, about one mile north of Wilbur Springs, several shallow wells were drilled near the contact of the Knoxville and Franciscan and close to the seeps that occur there. Showings of oil and gas were reported from these wells. (10) In the SW¼ of Sec. 35, T. 15 N., R. 5 W., the Herron Oil Company sank a well to a depth of 1000 feet in the serpentine. At the present time a tunnel is being driven into the serpentine, just south of the Herron well, by the Blue Ridge Petroleum Company. Crevices in the serpentine have yielded as much as a barrel of light amber oil. As stated above this can be regarded only as a freak occurrence of petroleum. The oil undoubtedly migrated from the shales which are found outcropping about 500 yards east of the tunnel. (11) At the present time the Blue Ridge Petroleum Company is drilling a well in the SW¼ of Sec 34, T. 13 N., R. 3 W. The well is located approximately on the axis of a sharply folded anticline.

Yolo County. In the Capay Valley, about two miles west of the town of Capay, the Lincoln-Esparto Oilfields Company is drilling a well, which is apparently located on the top of a dome in the Ione formation. Conclusive proof of this dome structure is, however, lacking.

Solano County. In the NE¼ of Sec. 24, T. 5 N., R. 1 W., the Rochester Oil Company drilled a well, in 1901, to a depth of 1820 feet. Gas was encountered at 1520 and the well produced at the rate of 20,000 cubic feet per day for several years. In 1919 the production was 8,000 cubic feet per day; since then the production has steadily declined. The well is located on the axis of a well defined anticline in the Chico sandstone. In the SW¼ of Sec. 13, T. 5 N., R. 1 W., about one-half mile northwest of the Rochester well and on the axis of the same fold the Honolulu Consolidated is now drilling a well. In the Potrero Hills, about four miles east of Fairfield, the Honolulu Consolidated Company is drilling a second well, which is located in the NE¼ of Sec. 9, T. 4 N., R. 1 W. The well is close to the axis of a dome in the Meganos shale.

In addition the following wells were drilled in the Cretaceous near Vallejo without obtaining an indication of petroleum: The Midas Oil Company, in 1914, drilled a well in Sec. 20, T. 3 N., R. 3 W., to a reported depth of 2000 feet. W. Hauluth, in 1916, drilled a well in Sec. 4, T. 3 N., R. 3 W., to a reported depth of 1400 feet.

NAPA COUNTY. In the Berryessa Valley, on the J. W. Harris Ranch, about seven miles north of Monticello, the Mount Shasta Oil Company drilled a well to a depth of 400 feet in the Knoxville and obtained showings of oil. In Sec. 25, T. 9 N., R. 3 W., the Fearless Oil Company drilled a well to a depth of 1475 feet in the Knoxville, obtaining a showing of oil at 270 feet. These wells were drilled in 1904.

(2) DISTRICT OF THE VALLEY FLOOR.

This district may be considered as embracing the flat-lying territory of the valley floor proper.

The geological formations exposed are confined to small areas in the Hooker Hills, Tehama County; the Marysville Buttes, Sutter County and the Montezuma Hills in Solano County. These three groups of hills are the only notable interruptions in the surface continuity of the flat-lying lands of the valley floor. The remainder of the district is covered by recent alluvium.

The Hooker Hills are a small group of erosional hills, along the Sacramento River, about five miles north of Red Bluff. The elevation is about 500 feet. A study of the topography of this region indicates that these hills are not due to any doming up of the strata, but rather they are to be regarded as an erosional feature of the topography. They are a part of an old flood plain of the Sacramento River, which recent movements have elevated and the present-day streams have cut down to a new flood-plain, leaving the hills more or less isolated. Remains of this old flood plain may also be seen in the well defined terraces on both sides of the valley. The formations exposed are the Red Bluff and Tuscan Tuff formations. The Red Bluff formation consists of about 75 feet of coarse red conglomerate of Quaternary age. The Tuscan Tuff consists of about 500 feet of andesitic tuff together with some conglomerate beds and lava flows. Some of the tuff is very fine, almost pumice and has frequently been mistaken for diatomaceous shale. While there is no direct evidence, the Tuscan formation is probably underlayed by the Chico sandstone. The so-called gas seepages that have been reported, are nothing more than iron oxide stain in the conglomerate beds of the Red Bluff formation. Neither the structural conditions, nor the character of the formations are favorable for the accumulation of petroleum in these hills.

The Tuscan Oil Company is at the present time drilling a well near Hooker station, in Sec. 25, T. 28 N., R. 4 E.

The Marysville Buttes in Sutter County are the most notable topographical feature of the Sacramento Valley. They form a nearly circular group of mountains with a diameter of about ten miles and rise from an elevation of about 100 feet at the valley floor to an elevation of 2000 feet in the central peaks. The buttes have been mapped in detail by the U. S. Geological Survey.[1] and Dickerson[2] has recently described the sedimentary rocks that are found there, so no detailed description of the geology is given herein.

[1]Folio 17, Marysville. Folio U. S. Geological Survey.

[2]Dickerson, R. E. Eocene of the Marysville Buttes-University of California. Bulletin of the Department of Geology. Vol. 7.

The buttes consist of three rings of different formations; an inner core of volcanic rocks, a middle ring of upturned sedimentaries consisting of the Chico and Ione formations and finally an outer ring of volcanic muds and lavas. The sedimentaries of Chico and Ione age are made up mainly of fine sandstones and clay shales, with a thickness of about 1500 feet. Showing of gas has been reported from these sediments from time to time and in 1864 a well was drilled in the Ione formations about one mile southeast of South Butte. A depth of twenty feet was reached and a small flow of gas was encountered, which can still be observed. There is no reason, however, to believe that this gas is connected with petroleum deposits as there is apparently no formation in this region capable of forming oil. It is probable that the tilting up of the sedimentaries against the central core of volcanics has caused the marsh gas (CH_4), which is present in varying quantities in practically all sedimentary formations, to collect in a noticeable degree along the upturned edges of the Chico and Ione.

There is nothing to indicate that there is sufficient gas to be of commercial value.

The Montezuma Hills cover an area of about ten square miles in southern Solano County, lying along the Sacramento River at a point where it empties into Suisun Bay. The average elevation is about 100 feet. The formations exposed consist mainly of soft clay shales, without distinctive strike or dip. The age is probably late Pliocene. Along the county road about a mile south of Denverton there are beds of conglomerate and volcanic ash, striking north and dipping 5° to the east. Just west of Rio Vista there are some sandy clay beds, striking north and dipping about 30° to the west. From these meager dips it would appear that the hills occupy a syncline in the middle of the great valley. The chief interest, however, lies in the fact that the diatomaceous shale (Meganos) which outcrops in the Potrero Hills, probably continues across Denverton slough and is present beneath the Montezuma Hills. These shale beds, being diatomaceous, may form oil. From a rough survey, the hills apparently have no structure that would be suitable as a reservoir for any oil that might be formed. However, they are worthy of being carefully mapped to determine if any favorable structure is present.

The greater portion of the valley floor, which is covered by recent alluvium, offers no inducement for drilling. At the same time this territory can not be condemned outright. While it may contain no positive evidence of petroleum, neither does it contain evidence that oil is not present. The recent silt and alluvium of the valley floor covers all evidence that might tell the tale. There always exists the possibility in cases like this that the flat-lying lands may be underlayed by productive folds.[1]

In the case of the Sacramento Valley, however, the character of the formations exposed on the edges makes it rather doubtful that any fold in the center of the valley would be productive.

[1]This matter of buried anticlines in the great valley is discussed in detail in Chapter XIII, Area of the San Joaquin Valley.

(3) DISTRICT OF THE EAST SIDE OF THE VALLEY AND THE FOOTHILLS OF THE SIERRA NEVADA.

The greater part of this district has been mapped more or less in detail by the United States Geological Survey and the detailed geology can be found in the following folios: Lassen Peak, 15; Marysville, 17; Smartsville, 18; Sacramento, 5; Placerville, 3; Jackson, 11.

The oldest rocks exposed are known as the Bedrock series and consist of ancient schist, gneisses and slates, mainly of Carboniferous and Jurassic age, together with associated granitic rocks. These formations constitute the core of the Sierra Nevada and probably underly the greater part of the area under consideration. They are exposed on the surface within this district from a point near Oroville as far south as the American River. Structurally they have been sharply tilted and folded.

The next oldest formation consists of beds of medium-coarse gray sandstone and sandy shale of Chico age (Cretaceous). The surface exposures of Chico are not extensive. They are found mainly in the deeper canyons of eastern Tehama County, and northern Butte County, where the streams coming down from the Sierra Nevada have cut down through the flat-lying lavas and exposed small patches of the underlying Chico. Roughly, these areas of the Chico formation extend from the head of the Sacramento Valley as far south as Oroville. A small isolated patch has been recognized on the American River near Folsom.

The Eocene is represented by the Ione formation (Tejon) and consists of fine clays and shales, together with beds of impure volcanic tuff. The Ione is found as far north as Wheatland, Yuba County, where small patches of from 20 to 30 feet are exposed. Near Lincoln, in Placer County, the thickness increases to 100 to 200 feet and in western Sacramento County, south of the American River, it attains its maximum thickness of nearly 1000 feet. In this district it lies upon the Bedrock series with marked unconformity except for a small area, near Folsom, where it is found unconformably upon the Chico.

The other Tertiary formations consist of beds of volcanic ash, known as the Tuscan Tuff (Miocene) which is overlayed by andesitic and basaltic lava flows of Pliocene age. These volcanics cover the major portion of eastern Tehama and northeastern Butte counties. The tuff is found unconformably upon the Chico and has a maximum thickness of about 1000 feet. The lava flows are found more or less conformably upon the tuff and vary in thickness from 50 to 200 feet.

The general structure of the Cretaceous and Tertiary formations within this district is that of a great monocline, dipping from 5° to 20° to the west. The only area where these formations have been folded is found at Tuscan Springs, where, in a crater-like area of about 80 acres in extent, the Chico, Tuscan Tuff and lavas have been tilted up into a nearly circular dome. An examination showed that this structure is not due to compressive earth movements, but rather to the efforts of a batholitic mass of lava from the Lassen Peak range of volcanoes trying to force its way up through the overlying formations.

In the vicinity of the hot mineral springs that are found here, shallow wells have encountered small amounts of gas. It is probable that this gas is of volcanic origin and is in no way connected with petroleum deposits.

There is no possibility of finding oil in the lavas, Tuscan Tuff, or Bedrock series. Apparently neither the Chico nor the Ione contain beds that would form oil, or structure favorable for its accumulation. While there have been occasional reports of seepages of gas and petroleum from this district, no authentic evidence of any oil or petroleum gas has been found.

CHAPTER VII.

AREA OF THE COAST RANGES FROM SAN FRANCISCO BAY AS FAR SOUTH AS THE PAJARO RIVER.

(Includes the counties of Contra Costa, Alameda, San Francisco, San Mateo, Santa Clara and Santa Cruz.)

The oil possibilities of this area will be discussed by counties.

Contra Costa County.

The southwestern one-third of the county has been mapped in detail by Lawson.[1] The Departments of Geology and Paleontology of the University of California have carried on extensive investigations in the northern portions of the county and in the territory around Mount Diablo. Perhaps no other part of the Coast Ranges has been so well studied. Therefore no detailed geology will be given here.

The strata exposed constitute a nearly complete section of the Coast Range formations from the Franciscan to the recent. Structurally these beds have been sharply tilted, folded and faulted into a large number of more or less independent geological areas. This has resulted in preventing any one formation from being continuous over a large area, which is an unfavorable condition for the accumulation of petroleum.

Those formations within the county which contain beds that might form oil, consist of an area of Chico shales on the north side of Mount Diablo; a small area of middle Eocene organic shales (Meganos) in the vicinity of Mount Diablo and finally an area of Monterey diatomaceous shale in the San Pablo and Rodeo valleys just east of the Berkeley Hills. However, none of these organic shale beds are continuous over a sufficiently large area to form any great amount of oil.

Indications of petroleum are found along the north side of Mount Diablo, about seven miles due south of Antioch; and in the San Pablo Valley, east of the Berkeley Hills.

The Mount Diablo indications consist of small intermittent seeps of light green oil, found in the vicinity of Oil Canyon, Long Valley and Deer Valley. Roughly, the territory embraced by the seepages and wells that have found small showings consist of Secs. 13, 14, 15 and 23, T. 1 N., R. 1 E. The formations exposed consist of beds of sandstone and shale of the Chico, dipping in a monocline of about 65° to the north. Beds of Eocene age overlie the Chico along the ridge north of Oil Canyon. Prospecting for oil in this district was first started in 1864, when several wells were drilled in either Sec. 13 or 14 to a depth of about 300 feet and encountered slight showings of green oil. In 1900 another attempt was made and several more wells were sunk to shallow depths and obtained small showings. The last well was drilled by the Atlas Development Company in 1918 on Oil Creek, in the SE¼ of Sec. 15, T. 1 N., R. 1 E. A depth of 1823 feet was reached and as no showings of oil were encountered the well was abandoned.

[1] U. S. Geological Survey. San Francisco folio 193. By A. C. Lawson.

About 1500 feet up the canyon and due east along the strike of the formation from the Atlas well, is an old hole known as the Harding well. This was drilled to a depth of 978 feet and encountered green oil from 950 to 978 feet. It is now used as a water well and shows about 1 quart of green oil per day. There is no reason to believe that future drilling in this region would show any better results than the former attempts.

Indications in the San Pablo Valley consist of seepages of heavy black asphaltic oil found in the vicinity of Lauterwasser Creek and in the lower end of the valley about 2 miles east of the town of San Pablo. A detailed geological map of this territory can be found in folio 193[1] and Arnold gives a brief description of the geology and development in Bulletin 304.[2]

The structure in the vicinity of Lauterwasser Creek consists of a rather sharply folded anticline plunging to the southeast and truncated at the northwest end by a fault. The oil has collected in the sandy beds of the Orinda formation (Pliocene), having been formed in the underlying diatomaceous shale beds of the Monterey series, which at this point are about 300 feet thick.

Beginning in 1889 and continuing up to 1900, eight wells were drilled on this structure, the depths ranging from 500 to 2700 feet, all encountered showings of oil and gas, but none showed sufficient quantities to be of commercial value. At the lower end of the San Pablo Valley about three miles east of the town of San Pablo, five wells were drilled to 1900 feet along a syncline in the Orinda formation. Slight showings of oil were encountered, but nothing of commercial value was developed. The oil has apparently collected in the sands of the Orinda formations from the Monterey diatomaceous shale, which outcrops to the east on Sobrante Ridge. Neither the geological conditions nor the results of wells drilled warrant any further attempts at development in this area.

Alameda County.

The northwestern portion of the county[3] and the area around Tesla and Altamont[4] have been mapped by the United States Geological Survey.

The formations exposed within the county consist of Franciscan, Cretaceous and a nearly complete section of the Tertiary sedimentaries, together with numerous lava flows of Pliocene age. The Franciscan is found in the extreme southeast corner of the county and in a long narrow strip along the west side of the Berkeley and San Leandro hills. It also is probably present beneath the alluvium of the flats that border the east side of San Francisco Bay. The Cretaceous, consisting of typical Knoxville shales and Chico sandstones, is found overlying the Franciscan in a rather broad area near the top of the western slope of the Berkeley and San Leandro hills. Other areas of Cretaceous are found in the hills south of Livermore and in the vicinity of Altamont and Tesla.

[1]United States Geological Survey folio 193. By A. C. Lawson.

[2]R. Arnold. Miner Ranch Oil Field. Bulletin 304. U. S. Geological Survey, 1907. Pages 339–342.

[3]San Francisco folio 193. By A. C. Lawson.

[4]Bulletin 603. By Anderson and Pack.

The Tertiary in the western portion of the county consists of the Monterey series, together with the Pliocene sedimentaries and lava flows. In the eastern portions there are outcrops of Eocene, upper Miocene and Pliocene beds. The Monterey series in the Berkeley and San Leandro hills contains diatomaceous shale but not in sufficient quantities to form any noticeable quantities of petroleum.

The only indication of oil in the county is found in the vicinity of Tesla. There are seepages of light-gravity oil in sandy beds of Miocene age. The seeps are best exposed on the Hamilton Ranch in the vicinity of Sec. 15, T. 3 S., R. 3 E. It is very probable that the oil was formed in the underlying Chico and migrated into the sandy beds of the Miocene. The Chico in this vicinity is known as the Moreno formations and consist of purplish shales containing organic material. It is best exposed along the south side of Corral Hollow, between Tesla and Carnegie. Altogether seven wells have been drilled in this area, five on Sec. 15, T. 3 S., R. 3 E., and two by the Standard Oil Company, near Altamont. The wells on Sec. 15 reported small showings of light oil, those at Altamont obtained no indications. In 1914 C. A. Waring[1] wrote a brief description of this area and in 1915 R. Anderson and R. Pack made a detailed survey,[2] giving a complete description of the geology, development and possibilities, together with an areal map. Anderson and Pack's conclusions are as follows:

"In conclusion, it may be said that the probability of obtaining a large quantity of oil in the Tesla district is remote, but that wells producing a little light-gravity oil may possibly be obtained in very small areas. Such wells may derive their oil either from sandy beds in the Cretaceous or from the lower beds of the unconformably overlying Tertiary, the latter offering the better chances. The areas which offer some inducements for drilling are a narrow strip along the south flank of the anticline which trends east through the hills north of Tesla, where the dip of the beds steepens abruptly, and an area of low dips at the east end of that anticline, where the surface is formed by the slightly dipping undifferentiated Miocene and San Pablo formations. Outside of these two areas the possibility of obtaining oil seems very poor, and the writers believe that drilling in other localities will prove a waste of money."

San Francisco County.

The county of San Francisco is covered entirely by beds of sandstone and chert, together with intrusive masses of serpentine and basalt, all of the Franciscan formation, and offering no possibility of producing oil.

San Mateo County.

The geology of the county has been described and mapped in detail by Lawson[3] and Branner.[4]

The area north of Halfmoon Bay may be considered as offering no possibilities for oil, the formations consist for the most part of the Franciscan, together with a granite area in the vicinity of Montara Mountain. The only area of Tertiary sedimentary consists of a narrow strip of Merced (Pliocene), running southeast from a point on the coast near the San Francisco County line to Milbrae on the bay side and a small area of Martinez (Eocene) in the San Pablo Valley.

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[1]Bulletin 69. California State Mining Bureau, 1914. Pages 439–440.

[2]U. S. Geological Survey. Bulletin 603. By R. Anderson and R. W. Pack, 1915. Pages 186–194.

[3]U. S. Geological Survey. San Francisco folio 193. By A. C. Lawson.

[4]U. S. Geological Survey. Santa Cruz folio 163. By J. C. Branner.

In the area south of Halfmoon Bay, while there are numerous evidences of petroleum, the structural conditions are not favorable for the accumulation in large amounts, there being an absence of any closed anticlines in the Purisima beds, which are the containers of the oil.

The oil has been formed in the Monterey shale beds and has migrated to the overlying porous beds of the Purisima formation. The oil averages about 48° in gravity and is of an asphaltic base. The reason for this light gravity oil of an asphaltic base in beds on an unsealed monocline, may be explained by the fact that the basal beds of the Monterey shale have been intruded by basaltic and diabase dikes. These igneous dikes have undoubtedly caused destructive distillation of the oil, with the result that a heavy residuum is found near the intrusion and the lighter constituents are found in the overlying Purisima beds.

The principal seepages are found along Purisima Creek, Lobitos Creek and Tunitas Creek and are in beds of the Purisima formation. There are also several seeps on branches of San Gregorio Creek. On Purisima Creek, fourteen wells have been drilled since 1880. Seven of these are reported to have obtained production varying from ten to thirty barrels. At the present time three wells are producing, yielding about one barrel per well per day of 50° oil. These are known as the T. B. Wilkensen wells. The average depth is about 700 feet and they have been drilled entirely in the Purisima beds, on a west dipping monocline of about 30°.

The same conditions exist on Tunitas Creek, where seven wells have been drilled, all reporting small showings. A distillation of the oil shows it runs 70 per cent gasoline.

The possibilities may be summed up by saying that in the area down the dip from the seepages mentioned above, small wells of light oil can probably be obtained, whether these would be sufficiently large to be of commercial value can only be told by actual drilling. Any development work should be guided by the geological conditions as shown in U. S. G. S. folio 163.

Santa Clara County.

The topographic features of Santa Clara County consist of the Santa Clara Valley running north and south through the center of the county, with the Santa Cruz Mountains bordering it on the west and the Diablo Range on the east.

The southwestern portion of the county has been mapped by the U. S. Geological Survey.[1]

The formations of the Diablo Range within this area consist mainly of Franciscan beds. On the western edge of the range, east of San Jose and the Mission San Jose, there are outcrops of Cretaceous and Tertiary which may underly the Santa Clara Valley at this point. The valley proper is covered with recent alluvium. On the western edge of the valley, the Santa Clara formation (upper Pliocene) consisting of sands and gravels and clays, is found outcropping. Beneath the

[1]U. S. Geological Survey. Santa Cruz folio 163. By J. C. Branner.

Santa Clara and forming the core of the Santa Cruz Mountains at this point are beds of the Franciscan formation. Along the western edge of the county which is practically parallel to the top of the western slope of the Santa Cruz Range, is a long narrow belt of Tertiary running the entire length of the county. The northern portion of this belt is made up of Oligocene, Vaqueros and Monterey beds. South of Loma Prieta, it consists mainly of Monterey shale, which continues as far south as the Pajaro River, where it turns east, crosses the range and finally dips under the Pliocene beds of the Santa Clara Valley at Sargent.

Oil indications within the county are limited to the following areas: (1) Moody Gulch. (2) Los Gatos. (3) Sargent.

(1) Moody Gulch is in a westerly branch of Los Gatos Creek about two miles south of Alma. The gulch may be entered from the main county road from Santa Cruz to Los Gatos. Fig. 5 shows the general structure of the region and the formations that outcrop. The oil probably formed in the diatomaceous shales of the Monterey and then by reason of the fault contact has migrated into the porous sands of the Vaqueros and San Lorenzo formation. Drilling was first started here in 1880 and all together about 85,000 barrels of oil have been shipped from the Gulch. The wells drilled number about 16, and the average depth is about 1200 feet. The gravity of the oil is 45° Baumé. The reported yield from the old wells varies from ten to forty barrels. Operations ceased about 1910, but recently the Trigonia Oil Co. has taken over the property containing the old Logan and Moody wells and is starting up operations again. The conditions that exist in the Gulch probably extend for a mile or so both to the northwest and southeast. It is probable that with careful management the area around the Gulch could be made to produce small wells of commercial value.

(2) Los Gatos. Following is a report by C. A. Waring[1] of this region:

"The Santa Clara Valley region east of Los Gatos is covered with alluvial gravel, sand and soil so that the underlying formations are completely concealed. From wells drilled in the region it is evident that this land is underlain by rocks of the Monterey series which carry some oil.

"Drilling for oil has been carried on near the reservoir of the San Jose Water Company, on the San Jose road two miles northeast of Los Gatos. Oil indications were first noticed on the ranch of Mr. R. C. McPherson in an 85-foot well.

"Four wells have been drilled in the locality. At two of these the rigs are still standing but no operations are at present being carried on. In a 1600-foot well back of the barn on the property of Mrs. H. H. Main, gas may be seen bubbling through oil which fills the casing. Some oil is said to have been bailed from this well for use as fuel by the owners. A well on the south side of San Jose road is said to have been drilled 2530 feet deep, and to have pierced three oil strata."

In 1918 the Traders Oil Company drilled two wells, but failed to obtain a commercial production. Well No. 1 was drilled on the McGrath Ranch to a depth of 2000 feet and well No. 2 was located on the San Jose road near Walker avenue and reached a depth of 2675 feet.

As stated above, it is probable that the region is underlaid by Monterey shale containing a little oil, but the presence of Franciscan rock on both sides of the valley restricts the shale to such a small area that production on a commercial scale is doubtful.

[1]State Mining Bureau. Bulletin 69, 1914, page 470.

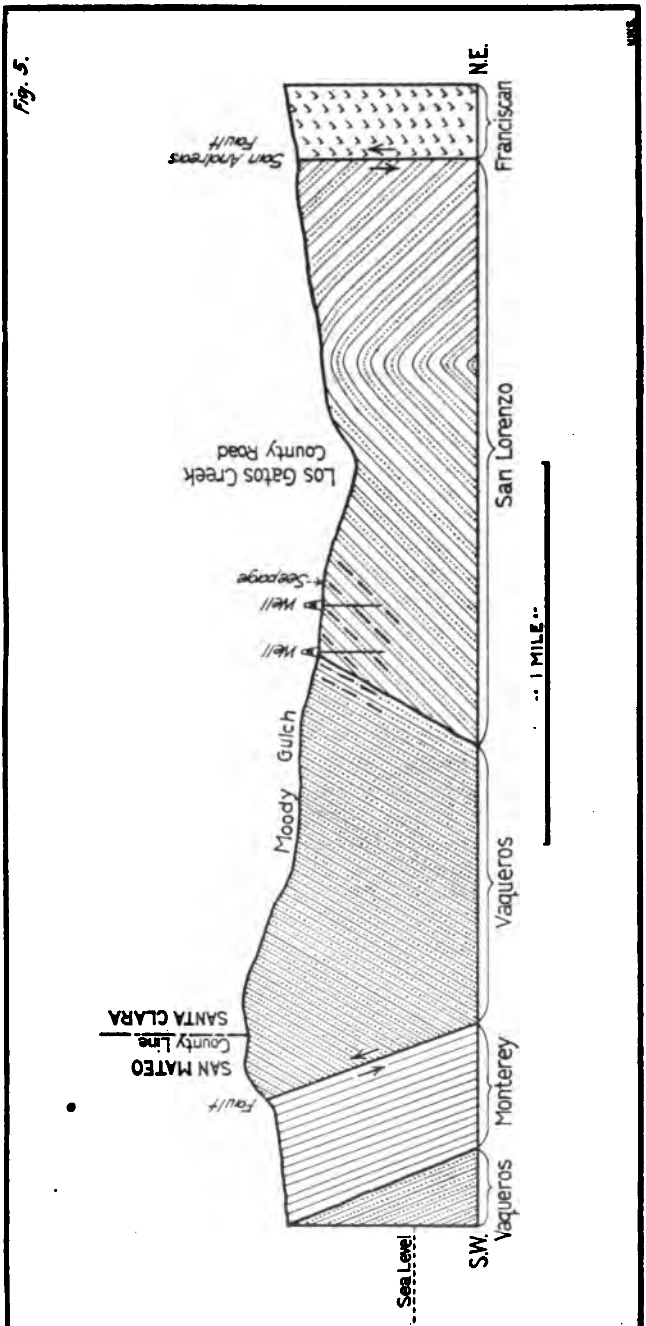

FIG. 5. Section up Moody Gulch, Santa Clara County.

(3) The Sargent Ranch field lies approximately in T. 11 S., R. 3 and 4 E., about three miles west of the railroad station of Sargent. The principal development has taken place along La Brea Creek. The formations outcropping are the Franciscan, Monterey sandstone and shale and Pliocene sands and clays. The oil originated in the diatomaceous shales of the Monterey and has collected in sandstone beds of the same formation. The Franciscan is found outcropping on the hills to the north of La Brea Creek and is overlaid by the Monterey formation which lies in the form of a crescent dipping at about 45° to the southeast. Westward the Monterey continues as far as a mile west of the Santa Clara-Santa Cruz County boundary, where it is truncated by the San Andreas fault. In its southward extension it is terminated by a fault along the Pajaro River. On the lower portion of La Brea Creek and in the hills just west of Sargent, the Monterey dips under the sandstones and shales of the Purisima. These later beds are dipping at an angle of 45° to the south. In the Lomas Muertas, south and east of Sargent, there are beds of sand and clay probably of upper Pliocene age. The axis of a small anticline runs southeast up the canyon just east of Sargent Station and finally flattens out into an east dip which is the general inclination of the strata in the Lomas Muertas. There have been about twenty wells drilled along La Brea Creek, all obtained a showing of oil. Those which have produced on a commercial scale are located about two miles up the creek from the state highway. The average depth is about 1500 feet and the oil is obtained from sandstone beds on a monocline in the Monterey. The gravity averages about 18° Baumé.

At the present time the Watsonville Oil Company is operating nine wells with a total production of 75 barrels per day, which is apparently the maximum yield of the field. On Pescadero Creek and near Chittenden, a number of shallow wells were drilled obtaining small showings of heavy oil. Due to the fault contacts on the west and south and the serpentine contact on the north, there is no hope of extending the field in those directions. On the east the oil-bearing sand of the Monterey dips so steeply under the Pliocene beds, that the chance that they would be within reach of the drill is doubtful. On the axis of the anticline just east of Sargent in the Lomas Muertas (San Benito County) there is a possibility that these beds may be reached by drilling. The Shell Company is at the present time drilling a prospect well here.

Santa Cruz County.

The area lying north and west of the town of Santa Cruz has been mapped in detail by the U. S. Geological Survey,[1] and it is in this portion of the county that the principal indications of petroleum occur. Briefly, the geology is as follows:

In the area around Ben Lomond Mountain, running from Little Basin to the town of Santa Cruz, the formations consist of granitic rocks, together with areas of ancient crystalline schists. In the region to the north of this crystalline area there are outcrops of the San

[1]U. S. Geological Survey. Santa Cruz folio 163. By J. C. Branner.

Lorenzo formations, the Vaqueros sandstone and the diatomaceous shale of the Monterey. These have been all sharply folded and faulted. The Monterey contains numerous seepages, but there is an almost total lack of an overlying formation which could act as a reservoir. This, together with the unfavorable structural conditions, make the possibility of obtaining oil in paying quantities in this area remote. In some cases, by reason of faulting, the oil has migrated from the Monterey into the underlying beds of the Vaqueros and San Lorenzo. It is probable that wells drilled in this area in either the Monterey, or the underlying Tertiary beds will encounter small showings of oil, but not of sufficient size to be of commercial importance.

In the area between Ben Lomond Mountain and the coast, the Vaqueros and Monterey lies in a monocline, dipping about 25° to the southwest. The Monterey is heavily bituminized and has been extensively quarried for asphaltum. This feature has been covered in a report by Eldridge.[1]

The lack of reservoir formations above the Monterey and the general monoclinal structure are not favorable conditions for the accumulations of any commercial quantities of oil in this area.

The remainder of the county which embraces the district lying between Santa Cruz and Watsonville and southwest of the Santa Cruz Mountains, may be likened to a coastal plain. In the country north of Aptos this likeness is not generally apparent, as the hills frequently rise to a height of 1500 to 1800 feet. Between Aptos and Watsonville, however, the county is characterized by low rolling hills, varying in elevation from 100 to 500 feet. The northeast boundary is marked by the steep escarpment of the west side of the Santa Cruz Mountains, formed by the San Andreas fault. The greater portion of the district is covered by loose incoherent sands and clay, varying in color from yellow to brown and having no distinctive strike or dip. The age is not definitely known, but very probably they belong to the Merced formation (upper Pliocene). With the exception of an area about three miles northeast of Watsonville (which will be discussed below) no distinctive structure could be made out in these beds. Near the town of Santa Cruz, the Monterey shale apparently dips under the Merced beds and very probably it underlies this entire area. Between the San Andreas fault and the Santa Clara County line, is an area of Monterey shale, referred to in the article on Santa Clara County. The shale apparently lies in a synclinal trough; the eastern limb resting on the Franciscan; the axis of the syncline approximately coinciding with the county line and the west limb is faulted against the Merced beds by the San Andreas fault.

On the Mount Madonna road, about four miles north of Watsonville and about one-half mile south of the Casserly school, is the axis of a small anticline in the Merced beds, the west limb of which is sharply compressed against the Monterey shales by the San Andreas fault. It

[1]Twenty-second annual report of the U. S. Geological Survey.—The Asphalt and Bituminous Rock Deposits of the United States. By G. H. Eldridge. 1901. Pages 381–407.

is in this area that the indications of oil occur. On the Webb Ranch, it is reported that two shallow wells were drilled and obtained gas. In the canyon just back of the ranch house there is apparently a dry seepage of black oil. On the Hughes Ranch, one well was drilled up the canyon just back of the house. A depth of 700 feet was reached and considerable gas was encountered. At the present time the Cymric Oil Company is drilling a well at this location. This area may be considered as worthy of being tested. As regards the remainder of the area under discussion it is worthy of being thoroughly investigated for structure before being condemned. It is apparently underlaid by bituminous shales of the Monterey and should detailed mapping reveal any favorable structure in the Merced beds, the locality would be worth testing.

CHAPTER VIII.

Coast Ranges from the Pajaro River as Far South as the Santa Maria River.

(Includes the counties of San Benito, Monterey and San Luis Obispo.)

San Benito County.

San Benito County occupies a nearly rectangular area in the heart of the Middle Coast Ranges. The length running north and south is about 66 miles and the width east and west is approximately 24 miles. The western portion is occupied by the Gavilan Range. The San Benito and Tres Pinos Valleys run through the center of the county for almost its entire length. The eastern portion is occupied by the Diablo Range. With the exception of the flat plain-like area north of Hollister and the narrow valleys of the Tres Pinos and San Benito Rivers, the county may be regarded as mountainous. In the Diablo Range the Vallecitos forms a rather high structural valley near the southeastern portion of the county. The Panoche River cuts through the range about the middle of the eastern boundary, draining into the San Joaquin and forming the Panoche Valley.

The general geology of the county is as follows: The Gavilan Range is composed of ancient crystalline schist and limestone, together with associated granitic rocks, all known as the Santa Lucia Series (Paleozoic). The northern portion of the Diablo Range within the county, embracing roughly the area east of Tres Pinos Creek and north of the Panoche Valley is composed of rocks of the Franciscan formation. The Franciscan is also present in the extreme southeastern portions of the county, in the vicinity of the New Idria mine. By the nature of the formations these areas may be considered as impossible for oil.

The sedimentary rocks are found as follows: (1) In the area between Hollister and the Lomas Muertas. (2) In the Tres Pinos, San Benito and Santa Ana Valleys. (3) In the Diablo Range south of Panoche Valley, and finally in the extreme southwestern portion of the county.

1. *Area between Hollister and the Lomas Muertas.*

In the area north of Hollister the exposures consist of sands and gravels probably of Pliocene age. In the Lomas Muertas, which are a low range of hills, just east of Sargent station, the beds exposed consist of fine clays and sandy shales, also probably of Pliocene age. As stated in the article on the Sargent Field (Chapter VII), the bituminous shales and sands of the Monterey, dip under these Pliocene beds and are probably present in the Lomas Muertas. Whether they would be within the reach of the drill in the area under consideration is doubtful. The axis of a small anticline runs southeast up the canyon just east of Sargent station. The Shell Company of California is at the present time drilling a prospect well here and the results obtained in this well should either prove or disprove the district.

2. *Area of the Upper San Benito, Tres Pinos and Santa Ana Valleys.*

In the area between Hollister and San Benito, including the San Benito, Tres Pinos and Santa Ana Valleys, the formations exposed consist of sandstone and shales of the Chico; massive brown sandstones of the Vaqueros formation; light grey sandstones and clays of the Santa Margarita; sands, gravels and clays of the upper Pliocene. These formations have been sharply folded, faulted and compressed into an area between the Gavilan and Diablo Ranges of ten miles in width and about 30 miles in length. Section AB, Fig. 6, shows the general structure and relationship of the formations in the vicinity of Tres Pinos. This area may be considered as unfavorable for oil for the following reasons: (1) No evidence that any of the formations contain organic shale beds. (2) No evidences of petroleum such as seepages, although the formations have been faulted so that if the bed contained oil, it would be free to run out. (3) The narrow area occupied by the sedimentaries is too small to allow any appreciable collection of oil even if the beds did contain it. There has been no drilling in this region.

3. *Diablo Range South of Panoche Valley.*

The Diablo Range from the Panoche Valley south has been thoroughly mapped in detail by the U. S. Geological Survey, so no detailed geology will be given herein.

The only localities in this area that show the slightest indication of oil are the Vallecitos and Ciervo Districts. The following is a portion of Anderson and Pack's[1] report on these two districts. Section CD, Fig. 6 (adapted from the report), shows the general structure and relationship of the formations in the two districts:

"**Vallecitos District. General Features.**

"The Vallecitos offers an excellent example of a completely inclosed synclinal basin. The topography roughly reflects the structure, so that it is at once a structural and topographic basin. The valley is a little over 10 miles long from east-southeast to west-northwest (not including the valley of Pimental Creek on the west, which is really a continuation of it) and has an average width of about 2 miles between the bases of the steeper hill slopes bounding it. It is divided into an eastern and a western part by a low drainage divide and is drained by two intermittent streams that have cut deep canyons northward across the structure at either end of the valley. The two divisions of the basin account for the name, which means 'the little valleys.' The structural trough is produced by the Cretaceous and Tertiary formations dipping rather steeply southward on the north side and even more steeply northward on the south side, the axis of the trough corresponding approximately to the bottom of the valley. On the east the trough is closed where the beds circle around the end of the valley east of San Carlos Creek and dip at a moderate angle westward. Toward the west end the sides of the trough gradually steepen, but the syncline continues up the valley of Pimental Creek.

"The formations involved in this syncline are as follows: (a) The Panoche formation, mildly concretionary sandstone, which forms the main mass of the Griswold Hills, on the north, and appears on the main ridge of the Diablo Range, to the south; (b) The Moreno formation, which on the north occurs along a belt of extremely variable width and in places hardly traceable and which owing to faulting is not recognizable with certainty in the western portion of the southern flank; (c) The Martinez (?) formation, of mingled concretionary sandstone and clay shale, which is so much like some of the other formations that its identification and delimitation are in many places difficult; (d) The Tejon formation, mostly of white sandstone and only locally traceable; (e) The Kreyenhagen shale, soft white diatomaceous shale, and hard siliceous shale occurring pretty continuously on both flanks; (f) The Vaqueros (lower Miocene), which encircles the valley and forms the steep sandstone hills bordering the lower slopes; and (g) the Jacalitos and Etchegoin formations composed largely of black, red and green clays with interbedded sand and gravels, representing the later Miocene and occupying the core of the syncline. Descriptions of the thickness, distribution and composition of these formations will be found in

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[1]U. S. Geological Survey. Bulletin 603. Anderson and Pack, 1915.

the separate sections of this report devoted to them. Of these formations those of chief importance with relation to oil are, as in the Coalinga district, the diatomaceous shales of the Moreno and the Kreyenhagen and the sandy beds overlying them. Seeps occur in the Moreno north of the west end of the Vallecitos and in supposedly equivalent beds in Mancillas Canyon south of the valley. (See p. 123). Seeps and indications of oil occur in the Kreyenhagen shale at numerous places along the south flank of the syncline and also at its east end. In addition surface indications of oil occur locally in the Vaqueros and at one place in the clays of the Jacalitos and Etchegoin formations. It is therefore evident that petroleum is present and pretty well distributed along the flanks of this fold, and the main question to decide is as to the amount that may be recoverable. In order to discuss the conditions and the evidence bearing on this point somewhat more in detail, the district will be divided into two parts—the steeply tilted south flank of the fold and the similarly steep north flank which merges with the more gently tilted east end of the syncline. For a more detailed discussion of the surface evidences of oil the reader is referred to the previous section of this report dealing with the seeps and other indications offered by the various formations. (pp. 123–136).

"South Flank of the Vallecitos Syncline.

"Along the south side of the Vallecitos the mountains and descending ridges are formed by a continuous monocline dipping steeply toward the valley. This monocline is the southern flank of the Vallecitos syncline. From San Carlos Creek, at the east end of the Vallecitos, it strikes westward for about 5 miles and then bends at an angle of about 35° and strikes northwestward to the west end of the valley. Beyond that place the same steep monocline continues in a similar direction along the south side of the valley of Pimental Creek. The area of chief interest in the present connection is the belt of Tertiary strata at the outer edge of the foothills. These beds consist of the Kreyenhagen shale and the sandstone and shale of the Vaqueros formation at the edge of the hills, overlain by the thick variegated clay of the Jacalitos and Etchegoin formations.

"The dip of the Vaqueros and older beds varies from about 40° to the vertical. For much of the way the formations are overturned along the front of the hills and appear to dip southward. The overturning, however, is not believed to extend very far below the surface. The overlying Jacalitos and Etchegoin formations are likewise steep along their contact with the Vaqueros, standing vertically in places and nowhere dipping less than 30°. The dip decreases, however, northward toward the axis of the Vallecitos syncline.

"The Kreyenhagen shale and the Vaqueros are oily practically throughout their extent along the south side of the Vallecitos, the siliceous diatomaceous shale of the Kreyenhagen and similar material interbedded with the Vaqueros being impregnated with oil, so that at almost any point when broken they give off an odor of petroleum. The sandy strata of the Vaqueros likewise are locally impregnated where in contact with the shales. At a number of places where the beds are traversed by gullies, the oil oozes out of them, and several wells have been drilled near by on the strength of these apparently promising indications. Among such seeps and wells the following may be mentioned: In the canyon of the Hamiltonian well, 1¾ miles south of John Ashurst's place, north of the center of Sec. 24, T. 17 S., R. 11 E., oil rises to the surface out of the overturned and broken strata near the contact between the sandstone of the Martinez (?) formation and the white sandstone of the Tejon. It doubtless has its source in the Kreyenhagen shale, which owing to the local overturn, here underlies the relatively thin Tejon formation. The Hamiltonian well was drilled without success about 1500 feet down into the stratigraphically underlying but owing to the overturn apparently overlying sandstone beds of the Martinez (?). Another seep occurs in the Kreyenhagen shale in the creek bed in the SE¼ Sec. 16 of the same township. No wells have been drilled here. A third locality is in the canyon of the San Carlos well near the center of Sec. 8. There and in the next small canyon to the northwest oil seeps out of the same belt of shale and also appears abundantly, impregnating the sandstone and shale of the Vaqueros formation throughout their thickness. Still another seep appears at the summit of the Kreyenhagen shale in a canyon at the west side of the SE¼ Sec. 6.

"The San Carlos well was drilled by hand to a depth of approximately 170 feet in the oily Kreyenhagen shale about 20 years ago and gave the region some notoriety. When bailed dry the well will fill with oil in the course of a few hours. In this way it was estimated originally that it might produce from 1 to 5 barrels of oil a day, but its capacity has never been tested and it is very doubtful if it would continue to fill as rapidly after the bailing process was continued for a short time The oil is of light gravity and very good quality. The Riley well was drilled nearly a half mile north of the San Carlos well in the same section a number of years ago. It started near the top of the steeply dipping Vaqueros formation and went down for 1200 to 1500 feet without reaching the base of the formation and without finding oil. It did not afford a test of the area.

"In the summer of 1912 a well called the Snelling well was started about 200 feet northeast of the old San Carlos well. It begins in heavy sandstone beds that are believed to be at the very base of the Miocene series. The monocline here dips approximately 50° N. When visited at the end of September, 1912, the well had reached a depth of 800 feet through the underlying siliceous Kreyenhagen shale At this depth the bailer was bringing up oil in quantities of a few gallons at a time. The oil is of a dark-green color and volatile, soon losing some of its lighter constituents on exposure. An analysis of the oil is given on page 131.

"About two miles northwest of the San Carlos well, in the southern part of Sec. 31, T. 16 S., R. 11 E., a good seep occurs in sandy and gravelly beds interstratified with the clay of the Jacalitos and Etchegoin formations. This seep has already been described (p. 135). At this locality the Ashurst Oil Co. put down two or three wells, the deepest of which was between 600 and 900 feet deep and got a 'showing' of oil and gas at about the horizon of the seep.

"The only other well that was drilled to a depth of more than a few feet along this belt bordering the south side of the Vallecitos was the Calistoga well, drilled many years ago and abandoned. It is said to have gone to a depth of about 1100 feet in the clay of the Jacalitos and Etchegoin formations on the terrace in Sec. 18, T. 17 S., R. 12 E., about a mile southeast of John Ashurst's place, and to have obtained considerable gas. It is not believed to have reached the sands of the Vaqueros formation The Fresno-San Benito well, which was drilled in Mancillas Canyon farther back in the hills, is mentioned on page 166 in connection with the discussion of the Moreno formation The Moreno formation is separated from the Vaqueros formation by a great thickness of deeply inclined strata, and both for this reason and because it is believed to be absent as a result of faulting south of the western half of the Vallecitos it bears little relation to the question of oil occurrence along the south side of this valley and is not discussed here.

"From the foregoing brief account of the wells along the south side of the Vallecitos it will be seen that none of them has afforded a real test of the area. Most of them were placed too near the outcrop of the oil-bearing beds for any large production to be reasonably expected and the better-located ones have not been drilled to a sufficient depth. The possibilities of the area are practically as much in doubt as if these wells had never been drilled. The conclusion reached from the geologic criteria is that the strata stand too steeply for the oil to be retained in very large quantities or for their deeper portions to be accessible to the drill at reasonable depths in more than a very small area. The beds undoubtedly contain petroleum, but the oil seems to have been disseminated and to have risen freely to the surface through a great thickness of strata rather than to have been concentrated in any particular porous stratum and held there. It is likely that wells started at some distance from the outcrop and striking the lower beds of the Vaqueros at a considerable depth would give a small production of oil, especially if a location were chosen where the monocline is not as steep as it is along most of its course. It is the opinion of the writers that although such wells will probably be able to produce oil commercially at some future date, the present cost of production and the present price of oil would not make it profitable. Moreover, it is possible that the porous beds are occupied by water at no very great depth and that most of the oil is near the surface.

"North Flank and East End of the Vallecitos Syncline. General features.

"In considering the north flank of the Vallecitos syncline attention must be given both to the Moreno formation and its associated or contained sands and to the higher oil-bearing zones of the Kreyenhagen and Vaqueros. Although seeps are not so numerous along this side of the valley as along the south side, indications do occur in both the lower and upper zones just mentioned. Along the western part of the north flank the structure is similar to that of the south flank, although the beds do not dip quite as steeply. The general dip of the monocline in the western part is between 40° and 50°, and increases slightly from a point near the axis of the Ciervo anticline outward, so that the Miocene beds dip more steeply than the exposed Moreno and Panoche formations. Toward the east, however, the reverse is the case, and a decline in inclination of the Tertiary beds to angles of 20° and 15° or less brings about a broadening of the northern portion of the synclinal basin. Moreover, the Vaqueros formation laps unconformably over the older strata and dips at an angle of only a few degrees on the summit of the first ridge north of the valley. It would seem that formerly the Vaqueros extended back to the north a considerable distance at this low angle, over the truncated edges of the older strata. Just south of the summit of the ridge bordering the north side of the Vallecitos the Vaqueros formation slopes more steeply beneath the syncline, thus forming a monoclinal flexure on this portion of the north flank. The attitude of the hard sandstone beds of the Vaqueros (lower Miocene) is here represented fairly well by the surface slopes which these beds form. Around the east end of the basin the gentle inclination of the Tertiary beds continues, until they turn rather sharply into the steep southern flank. The surface indications of oil and developments that have taken place will here be described, beginning on the west.

"West Half of North Flank of the Vallecitos.

"No certain evidences of oil have been discovered at the surface in the Kreyenhagen shale or Vaquoros formation along the western part of the northern flank of the Vallecitos syncline, but seeps occur in the Moreno formation and certain wells have obtained oil in small quantities from it. These wells have already been described in connection with the discussion of evidences of oil in the several formations.

"These seeps appear in the upper beds of the Moreno in the canyon of the Union Oil Co's wells west of the stage road to Panoche, which follows down Griswold Canyon. The oil is of dark brown color and is comparatively light and fluid. It emits a pleasant odor, and the seeps resemble in this respect and in general appearance those in the Oil City area in the Coalinga district. In fact, the formation here is the continuation of that at Oil City and the oil has doubtless had the same origin. The structure, however, is somewhat different, for in the Oil City locality the beds have a much lower dip and are folded into an anticline, whereas here they form a steep monocline. The character of the oil is indicated by the fact that at these seeps no large quantity of asphalt has been deposited.

"The analysis of the oil quoted on page 123 shows it to have a specific gravity of 0.9150 to 0.9090 (23° to 24° Baumé) and to be intermediate between a true paraffin and an asphalt oil. In this respect it is like the asphaltic paraffin oil of Oil City. The sample analyzed was not fresh, having stood in an open shallow well for some time; hence it is likely that the oil is of lighter quality when it issues from the rocks. In a personal communication to the writers, Mr. W. W. Orcutt, of the Union Oil Co., stated that the oil obtained in this well (the 'Rebecca,' a dug well about 80 feet deep) was of 0.8433 (36° Baumé) specific gravity, and that about 5 barrels a day of this oil was pumped out with a hand pump for several days in succession. Several wells were drilled in this vicinity to shallow depths many years ago, but the amount of oil obtained was small and the wells were abandoned although a man was kept there to look after the property.

"Below the horizon of the seeps the purple shale is impregnated with oil through a thickness of many hundred feet. The shale is about 1000 feet thick and is oily practically throughout. It contains a number of large lenses of fine-grained gray and yellowish sandstone much like that typical of the concretionary members below and above, and these lenses might be expected to form local reservoirs for the oil at depths. The shale, as usual in rock of this type is crushed and distributed, but the general structure is that of a monocline dipping about 45° S. The concretionary sandstone of the Martinez (?) immediately overlies the shale, and signs of its being slightly impregnated with oil at the very base were noted locally.

"The conditions here are very much the same as in the area of the siliceous shale in the Kreyenhagen and Vaqueros formations on the south side of the valley, already described. It is probable that a small production which might assume economic importance at some future time, in view of the good quality of the oil, would result from drilling operations in the shale of the Moreno formation here, but the prospect does not seem alluring under present conditions. It is not unlikely that oil might be found locally in sandstone lenses entirely sealed within the shale

"There is also the possibility of wells obtaining oil from the lower part of the sandstone that overlies the shale, and if serious drilling operations were to be commenced the logical place to start would seem to be at a point south of the outcrop of the Moreno, where the base of the sandstone and top of the shale would be reached at a depth of at least several hundred feet It is believed, however, that the steep dip, the uniform monoclinal structure, and the dissemination of the oil through so great a thickness of beds preclude the hope that the Moreno and the Martinez (?) formations will be found commercially productive in the near future The area to which these conclusions apply lies in the N½ Sec. 19, the S½ Sec. 18, T. 16 S., R. 11 E., the NE¼ Sec. 24, and the S½ Sec. 13, T. 16 S., R. 10 E. Farther east the purple shale of the Moreno formation is reduced to a thin zone, and in that direction the outcrop of the shale itself does not afford promising territory for the production of even a small amount of oil What possibility there may be in this area farther east for oil gathering from below into the concretionary sandstone overlying the shale can not be forecast, but it is unlikely that any important quantity gathers there. In a westerly direction the area above outlined extends to Griswold Canyon, the western limit of the region studied. The same steep monocline of the Cretaceous and later beds continues westward from Griswold Canyon along the north side of the valley of Pimental Creek.

"As the structure of the Vaqueros formation is very similar to those just described, and as there is no good surface sign of petroleum in it or in the Kreyenhagen shale, the chances for oil in this upper zone appear even slighter than those for oil in the lower zone, along the western half of the north flank of the syncline. At one point about a mile east of Griswold Canyon an oily appearance was observed in the Vaqueros formation and a faint petroleum odor obtained This was just enough to indicate that the slightly petroliferous character of this formation persists this far west. One well—that of the Sussex Oil Co.—was drilled in this region between 1910 and 1912 It is situated near the center of Sec. 30, T. 16 S., R. 11 E. It started in the steeply dipping clay and gravel beds of the Jacalitos and Etchegoin formations and is reported to have been drilled a little deeper than 1800 feet and to have obtained signs of oil and gas before operations were stopped At this depth it had probably reached the middle portion of the Vaqueros, but it could not have gone as far as the base of that formation, which should have been reached in order to make an adequate test.

"It should be noted, as having a possible bearing on the question under discussion, that an intrusion of basalt occurs at one place on the north side of the Vallecitos. It penetrates the formations at least as far up as the summit of the Vaqueros sandstone and shale. The basalt outcrops about two miles north of the divide between the two arms of the Vallecitos, as a small intrusion parallel to the bedding near the contact of the Vaqueros with the overlying Jacalitos and Etchegoin formations. It is the only known evidence of igneous activity later than Jurassic or early Cretaceous in a wide stretch of county south of Panoche Creek and east of Griswold Canyon. Owing to its local nature it is very doubtful if it has seriously affected the oil-bearing character of the beds, except in its immediate vicinity.

"East Half of North Flank of the Vallecitos.

"The problem to be considered in the area along the eastern portion of the north flank and around the east end of the fold differs from that presented by the more westerly area, owing to the lower dip in the Tertiary beds and the presence of signs of oil in them The Moreno and the formation immediately overlying do not assume much importance here, owing to the lack of seeps, as well as to the continuation of the unfavorable structure of the area farther west. Very likely these beds contain a little oil disseminated through them, but unless some as yet unsuspected evidence should be brought to light, it seems foolish to spend money drilling to or into the Moreno formation here.

"Structural conditions, although not highly favorable, suggest that oil may have collected in the Vaqueros, in the northeastern part of the Vallecitos. This formation, moreover, shows undoubted indications of oil. The area has certain points of resemblance to the Westside field, which make it worthy of careful consideration. The Vaqueros formation here is the same formation as that containing the main oil sands of the Coalinga district and consists of similar porous sands. It overlies unconformably the siliceous Kreyenhagen shale, the supposed original source of the oil, just as it does at Coalinga. It lies in a gently dipping monocline on the flank of a syncline, as in the Westside field. It shows at least in one place at the surface signs of petroleum only a little less pronounced than those in the Coalinga field, and it is overlain here, as there, by relatively impervious clay and shale. The main difference from the Westside field is not one of local attitude or character of the beds but involves a consideration of the broader structural relations, which are perhaps of greater importance than the similarities above mentioned and will be discussed in the final paragraph of this section (p. 177), where conclusions regarding the possibility of this area and of the Vallecitos as a whole will be expressed.

"The outcrop of oily sand above referred to occurs on Silver Creek in the basal beds of the Miocene, where they rest on the truncated edges of the slightly more steeply dipping Kreyenhagen shale. The locality is on the northeast edge of the Vallecitos, in the western part of the SW¼ Sec. 5, T. 17 S., R. 12 E., just east of the New Bedford well. The same beds show slight evidences of being oily at other points along the outcrops to the northwest, but not sufficiently so to prove the existence of a considerable petroleum reservoir.

"The Vaqueros contains beds of hard sandstone that may easily be traced along their outcrops, because they form the first high ridge parallel with the Vallecitos on its north side. The formation is 700 or 800 feet thick and consists of a lower zone about 100 feet thick of variable sandy, gravelly, and shaly beds, an overlying zone about 80 feet thick of siliceous diatomaceous shale, and an upper portion over 500 feet thick composed chiefly of sandy strata with some interbedded shale and containing two prominent beds of hard sandstone in its central part, each about 100 feet thick. (See the tabulated section on p. 86.) The lower sandy zone has the thickness and lithologic qualities that would make it an excellent reservoir were oil present in large quantity. Furthermore the overlying flinty shale ought to serve as an impervious cap to prevent the oil from rising into higher beds. The escape of the oil along the bedding planes would be hindered by the lowness of the dip and by the tendency of the oil to seal itself in by the deposition of solid residue near the surface. The monoclinal dip of the Vaqueros formation within about a mile west of Silver Creek is slightly variable, but on the average it is only from 3° to 8° toward the southwest. Locally there is a tendency toward flattening, affording small wrinkles that might be a factor in helping to hold oil. The dip of the monocline is sufficiently low to make the basal portion of the Miocene beds accessible within a reasonable depth, even as far out as the axis of the Vallecitos syncline.

"About 2 miles west of Silver Creek there is an abrupt steepening of dips in the Miocene formations along the edge of the valley to 20°, 30° and finally 45° or more. For several miles beyond the beds preserve a low dip on the very summit of the ridge, but they fold over abruptly into the steep dips on the south side. The steepness of these dips, combined with the lack of evidence of any appreciable quantity of oil in the beds, would seem to leave little basis for expecting them to be commercially productive west of the very small area of low dips at the east end of the north flank, already described.

"Around the east end of The Vallecitos the Tertiary beds are brought to the surface from beneath the valley by the rising end of the syncline and occupy crescent-shaped belts that curve around the end of the valley. The dip of the beds is everywhere toward the valley and varies between 5° and 30°. The structure is not of the most favorable type for the accumulation of oil, and yet it is such that a certain amount of oil would be expected to accumulate if any existed in the beds. The shale of the Vaqueros lies unconformably upon the Kreyenhagen shale, as in the Coalinga field, and if oil were present in the shale, it should rise and collect in the sandy strata overlying its truncated edges, making itself apparent at the outcrop. No seeps or other surface signs of oil were discovered east of San Carlos and Silver Creeks, but this does not prove that they do not exist, for the beds are locally masked by terrace deposits.

"The following wells have been drilled in the area under discussion: The New Bedford Oil Co.'s well, in the NE. ¼ SE. ¼ sec. 6, T. 17 S., R. 12 E.; the Vallecitos Development Co.'s well, in the NE. ¼ sec. 12, T. 17 S., R. 11 E.; and the Range 16 Oil Co.'s well, in the SE. ¼, sec. 3, T. 17 S., R. 11 E. The New Bedford well is situated just west of Silver Creek, near the outcrop of the oil sand above mentioned. It starts in the basal portion of the Vaqueros and passes through the oil sand that outcrops on Silver Creek at a depth of only about 100 feet, but obviously it is too near the outcrop of the oil sand of the Vaqueros to obtain any production from it. Practically the whole depth drilled, which is now reported as more than 3000 feet, has been below the oil zone of the Vaqueros, the zone in which oil should be sought for in this district. At about 1600 feet this well passed through a 6-foot bed of coal in white sand, evidently coal-bearing white sandstone of the Tejon. Oil is said to have been struck at a depth of about 1700 feet, but it has not been possible to substantiate the report. At a depth of 3000 feet, the well should be in the midst of the Martinez (?) formation, which is here very thick. It would probably require a depth of at least 1000 feet more to reach the possibly oil-bearing beds at the top of the Moreno formation.

"The well of the Vallecitos Development Co. was started in 1910 on the terrace a mile north of John Ashurst's place. It started in the lower beds of the Jacalitos and Etchegoin formations, where the synclinal flank has a low dip, and was excellently placed to test the possibilities of the zone at the base of the Vaqueros. Definite information regarding the results obtained are not available, but the well is reported to have gone to a depth of over 2,000 feet, or entirely through the Vaqueros, and to have found some oil at the base of this formation. The tools brought up from the bottom were said to be covered with oil. From the fact that the well was practically abandoned in 1911 the writers infer that it did not prove a success.

"The Range 16 Oil Company's well is situated over two miles farther northwest and starts in the midst of the Jacalitos and Etchegoin formations, on a part of the synclinal flank where the dip is steeper than farther east. It was drilled in 1910-11 to a depth of 2300 feet, without obtaining oil in any important quantity. At this depth the well must have nearly if not quite reached the base of the Miocene series.

"Conclusions Regarding the Vallecitos District.

"Considering only the evidence obtainable from a surface study, the area described in the paragraphs just preceding—that is, the east end of the north flank and the curving east end of the syncline—seems a fairly promising place to search for oil and the most promising portion of the Vallecitos district. The amount of oil that comes to the surface at various points in The Vallecitos, and the resemblance of the structure in the east end of the valley to that of the Westside field, make it not unreasonable to suppose that oil may have collected here in fairly good quantity. This conclusion was expressed in the preliminary report on the Cantua-Panoche region.[1] That report was prepared before any wells had been started to test the sands in the Vaqueros formation at the east end of The Vallecitos, and it suggested a small area at that end of the valley as offering a reasonable location for the drilling of a test well. Such a test has subsequently been made by the well of the Vallecitos Development Co. before mentioned, and, although it has not been possible to ascertain definitely the results obtained in this well, numerous indications point to its having been a failure. The writers believe it likely that below the surface the Vaqueros formation does not contain as much oil as one might be led to believe by a comparison of the surface evidences of oil in this region with similar evidences in regions that have been found highly productive. As stated in the preliminary report, the drill alone can determine with certainty whether oil exists in paying quantities in the beds which at the surface show traces of oil. The opinion at present held by the writers is based on the apparently unfavorable evidence afforded on this point by the well previously referred to, and on a more general consideration of the conditions governing oil accumulation along the western border of the San Joaquin Valley or from any other outside territory that might be tributary to its oil and water supply points to the probability that no very important petroleum accumulations are to be looked for in this valley. The writers would not recommend the expenditure of any money in further attempts to obtain paying quantities of petroleum anywhere in the Vallecitos district, until the value of oil has increased or the expense of operating decreased to such a point that risks could be taken for the sake of obtaining occasional very small producing wells.

"Crest and Flanks of the Ciervo Anticline.

"The Ciervo anticline is an oblique offshoot of the main structure of the Diablo Range, similar in type to the Coalinga anticline. It is probable that in the past history of the region, in late Tertiary or early Quaternary time the summit of the anticline was covered throughout areas many square miles in extent by the Tertiary formations and that oil accumulated in large quantities along it. During the course of time, however, the oil-bearing formations, together with their stores of oil, have been worn away from the major portion of the anticline, leaving the underlying unproductive sandstone of the Panoche formation (Upper Cretaceous) exposed in a wide belt on either side of the axis. The only place where beds as young as the lower oil-bearing zone of this region remain over the axis of the fold is at its east end, where it plunges steeply and merges with the monocline of the foothills. At this place it is covered by shale of the Moreno formation, the overlying concretionary sandstone and clay shale of the Martinez (?) formation, and the succeeding Tejon formation. The area embracing this end of the anticline is the one which will be discussed here.

"The structure of this area is similar to that of the plunging end of the Coalinga anticline, which has proved so productive, and the chance for the presence of oil here deserves careful consideration. The most important differences between this area and that on the nose of the Coalinga anticline are as follows: The Ciervo anticline is not so extensive a fold as that at Coalinga. It stops short without reaching the San Joaquin Valley and plunges abruptly without affecting strongly the Tertiary beds of the foothills, whereas the Coalinga fold continues on for many miles into the valley with a perfect cover of Tertiary formations. On the Ciervo fold only one of the shale formations of organic origin (the Moreno, Upper Cretaceous) is present and the evidences of oil in this formation are not pronounced; on the Coalinga anticline the two oil-bearing shale formations are present, and both give at their outcrops unmistakable evidence of their petroliferous character. Moreover, on the Ciervo fold the Moreno formation outcrops just at the point where the fold plunges steeply to its termination, instead of continuing along the axis at a relatively low and constant dip beneath the later formations. These differences are all unfavorable to the Ciervo area when its possibilities of yielding oil are compared with those of the Coalinga fold. They lead to the conclusion that the Ciervo area, if productive at

[1]Anderson, Robert. U. S. Geol. Survey. Bulletin 431. Pp. 76-77, 1910.

all, will be very much less so than the Coalinga anticline. Owing to the limitation as regards possible oil-bearing formations on this fold, the proper comparison to be made is with the Oil City field and with the sands in the Martinez (?) and Tejon formations in the Coalinga district. The result of this comparison is likewise unfavorable to the Ciervo field, and yet there is enough similarity to suggest the possible existence of a commercial quantity of oil here.

"The purple shale of the Moreno formation is exposed in an area of several square miles near the axis of the Ciervo anticline in Secs. 14, 15, 21 and 23, T. 16 S., R. 12 E., and passes beneath later beds along the summit of the fold in the SW¼ Sec. 24, the NW¼ Sec. 25 and the N½ Sec. 26 of the same township. The area near the summit of the fold in which the shale of the Moreno would be within reach of a drill or at a depth of not more than 3000 feet below the surface is approximately outlined by a red line on the geologic map (Pl. 1). Several doubtful factors, such as abrupt variation in thickness of the different formations and uncertainty as to the attitude of the beds, make the drawing of such a line difficult, and it is shown merely for the purpose of giving a rough indication of the more important part of the area here under discussion.

"If any appreciable quantity of oil is present in the Moreno formation the conditions of structure in this area make it probable that productive wells could be obtained by drilling down to included lenses of sand, or to the sandstone beds that overlie the shale.

"Mention has previously been made (in the section dealing with oil indications in the several formations) of the oily sands discovered at certain places in the Moreno formation near the axis of the Ciervo anticline. In addition the shale gives the appearance of having been thoroughly impregnated with petroleum. It is characterized by the blackish-brown discoloration and strong sulphurous odor that seem to result from the presence of oil in shale of this type in many places. The oil sands easily escape notice owing to the weathered nature of the exposures, but the appearance of fresh specimens of the rock leads to the belief that a large part of the formation has previously been and may still be soaked with oil and that a considerable amount of free oil might be found in the beds at greater depth, away from the surface zone of weathering and evaporation. The light oil found in the purple shale at Oil City and at the Union wells, north of the west end of The Vallecitos, which appears to be characteristic of this horizon, is of a type that would not be expected to leave at the surface as marked evidences of its presence as the asphalt oil in the Miocene formations of the Coalinga district and other parts of California.

"If the formation contains as large an amount of oil as is believed, the question remains whether the oil is too widely disseminated through many hundred feet of beds to be obtainable in commercial quantity, or whether some of it has accumulated in reservoirs that may be profitably tapped. There can be no doubt that a large amount has been lost by dissemination through the beds and escape at the surface, as is attested by the prevalence of the oil discoloration throughout the formation. But it is an important fact that thick lenticular beds of porous, fine-grained sand which ought to be good reservoirs are included in the shale, and it is highly probable that much oil has been absorbed by these lenses and retained in them. The lenses are not confined to any particular part of the shale but occur in its upper as well as its lower portion and would be found somewhere within the shale in any section that might be made of it. Some of the lenses attain a thickness of 100 feet or more. The body of oil-bearing beds of which the purplish shale is the chief constituent is likewise overlain by sandy strata in which, it might be expected, oil would accumulate. Wells drilled through the later beds at a considerable distance from the outcrop of the purple shale would probably reach the shale and its included sands at a depth at which the petroleum contents would be sealed in and preserved intact. A good situation for a test well is about 2 miles northwest of Ciervo Mountain.[1]

"The dip of the beds in the Ciervo Mountain region is low and the structure is undulating, and it is not impossible that some of the minor folds might aid in the concentration and confinement of a local body of oil. In this connection it is worthy of note that a number of small faults in the Tertiary formations in this region have not brought to light any oil through seepage; but in the opinion of the writers this fact does not carry great weight as against the favorable conditions mentioned. The conclusion is that the area on and adjacent to the Ciervo anticline offers possibilities that should be tested. It is believed that a well drilled near the summit of the anticline, as sugested, would have a chance of obtaining a light oil in paying quantity, but the risk of failure would be great and the likelihood would be of a small production, if any, being obtained. This much, at least, may be said—that the conditions are much more favorable than those in many places where 'wild-cat' wells are being drilled in California outside of the developed fields.

The Extreme Southwestern Portion of the County.

This area consists of the territory south of the town of San Benito and includes the upper portions of the San Benito Valley and the areas around Toro Creek, Bitterwater Creek and Lewis Creek.

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[1]Since the publication of the above report the Standard Oil Company drilled a well in Sec. 25, T. 16 S., R. 12 E., about 3 miles northwest of Ciervo Mountain and about a mile east of the San Benito County line in Fresno County. A depth of 3869 feet was reached and no indications of oil were encountered.

The dominant structural feature of this region is the San Andreas fault, which runs south along San Benito Creek as far as the town of San Benito where it crosses a low divide into the Rabbit Valley and from there it runs down Bitterwater Creek to its junction with Lewis Creek and then continues southward up Lewis Creek.

East of the San Andreas fault the formations exposed are sands, gravels and clays of the Etchegoin and Jacalitos formations, which rest on the east against the Franciscan. In the fault zone of the San Andreas fault, which averages about one mile in width, the faulting has exposed beds of Franciscan and Cretaceous age, together with masses of granite and ancient crystalline metamorphics. West of the San Andreas fault the formations consist of beds of sand and gravels of the Paso Robles formation with a thickness of about 200 feet. Below the Paso Robles is about 3000 feet of the Santa Margarita formation consisting of beds of medium coarse white sand and about 1000 feet of sandy diatomaceous shale. This shale is found near the bottom of the formation and is the source of the oil found in this area. Along its northwestern edge in the vicinity of the Pinnacles, the Santa Margarita rests against the eroded surface of the crystalline rocks of the Gavilan Range.

An area of granite probably belonging to the batholithic mass of the Gavilan Range, outcrops along San Lorenzo Creek just west of Lonoak and the Santa Margarita sands rest unconformably against its edges.

Indications of petroleum are found in seepages along the San Andreas fault zone in Lewis Creek and at the contact of the Santa Margarita with the granite in the vicinity of Lonoak and San Lorenzo Creek. Apparently on account of unfavorable structure, the oil has tended to collect along faults and at the contacts with the igneous rocks.

The region is apparently unfavorable for the accumulation of petroleum in commercial quantities. This statement is based on the following facts: (1) The structure is unfavorable (See Sec. EF, Fig. 6). (2) The source of the petroleum is the diatomaceous shale of the Santa Margarita, which is too limited in thickness and extent to form much oil. (3) Twenty wells have been drilled in the area and none showed sufficient production to be of commercial value (list of wells is given below.)

The greater portion of the district has been mapped and examined for oil possibilities, both by the State Mining Bureau[1] and the U. S. Geological Survey.[2] The report by the State covers the southwestern part, while that of the Geological Survey practically covers the entire area in detail. Both reports contain a list of the wells drilled, together with areal maps.

Following is a portion of the Geological Survey's report, dealing with the area under discussion, and also including that part of Monterey County east of King City and along the Peachtree and Lewis Creek

[1]California State Mining Bureau. Bull. 69, 1914. Petroleum Industry of California. By R. P. McLaughlin and C. A. Waring. Pp. 418–428, plate IV in folio.

[2]United States Geological Survey. Bull 581-D, 1914. Geology and Oil Prospects of the Waltham, Priest, Bitterwater and Peachtree valleys. By R. W. Pack and W. H. English.

valleys, Sec. EF, Fig. 6 is adapted from this report and shows the general structure:

"Bitterwater and Peachtree Valley and Foothills to the West. Geology.

"West of the San Andreas fault zone the beds mapped as upper Miocene rest directly upon the eroded surface of the granite. In the area shown on the map these beds have a maximum thickness of about 3300 feet and comprise two formations, of which the lower, made up of sand, clay, gravel, and diatomaceous shale and filled with marine fossils, is believed to be the equivalent of the Santa Margarita formation, and the upper, composed of material that was probably laid down in lakes or subaerially, is the equivalent of the Tulare formation. West of Peachtree Valley the upper of the two formations is relatively unimportant, appearing only in isolated areas along the crests of the ridges as a cap less than 200 feet thick. The beds that are comprised in the formation that is considered the equivalent of the Santa Margarita are variable in character, ranging from coarse conglomerate to fine diatomaceous shale, but for the most part are fine grained. Near Lonoak and in Bitterwater Valley the lower 1000+ feet is composed of diatomaceous shale, which forms prominent white outcrops that are especially noticeable about 2 miles northwest of Lonoak postoffice. Shale of this type forms the lower part of the Tertiary along the west side of Bitterwater Valley, in the north end of Mustang Ridge, in small areas near the east corner of the Peachtree ranch, and in much of the Topo ranch northwest of the area mapped. In many other parts of the region, however, sandy or even gravelly beds, such as those exposed near the asphalt quarry west of Lonoak, rest upon the granite. Practically no diatomaceous shale appears resting upon the granite near its exposures in small areas 4 miles southwest of Lonoak. The variability in the lithology of the lower part of the Tertiary is well shown along the north side of San Lorenzo Creek west of the granite that is exposed at the edge of the area mapped. Possible explanations of the variability in the thickness of the diatomaceous shale appear to be (1) that the Tertiary beds were laid down upon a very uneven surface of granite and that in parts of the region the lower beds were not deposited; (2) that the shale actually grades laterally into coarser materials; (3) that the diatomaceous shale is older than the clay and shale and is separated from them by an unconformity. The most probable explanation seems to be that the variability in the thickness of the shale is due both to lateral variation in character and to the uneven surface upon which it rests. Sandy beds intercalated with the diatomaceous shale contain fossils apparently of precisely the same type as those in the overlying sandy beds, and it seems improbable that any considerable time intervened between the deposition of the two divisions. The presence or absence of the diatomaceous shale is of considerable importance, for the seeps of oil appear only in those areas where it has considerable thickness.

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

"Surface Indications of Petroleum.

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

"Oil-saturated sands outcrop at two places near the southeast corner of the Peachtree ranch, in what corresponds to the SE¼ Sec. 22 and the SW¼ Sec. 25, T. 20 S., R. 11 E. At the first-named locality a massive sandstone that stands almost vertical occurs on the west side of an area of much contorted diatomaceous shale. The relationship of the sandstone and shale is not entirely clear, as the rocks are considerably faulted, but the sandstone is believed to be stratigraphically above most or possibly all of the shale. The sandstone is impregnated with heavy oil, which slowly seeps out in the bottom of one of the steep arroyos. About 1¼ miles southeast of this seep a sandstone 50 to 60 feet thick, bedded with the diatomaceous shale that occurs near the base of the Tertiary, is impregnated with oil. This bed appears to be a sandy lens in the upper part of the diatomaceous shale. It lies at the western edge of the San Andreas fault zone, is much fractured, and is truncated on the east by a fault that brings it into contact with the clay in the Tulare formation.

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

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

"Wells Drilled for Oil.

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

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

"The Nonpareil wells were drilled about 13 years ago near the seep where the San Andreas fault crosses Alvarez Creek. Previous to the drilling of the main wells, two wells were drilled by hand, the deeper of which is said to have obtained light-gravity oil at 60 to 70 feet. At the time of the writers' visit it had caved below the 55-foot depth and was dry of oil, although containing considerable gas. Of the three larger wells, No. 1 is said to have reached a depth of 1038 feet without obtaining more than a trace of oil. Well No. 2 was drilled 653 feet and obtained oil between 400 and 520 feet. Oil now stands in the hole, but the well has never produced. Well No. 3 reached a depth of 1300 feet, having been drilled through 'a great mixture of rocks,' but obtained no oil.

"Lonoak well No. 1 was sunk about 2700 feet and is said to have reached granite at that depth without having encountered a trace of oil. Well No. 2 reached a depth of 3009 feet, getting a little tarry oil at 600, 800, and 1800 feet. A few barrels of oil is said to have been pumped.

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

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

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

"The Le Franc well of the Standard Oil Co., at the head of Bitterwater Valley, within a few hundred feet of the San Andreas fault line, was drilled to a depth of more than 2000 feet. It is said to have penetrated considerable oil sand but produced no oil. The fractured condition of the beds here prohibits an estimate of the stratigraphic position of the oil sands penetrated.

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

"The Miller well of the Union Oil Co., near the west edge of the Peachtree ranch, along the road from Peachtree Valley to Salinas Valley was drilled to a depth between 2500 and 2600 feet, but no oil was found.

"Economic Possibilities.

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

"Of the 3000 feet or more of Miocene beds which are infolded in the Peachtree syncline near Lonoak the lower 1000 feet or so is largely diatomaceous shale. This shale is continuous southward but seems to become more sandy in that direction. That the beds associated with the shale contain some oil is shown by the outcropping oil sands in the southeast corner of the Peachtree ranch and by the results obtained in the wells near the mouth of Lewis Creek. However, the writers believe it doubtful that oil has accumulated here in any considerable amount. The syncline is structurally isolated, being bounded sharply on the east by the San Andreas fault zone and on the southwest by the granite and probably by a fault extending along Peachtree Valley. Thus it seems improbable that oil could have collected in this basin from the rocks underlying any very extensive area. Any oil which might have been formed in the beds beneath Salinas Valley would probably not travel eastward beyond the area west of Peachtree Valley, in which the Tertiary beds are wrinkled irregularly. Moreover, except in a small area near the mouth of Lewis Creek, where the beds are slightly domed, the general synclinal structure is not favorable for the collection of petroleum. Even the doming cited is really so slight and lies so close to the badly fractured San Andreas fault zone that it is improbable that oil has collected in it. The wells which have been drilled here have pretty thoroughly tested the area, and it is believed that further drilling, even along the small fold mentioned above, will fail to disclose any extensive accumulations of oil.

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

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

"It seems probable that the first question must receive a negative answer. Seeps of oil and dry oil sands occur not only in the region described but also to the southeast, in the Parkfield region, and at intervals for several miles on the west side of the valley. In other words, the outcrop of the Tertiary rocks on both sides of the basin show evidence of petroleum, and it is reasonable to suppose that the beds in the center of the basin, now covered by alluvium, also contain or at one time contained it. The basin occupied by sedimentary rocks here is, however, of much smaller area than that at the southern end of the San Joaquin Valley; the diatomaceous shale in it is far thinner than that in the Temblor Range and along the east side of the Salinas Valley, is somewhat irregularly developed, owing, in part, to its having been laid down upon a very irregular surface of granite and probably also in part to the fact that it is replaced in some areas by sandy beds. This irregularity is well shown along the San Lorenzo Creek. Near Lonoak the lower 1000 feet or so of the later Miocene is fairly pure diatomaceous shale, but less than 2 miles downstream sand and sandy clay, in lithologic character precisely like the beds overlying the diatomaceous shale near Lonoak, rest directly upon the granite. Also, near the small granite exposures some 4 miles southwest of Lonoak the sedimentary beds are entirely sand and sandy clay. Thus, if the diatomaceous shale is regarded as the ultimate source of the oil it is unreasonable to suppose that so great quantities of oil were formed here as were formed in the southern end of the San Joaquin Valley.

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

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

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

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

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

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

"OUTLYING DISTRICTS.

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

"Topo Ranch.

"The Peachtree syncline continues as a broad, shallow fold northwestward beyond the area shown on the map, passing through the Topo ranch. On the east the syncline is terminated by the San Andreas fault zone and on the west by the granite which here appears at the surface in the Gabilan Range. Along the west side of the syncline the lower part of the Tertiary section consists of chalky white diatomaceous shale having a maximum thickness of not more than 1000 feet. Upon the shale rest a few hundred feet of sandy beds, which constitute both the Santa Margarita and the Tulare formations. The beds for half a mile on either side of the axis of this syncline dip at angles of less than 5° and on the west flank of the fold at angles of less than 10° as far as the granite hills. The Matthews asphalt quarry (see p. 147) is on the west flank of this syncline at the contact between the granite and granite and overlying Tertiary beds.

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

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

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

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

"San Benito River Valley.

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

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

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

"The McMurtry-Hoeppner well, near the west line of Sec. 32, T. 17 S., R. 10 E., is on James Creek, a tributary of San Benito River from the northeast. The well starts in the fossiliferous late Miocene beds and, when visited in November, 1913, had been drilled to a depth of 1462 feet, and had apparently reached the clay and gravel that form the lower part of the upper Miocene. No trace of oil had been obtained."

Monterey County.

Monterey County, lying in the central coast region of the state, borders the Pacific for a distance of about 85 miles and stretches back into the Coast Ranges with an average width of about 45 miles.

The principal topographic features consist of the Santa Lucia Range which borders the coast from Monterey Bay south into San Luis Obispo County, reaching elevations of from 3000 to 6000 feet; the Salinas Valley, which drains the central portion of the county for its entire length; the Gavilan Range which borders the Salinas Valley on the east, from the Pajaro River to a point near King City. South of King City the east side of the Salinas Valley is composed of low rolling hills, which gradually rise to the Temblor Range, along the eastern border of the county.

The county will be divided into the following areas and the oil possibilities of each discussed: (1) Mouth of the Salinas Valley and the district bordering on the Bay of Monterey. (2) Area of the Santa Lucia Mountains. (3) Area of the Gavilan Mountains. (4) Salinas Valley from Salinas to Greenfield. (5) San Antonio Hills. (6) Salinas Valley from Greenfield south to the county line. (7) Area east of the Salinas Valley from King City south to the county line.

Mouth of the Salinas Valley and District Bordering on the Bay of Monterey.

This region may be considered as a coastal plain, consisting of low rolling hills and marsh land and it is continuous with a similar area in the vicinity of Watsonville, Santa Cruz County (Chapter VII).

The surface formations consist of soft, incoherent sands and clays, of a yellow-brown color, probably of Quaternary age. There is no definite evidence as to what underlies these beds, but it is probable that the Vaqueros sandstone and diatomaceous shale of the Monterey are present beneath a portion of the area. Evidence as to this may be found in examining the edges of the district and noting what formations apparently dip under it. On the south edge in the vicinity of Del Monte and Seaside the Monterey shale which forms the foothills of the Santa Lucia Range is dipping to the northeast and apparently disappears beneath the Quaternary sands just southeast of Seaside. From this point east to Salinas, the Quaternary is resting against sands and shales of the Monterey Series. Along the east edge from a point due east of Salinas to a point about three miles southeast of Dumbarton, the Quaternary rests directly on the crystalline rocks of the Gavilan Range. This contact may be seen near the Lagunita School, along the State Highway, from Salinas to San Juan. From the vicinity of Dumbarton north to Aromas on the Pajaro River, the Quaternary is resting against a massive medium to fine-grained yellow sandstone, which weathers into large, bold outcrops. The dip is about 45° to the southwest and thickness about 5000 feet. Four miles due east of Dumbarton the bottom of the formation may be seen resting on the granite. The age is not definitely known, but from the lithology and its relationship to the granite, it can probably be correlated with the Vaqueros sandstone of the Santa Lucia Range.

While the area contains no evidence of petroleum, it has certain possibilities, similar to those of the area around Watsonville. These possibilities are that the sands and diatomaceous shales of the Monterey Series may underlie the area and be folded into favorable structure hidden beneath the Quaternary sand. The area is therefore worthy of being mapped in detail to discover if such conditions actually exist.

Area of the Santa Lucia Mountains.

This district occupies that portion of the county lying south of Monterey and west of the Salinas River. The San Antonio Hills, a detached range of the Santa Lucia Mountains lying between the San Antonio River and the Salinas Valley, will be discussed separately. The major portion of this area is covered by crystalline and metamorphic rocks.

These may be divided into two series. The older, known as the Santa Lucia Series of Paleozioc age, and the younger series belonging to the Franciscan formation (Jurassic). The Santa Lucia Series is found in the north, northeastern and western portions of the area and consists of massive limestones, marbles, schists, granites and gneisses. The Franciscan is found overlying the Santa Lucia in isolated patches along the coast and in a rather broad area south and west of the Nacimiento River. It consists of beds of altered sandstone slates and intrusive serpentine. The area occupied by these two series may be considered as impossible for oil.

The areas occupied by sedimentary rocks and which could possibly contain oil will be noted below.

The first of these areas lies along the valley of the Carmel River and Tularcitos Creek and the low foothills between Monterey and Salinas. The formations exposed consist mainly of diatomaceous shales of the Monterey Series. These shales vary from the soft chalky form to the rather hard brittle variety. From the junction of the Carmel River with Tularcitos Creek, southeast to Jamesburg, the shales occupy a narrow trough about ten miles wide, between the main range of the Santa Lucia Mountains on the southwest and the Soledad Hills on the northeast. On both edges of the trough the shales rest on the eroded surface of the Santa Lucia Series. From Jamesburg southeast the Monterey area thins to about two miles in width and crosses a low divide in the vicinity of Secs. 35 and 36, T. 18 S., R. 4 E., joining a body of sedimentary rocks along the Arroyo Seco on the east slope of the range.

Along the Carmel Valley proper, west from its junction with Tularcitos Creek, the base of the Monterey is resting on the Santa Lucia Series along the south side of the valley. The general structure is that of a monocline, dipping about 20° to the northeast. On the west this monocline rests against crystalline rocks along Carmel Bay and the granite areas west of the town of Monterey. On the east it is prevented from dipping into the Salinas Valley by the granite of the Soledad Hills. On the north it dips under the Quaternary of the mouth of the Salinas Valley, along the edge of the foothills that run from Monterey to Salinas. This contact is described in the previous article on the "Mouth of the Salinas Valley." It is possible that in the vicinity of Toro Creek the Monterey may be overlaid by sands and shales of the upper Miocene and Pliocene which in turn dip under the Quaternary sands of the valley. Along the north and south sides of Carmelo Bay are small patches of coarse sands and conglomerate, probably of Eocene age. In Malpaso Creek about two miles south of the bay, similar beds containing coal occur. The total thickness of this Eocene is about 500 feet.

Save for an occasional speck of bitumen in the shale there is no indication of petroleum in this area. This, together with the lack of favorable structure and reservoir formations, make the district rather improbable for the accumulation of oil.

The second area of sedimentary rocks occurs on the east slope of the Santa Lucia Range, opposite the Salinas Valley, between Greenfield and King City. This body of sediments is best exposed along the Arroyo Seco, Reliz Creek and Vaquero Creek. It continues west from the edge of the Salinas Valley about twelve miles and the bottom is exposed, resting on the crystalline rocks about three miles east of Tassajara Hot

Springs. A small body of it continues northwest and crosses the divide, joining the Monterey area southeast of Jamesburg. On the south it connects with the sediments of the San Antonio Hills and the San Antonio Valley.

The formations that compose this body of sediments are as follows: A body of coarse white and yellow sandstone about 2000 feet thick, containing near the base conglomerate beds, made up of fragments of Monterey shale. This formation lithologically resembles the Santa Margarita of the Salinas Valley and it can probably be correlated with that formation. It is found outcropping on the south side of the Arroyo Seco at its mouth and forms the low hills that border the west side of the Salinas Valley from the Arroyo Seco to King City. It dips about 15° to the northeast and disappears beneath the alluvium of the valley. The base of the formations is exposed along Reliz Creek, resting unconformably upon the eroded surface of the Monterey shale. Along the north bank of the Arroyo Seco from its mouth on west to the headwaters in T. 19 S., R. 5 E., are outcrops of diatomaceous shale of the Monterey. It is also found on the south side of the arroyo in the area west of Reliz Creek and in the vicinity of Vaquero Creek. It is very probable that the general inclination of the strata is to the northeast, but the shales have been so fractured that any accurate mapping of the structure is impossible. As many as seven sharp folds may be seen within a distance of one-half mile.

Seepages of black asphaltic oil are reported as being quite common in the shale, particularly in the vicinity of faults. The principal seepages occur as follows: On the north bank of Paloma Creek, about the center of Sec. 21, T. 19 S., R. 5 E.; at a fork in Piney Creek near the west quarter-corner of Sec. 12, T. 19 S., R. 4 E. This latter seepage is probably at the contact of the shale and the granite. In Sec. 20. T. 19 S., R. 6 E., at the north quarter-corner, a well was sunk to a depth of 1400 feet, encountering salt water and gas. Up Reliz Creek several seepages are reported and shallow wells are said to have encountered oil to the amount of almost a barrel per day.

Beneath the Monterey shale is found a rather coarse white and yellow sandstone. It is best exposed about seven miles up Vaquero Creek from its junction with the Arroyo Seco. Homer Hamlin[1] first described it at this locality, giving it the name of Vaquero sandstone, and hence this locality has been regarded as the type-section for the Vaqueros formations. The sandstone is resting on the western edge against the crystalline rocks of the Santa Lucia Series.

This district cannot be regarded as favorable for the production of oil in commercial quantities at the present time. While the Monterey shale contains evidence of petroleum, it is probable that the greater portion of whatever oil was once in the shale has run out and been lost by reason of the severe crushing and erosion to which the shale has been subjected. As there are apparently no sand beds in the portion of the Monterey that is left, any oil present would have to collect in the fractured zones of the shale and showings of oil can probably be obtained by drilling along faults.

[1]U. S. Geological Survey. Water Supply Paper 89. By Homer Hamlin.

In the strip of Santa Margarita which overlies the Monterey with marked unconformity east of Reliz Creek no indications of petroleum are found, and it is probable that the Santa Margarita sands were laid down on the eroded surface of the Monterey long after the oil content of the shale had escaped.

The third area of sedimentaries in the Santa Lucia Range runs from the vicinity of Mount Piron south to the San Luis Obispo County line and lies between the San Antonio and Nacimiento rivers. On the east it adjoins the sedimentary rocks of the San Antonio Hills and on the west it is bounded by the metamorphic rocks of the Franciscan formation lying west of the Naciemento River. The rocks that outcrop in this area consist mainly of Vaqueros sandstone. A small area of Monterey is found south of Pleyto, and sandstone and shale of the Santa Margarita formation outcrops along the San Luis Obispo boundary line. The thickness of these formations is not very great, for at Bald Mountain a considerable area of Franciscan is exposed and in Sec. 22, T. 24 S., R. 9 E., there is an outcrop of granite surrounded by the Monterey and Santa Margarita formations. This district shows no indications of petroleum.[1]

Area of the Gavilan Mountains.

The eastern one-half of the Gavilan Mountains lie in San Benito County and the western half form the northeastern boundary of Monterey County. This portion of the range borders the Salinas Valley from its most northerly point, south as far as Metz. South of Metz and Topo Creek, the range, which has been a rugged mountain chain with elevations as high as 3381 feet, gives way to low rolling hills of sedimentary rocks. This latter area was discussed in the article on San Benito County. As stated before, the rocks of the Gavilan Range belong to the Santa Lucia Series of Paleozoic age and consist of highly metamorphosed marbles, schists and gneisses, together with masses of intrusive granite. This series of rocks is frequently referred to as the Basement Complex of the Coast Ranges, as it forms the core, and is the oldest formation exposed in these ranges. There is no evidence that the Santa Lucia formation contains oil and the character of the rocks, together with the intense deformation they have suffered, practically make it an impossibility for them to contain oil.

Area of the Salinas Valley from Salinas to Greenfield.

The Salinas Valley from Salinas to Greenfield occupies a flat area of about six miles in width and 33 miles in length. It is bounded on the west by the Santa Lucia Range and on the east by the Gavilan Mountains. The formations exposed on the valley floor consist of recent alluvial deposits, which on both sides of the valley rest against the crystalline rocks of the Santa Lucia Series. It is probable that the structure consists of a synclinal trough between the two mountain ranges, with the crystalline rock forming the syncline and the recent alluvial deposits resting horizontally on the older rocks. The western side of the valley

[1]The southwest portion of this area has been mapped by the State Mining Bureau and published in the folio that accompanies Bulletin 69, "Petroleum Industry of California."

is characterized by large alluvial fans running out of the steep canyons of the Santa Lucia Range and a fault of considerable magnitude probably parallels the west side of the Salinas River.

The apparent lack of any sedimentary deposits other than the recent alluvium make this portion of the valley unfavorable for the accumulation of oil.

The Area of the San Antonio Hills.

The San Antonio Hills may be considered as a detached portion of the Santa Lucia Range, lying between the Salinas Valley and the San Antonio Valley. The northern limits will be fixed as terminating on a line running due west from King City. On the south, while the hills actually terminate at the bend of the San Antonio River, for the purpose of this report that portion of San Luis Obispo County lying between the east bends of the San Antonio and Naciemento Rivers will be considered as a part of the area under discussion.

The San Antonio Hills may be considered as a fault block bordered by well defined faults on two sides On the east the hills are separated from the Salinas Valley by a fault that runs along the west side of the valley from its mouth to a point about five miles south of San Ardo. The fault on the west side begins about six miles north of Jolon, in Sec. 3, T. 22 S., R. 7 E., and runs southeast along the east side of the San Antonio Valley, crossing the San Antonio River and the San Luis Obispo boundary line in the SW. ½ of Sec. 34, T. 24 S., R. 10 E. The formations within this fault block consist mainly of diatomaceous shale beds of the Monterey Series (called by the United States Geological Survey, 'Salinas Shale'). Owing to the intense crushings and foldings which the shale has undergone, no definite statement can be made as to the thickness or structure. In three areas the shale is overlaid by beds of incoherent sand, gravel and clays of fresh-water origin, known as the Paso Robles formation (Pliocene). These areas are as follows: In the Hames Valley, about four miles northeast of Bradley, the Paso Robles beds are folded in a broad synclinal trough; at the east bend of the San Antonio River, about six miles southwest of Bradley, the Paso Robles is present along the axis of a small syncline and along the flank of the corresponding anticline; along the east side of the San Antonio Hills, between King City and a point three miles north of San Ardo, the Paso Robles is present in a monocline, lying on the Monterey and dipping at a rather high angle to the east. Several seepages of petroleum have been reported as occurring in the Monterey shale beds, probably along fault lines. The most notable of the seepages occur in what is known as the Pleyto District. This district lies about six miles southwest of Bradley in the vicinity of the eastward bend of the San Antonio River. This district has been mapped and reported on, both by the State Mining Bureau[1] and the United States Geological Survey[2].

Following is a portion of the Geological Survey report by W. A. English dealing with the Pleyto District. The term Salinas shale used in

[1]California State Mining Bureau. Bull. 69, 1914. Pp. 435–436.
[2]U. S. Geological Survey. Bull. 691-H. By Walter A. English.

Mr. English's report is synonymous with Monterey shale, as used in this Bulletin:

"Pleyto Oil District.

"The Pleyto district (see Fig. 36) lies near the bend in San Antonio River, about six miles southwest of Bradley and eight miles southeast of Pleyto. Attention of oil men was early attracted to this area by the outcrops of asphalt rock, and a number of wells have been drilled, but they did not encounter enough oil to justify pumping.

"Structure.—The anticline that crosses the SW¼ Sec. 36, T. 24 S., R. 10 E., constitutes a structural spur extending out into the area of gently dipping beds of the Paso Robles formation, very much like the productive anticlines in San Joaquin Valley, though on a much smaller scale. Owing to this similiarity it has been thought that oil may have accumulated in this anticline.

"Indications of oil.—The basal 150 feet of beds of the Paso Robles formation along the contact just south of San Antonio River are impregnated with asphalt. The quality of the asphalt rock is variable, the best being confined to a bed of fine sandstone about 20 feet thick. An open cut has been made in this bed, and what probably amounts to several hundred wagon loads of asphalt rock has been removed for local use in road making. To the southeast there are stringers of rich asphalt rock in the basal Paso Robles beds where they cross the Nacimento River, and small pockets of sand that has been squeezed into the underlying Salinas shale are heavily impregnated with asphalt. The Salinas shale adjacent to the Paso Robles is hard and broken into angular fragments, between which a tar cementing material is locally present. The tar occurs only on the surfaces of the shale fragments and seems to have migrated to this locality from elsewhere in the shale.

"Economic possibilities.—The Salinas shale is the probable source of any oil present in this district, and the most likely collecting place of the oil would be in the overlying Paso Robles or in the Santa Margarita sandy beds where they are present. The asphalt along the outcrop of the Paso Robles on the west side of the syncline furnishes direct evidence of the presence now or formerly of oil in the district. Against these favorable features may be urged the following: (1) The bed of asphalt rock is 150 feet thick just south of San Antonio River but thins out to a few feet within a quarter of a mile in each direction, and there is no asphalt in Sec. 26 in the sandy beds on the flank of the anticline. The accumulation of asphalt appears to be due to fractures in the shale caused by movement along a fault that continues eastward from Sec. 33, where it forms the contact between the Salinas shale and the Vaqueros formation. These fractures apparently allowed a ready migration from the shale into the overlying Paso Robles. Thus the presence of asphalt here is apparently not due to the anticlinal structure to the east and is not very good evidence of a concentration of oil in the anticline. (2) The four wells that tested the beds overlying the shale got negative results. The Metropolis well, which passed through the Paso Robles into the underlying shale without encountering either oil or tar sand, furnishes the best test. Two shallow wells close to the outcrop near the south line of Sec. 35, got tar sands but no oil. The King well of the Bradley Oil Company is said not to have reached the Salinas shale so its results are inconclusive. The Metropolis well went far toward proving the absence of oil in this anticline. However, the King well should be depended to reach the shale. If, after reaching the shale, it proves a failure also, more drilling in the field would seem inadvisable, though a well a quarter to half a mile east of the King well would give the most conclusive test of the anticline.

"Wells drilled for oil.—The wells drilled in the Pleyto district are here listed and numbered to correspond with numbers on the geologic map (Fig. 36):

"Well No. 1, in Sec. 27, drilled by the Monterey Oil Co. (?) is said to have reached a depth of 1100 feet and struck flowing water.

"Well No. 2, in the SE¼ Sec. 26, drilled by the Pleyto Oil Co. and successors, is said to have reached a depth of 3300 feet, getting a small quantity of tarry oil near the bottom. It is in the Salinas shale for at least the upper 3100 feet. Drilling was started about 1909 and finished 1912.

"Well No. 3, the Metropolis well, in Sec. 35, drilled by the Hames Valley Oil Co. in 1911–1913, is 3100 feet deep and obtained only a small quantity of heavy oil. The drill entered the shale at a depth of about 1000 feet without having passed through any tar sands.

"Well No. 4, in the southwest corner of Sec. 36, drilled by the Bradley Oil Co. (King well), is said to have reached a depth of not more than 800 to 900 feet.[1]

"Well No. 5 (location approximate) was drilled about 1900 by the White Oaks Oil Co. Another well, drilled by the Great American Oil Co. is a few hundred feet to the south. Both are close to the outcrop and are said to have penetrated the asphalt sands.

"Well No. 6, the Cavanaugh well, drilled with a standard rig, is said to have reached a depth of 800 fet in the Salinas shale.

[1]Since the above was written, the King well was taken over by the Associated Oil Co. and deepened to 2035 feet, when it was abandoned. Through the courtesy of the company the writer has been furnished with the log. According to the writer's interpretation, the drill reached the Salinas shale at 1445 feet. Seven feet of tar sand was passed through at a depth of 1320 to 1327 feet, but no other oil or tar sands were encountered.

"Well No. 7, the other Cavanaugh well, drilled with a portable rig, is said to have reached a depth of 2500 feet without getting any appreciable quantity of oil.

"The Veratina well, on the south bank of San Antonio River about a quarter of a mile east of the west line of Sec. 35, is said to have been drilled shortly after 1900 and to have encountered considerable salt water and some gas."

The general geological conditions for the accumulation of oil in the San Antonio Hills is unfavorable. A more detailed statement regarding these conditions is given in the following article:

The Salinas Valley from Greenfield South to the County Line.

The geology and oil resources of this area have been reported on in detail, both by the State Mining Bureau[1] and the United States Geological Survey.[2]

The Mining Bureau's report covers the entire portion of the Salinas Valley south of King City, and the Geological Survey's report takes in that portion of the valley from the vicinity of San Ardo to a point about three miles south of San Miguel These reports contain detailed geological maps of the district, together with a list of wells drilled in the area. The general geology of this region may be summed up as follows: The Tertiary sedimentary rocks that occupy this portion of the Salinas Valley lie in a broad, shallow syncline between the Diablo Range on the east and the Santa Lucia Range on the west. The axis of the syncline approximately parallels the center of the valley. Along the east side of the valley, the east limb of the syncline is formed by beds of the Santa Margarita, Etchegoin and Jacalitos and Paso Robles formations, dipping at about 4° to the west. These beds probably flatten out beneath the alluvium of the valley floor and then turn and dip to the east on the west side of the valley. From King City south to a point about three miles south of San Ardo, this west limb of the syncline is sharply faulted and the upper Miocene and Pliocene beds rest at a sharp angle against the Monterey shale of the San Antonio Hills. This fault contact may be plainly seen in the hills west of San Ardo, the Santa Margarita resting at an angle of about 70° to the east against the Monterey, which dips to the west. This fault apparently dies out about six miles north of Bradley, and the upper Miocene and Pliocene beds rest with their normal unconformity on the Monterey from this point on south. Beginning at a point about four miles north of Bradley, in Sec. 23, T. 23 S., R. 10 E., a broad, plunging anticline appears, which runs southeast through the town of Bradley and gradually dies out in the hills about three miles east of San Miguel. This fold is known as the Bradley anticline. The Paso Robles beds are exposed on the surface of the fold and well logs indicate that the Monterey is present beneath the Paso Robles. The Bradley anticline is apparently the most favorable location to obtain oil in the Salinas Valley. It fulfills at least three conditions necessary for the accumulation of petroleum—that is (1) the structure is favorable; (2) beds of organic shale underlie the fold; (3) porous reservoir beds are present overlying the organic shale. Nevertheless, with all these qualifications, this fold has to date failed to show oil in commercial quantities. It is the opinion of the writer that this is due to the fact that the Monterey shale from which the oil would have to come was

[1]California State Mining Bureau. Bull. 69. Pp. 418–432. By C. A. Waring.

[2]United States Geological Survey. Bull. 691-H. Salinas Valley-Parkfield Area. By W. A. English.

uplifted and eroded with the loss of most of its oil content previous to the time at which the upper Miocene and Pliocene beds were laid down. Hence these beds show no oil, and the Monterey contains only small quantities in its lower portion. This applies in general to those areas in Monterey and San Luis Obispo counties where the Monterey shale and the Paso Robles formation are exposed.

The following wells have been drilled, or are drilling, in the Bradley anticline: A well in Sec. 4, T. 25 S., R. 12 E., is said to have been drilled to 1340 feet, getting small amounts of gas but no oil. This well was apparently located in the axis of the Bradley anticline. Just south of the town of Bradley and located on the axis of the fold, the Bradley-San Miguel Oil Company has a well down about 2000 feet. Showings of oil and gas have been reported.

In Sec. 32, T. 24 S., R. 12 E., the Shell Company of California has a well down 4200 feet. This well is located approximately on the axis of the fold and apparently went through the Pliocene beds at 1600 feet, logging Monterey shale from that point to its present depth. Several showings of oil have been reported in the Monterey, but nothing of commercial value has been found to date.

In the area west of San Ardo along the fault contact between the Monterey and Santa Margarita, there are several seepages of oil. Following is a portion of English's[1] report on this territory:

"**Area West of San Ardo.**

"Geology.—The San Antonio Hills, along the west side of Salinas River, consist entirely of the Salinas shale, except for a belt of the sandstone and shale of the Santa Margarita formation about a half mile wide close to the edge of the valley. The Santa Margarita beds in this belt overlie the Salinas shale with marked unconformity. They dip 40° to 60° NE., in marked contrast to the gently dipping beds of the same age on the east side of the river. There must be a syncline or a faulted syncline somewhere beneath the valley alluvium and terrace formation, but there is no surface evidence to indicate where the syncline shown on Plate XXVII really lies beneath the Quaternary cover. The Santa Margarita is here markedly unconformable on the Salinas shale.

"Evidence of oil.—In Garrissere Gulch, west of San Ardo, tar sands in the Santa Margarita extend through a thickness of several hundred feet; farther south, in Sec. 19, T. 22 S., R. 10 E., the lower beds of the Santa Margarita are richly impregnated with oil and tar; and other oil sands are exposed close to the base of the sandstone as far south as the southern limit of this belt of Santa Margarita in Sec. 33.

"Economic possibilities.—Surface evidence indicates that the oil migrated from the underlying shale into the Santa Margarita, and that it is confined to the west side of the syncline which lies somewhere out in the valley. The abundance of oil sands at the surface suggests that oil might be obtained by wells that would reach the lower part of the Santa Margarita at a considerable depth. The best place for a test is opposite the best outcropping oil sands, which occur between the north line of Sec. 13, T. 22 S., R. 9 E., and the south line of Sec. 19, T. 22 S., R. 10 E. The well should be far enough east of the outcrop to reach the base of the Santa Margarita at a depth between 1000 and 1500 feet.

"Wells drilled for oil.—The wells drilled in this area are described below in order from north to south. They were all drilled some time ago, and the information obtained about them is fragmentary.

"The Newell well, east of Sec. 12, T. 22 S., R. 9 E., is said to have reached a depth of 1310 feet. It probably entered the oil sands at about 600 feet and continued in them to the bottom. It furnishes a fair but incomplete test of this area, as it should have been drilled to the underlying shale, which is here probably several hundred feet deeper.

"The Capt. Barrett well, near the north line of Sec. 19, T. 22 S., R. 10 E., is said to have reached a depth of 800 to 1000 feet. It is located too close to the basal contact to test the Santa Margarita.

"The Tomboy well, about 1800 feet southeast of the Barrett well, is said to have reached about the same depth. It probably entered the Salinas shale at from 500 to 600 feet and proves that at that depth the overlying Santa Margarita does not contain oil.

[1]U. S. Geological Survey. Bull. 691-H. By W. A. English.

"The Doheny well, in the southwest corner of Sec. 20, T. 22 S., R. 10 E., is practically on the basal contact of the Santa Margarita. Its depth was not learned.

"The well of the Norman Oil Co., in the northeastern part of Sec. 4, T. 23 S., R. 10 E., starts down in the Salinas shale on the north flank of a well-marked anticline. Its depth and history were not learned."

Area East of the Salinas Valley from King City South to the County Line.

This district may be considered as embracing the territory that lies between the Kings County line and the headwaters of the streams that drain into the Salinas Valley, with a length north and south from Lonoak to the Chalome Ranch. It is characterized by a number of narrow north and south valleys, chief of which are Lewis Creek, Peachtree Valley and Priest Valley in the northern portion and Chalome Creek and the Parkfield area in the southern portion. The district has been mapped in detail both by the Geological Survey[1] and the State Mining Bureau[2].

The general geology of the region may be summed up as follows: Along the ridge that divides this area from the Salinas Valley the formations consist of white sandstone and diatomaceous shale of the Santa Margarita, overlaid in places by the sands and gravels of the Pliocene. The general dip is about 10° to the west. The Santa Margarita is apparently resting on the eroded surface of the granite. Along the east side of the Peachtree Valley there is a syncline in the upper Miocene formations. Running along headwaters of Big Sandy Creek and Vineyard Canyon and thence southeast into the Chalome Hills is the axis of an anticline, partly in the Santa Margarita and partly in the Pliocene.

The San Andreas fault, which is the dominant feature of this area, runs south down Lewis Creek and then across a divide into Charley Valley and thence across another divide into Chalome Creek and continues south down the latter, passing just east of Parkfield.

The fault zone averages about three miles in width and the formations exposed along the rift consist of the basement complex, the Franciscan, the Chico, the Vaqueros and the Santa Margarita. All the beds have been sharply tilted and crushed and the area occupied by any one formation is relatively small. In the area east of the fault the upper Miocene formations are found lying on the Chico and the Franciscan.

Indications of oil are found along the Peachtree Valley and in the vicinity of the San Andreas fault, particularly in the Parkfield area. The oil apparently originated in the diatomaceous shales of the Santa Margarita and has collected at the contact of this formation with the underlying granites, or where the shales have been brought in contact, by faulting, with the Pliocene sands. Sec. E-F, Fig. 6, shows the general structure in the northern portion of this region.

The unfavorable structure and the lack of any great amount of diatomaceous shale, make the region unfavorable for the accumulation of petroleum in any large quantities.

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[1]U. S. Geological Survey. Bull. 581-D. Geology and Oil Prospects in the Waltham, Priest, Bitterwater and Peachtree Valleys, 1914. By R. W. Pack and W. A. English.

U. S. Geological Survey. Bull. 691-H. Geology and Oil Prospects of the Salinas Valley-Parkfield Area, 1918. By W. A. English.

[2]California State Mining Bureau. Bull. 69. Petroleum Industry of California, 1914.

In the article on San Benito County, page 78, a portion of Pack and English's[1] report on the Peachtree area is given. Below is a portion of the same report dealing with the Parkfield area:

"Parkfield District.

"The Parkfield district (Fig. 35, Pl. XXVIII) lies in an elevated part of the Diablo Range about 28 miles from Coalinga, in San Joaquin Valley, and 22 miles from San Miguel, in the Salinas Valley, the two nearest railroad points. Despite the poor transportation facilities the presence of numerous oil seepages here has led to the drilling of a number of wildcat wells, though without any distinctly favorable results. Nevertheless, there are many people who still believe that the district will ultimately prove productive.

"Stratigraphy and structure.—Though most of the formations common to the Coast Range crop out within this area, the only one present in which oil is likely to have originated is the Santa Margarita (?) formation, which is exposed on the southwest flank of the syncline east of Parkfield. Oil is, therefore, to be looked for only in beds adjacent to this formation and particularly those overlying it, in areas of favorable structure. The beds throughout the Parkfield district dip steeply, and the structure is complicated. Toward the north, where the Parkfield syncline approaches the San Andreas fault, beds of widely different ages have been brought close together by the extensive faulting. East of Parkfield, the syncline is less faulted but presents a remarkable disparity in the succession of formations outcropping on the two sides of the axis. It may be seen from Plate XXVIII that the Vaqueros formation and the Santa Margarita (?) formation, which are well developed on the southwest side of the fold, are absent on the northeast side, along the flank of Table Mountain. The absence of these beds is accounted for partly by faulting along the Tertiary-Cretaceous contact but is due, also, to an unconformable overlap by the upper Miocene formations upon the older formations. Some time before the deposition of the upper Miocene sediments the Table Mountain area was uplifted and the Vaqueros and Santa Margarita (?) formations were entirely eroded away. At the same time the beds which now crop out on the southwest flank of the fold were not eroded to any great extent. The Santa Margarita (?) formation is believed to underlie the upper Miocene to a point considerably east of the synclinal axis, as the shale crops out on the northeast flank of the fold only a short distance southeast of the area shown on Plate XXVIII.

"Indications of oil.—Numerous seeps occur in this district and are important as giving direct evidence that oil is present. The seeps are on both flanks of the Parkfield syncline, some near the Table Mountain group of wells and others northwest of Parkfield, close to and within the San Andreas fault zone.

"On the slope of Table Mountain from the east boundary of the upper Miocene sandstone down to the lower group of wells there are numerous seeps of tarry oil in each of the small gulches, and small pools of nearly solid tar have collected below the seeps. Down the canyon from the Table Mountain wells, in the eastern part of Sec. 13, are accumulations of tar, indicating a former seep.

"The Parkfield syncline is truncated northwest of Parkfield by the San Andreas fault, and the diatomaceous shale comes close to the fault. In this zone oil seeps are numerous and occur in all the formations, even in the granitic rocks. The following are the principal ones seen:

"Near the center of the north line of the SE¼ Sec. 9, T. 23 S., R. 14 E., a small pit has been dug in sandstone immediately overlying the diatomaceous shale, and a small quantity of oil has collected in the pit.

"An almost continuous line of small seeps occur in the Paso Robles and the Vaqueros formations in the bed of the small creek which drains eastward across the center of the NW¼ Sec. 5, T. 23 S., R. 14 E.

"Seeps of heavy oil occur every few feet in a fault block of crushed granite where it is crossed by the bed of a small gulch that trends eastward and joins Little Cholame Creek about 1000 feet northeast of the center of Sec. 31, T. 22 S., R. 14 E. Seeps of oil in granite are of course very unusual, though in the present case no unusual explanation is necessary to account for the facts. The granite is a fault block which was crushed and jointed by movements along the San Andreas fault zone. Thus the normally impervious granite became sufficiently porous for oil to enter it from adjacent bodies of shale, in exactly the same way that the oil which now seeps from the Paso Robles and Vaqueros entered those formations.

"Economic possibilities.—The Parkfield syncline is the only fold in this area in which any great amount of the Santa Margarita (?) formation is present and in which it is overlain by a sufficient covering to retain any oil originally derived from the shale. About 2500 feet of upper Miocene beds are included in the syncline, and oil might be expected to occur at their base on one or both flanks of the fold. This syncline could not safely be condemned as barren of oil by reason of the surface evidence, though the flanks of an isolated syncline of this type are not the most favorable structure imaginable.

"The Tricounty well and the Table Mountain group of wells have given actual proof that only small quantities of oil are present, and as these wells penetrate the beds most likely to contain oil if it were present at all, further drilling upon this syncline would appear inadvisable.

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[1]U. S. Geological Survey. Bull. 581-D. Geology and Oil Prospects of the Waltham, Priest, Bitterwater and Peachtree Valleys, 1914. By R. W. Pack and W. A. English.

"Unfavorable results were also obtained by test wells in the Vallecitos,[1] an area northwest of Coalinga, in which the structure is essentially similar to that of the Parkfield syncline. The tests of these two areas go far toward proving that isolated synclines of the oil-bearing series, surrounded by older rocks, will not prove productive in California. There are three factors which may account for the lack of oil. First, there may be an insufficient amount of shale present to have originally furnished any large quantity of oil. Second, the oil originally present could not be greatly concentrated at certain points, as migration could take place only along the comparatively short distance between the axis of the syncline and the outcrops of the oil sands on the flanks of the fold. In contrast are the productive San Joaquin Valley fields, where the oil in the productive folds may have come from areas far out in the valley syncline and also have migrated up the rise in anticlines. The third factor is the probable loss of oil at the outcrop of the oil sands. In an isolated syncline there is nothing to prevent the oil migrating up the dip and escaping at the outcrop.

"Wells drilled for oil.—In the following descriptions of wells the numbers correspond to those on the geologic map of the Parkfield area (Pl. XXVIII)." (See end of article for locations.):

"At the localities numbered 1 and 2 remnants of rig timbers, etc., probably represent old holes drilled by Captain Barrett and associates before year 1900. The locations are unfavorable.

"Well No. 3, the Oakshade well, owned by the Monterey Oil Co., is said to have been drilled to a depth of 1910 feet and to have encountered some oil and gas. This well is situated in the zone of complicated structure along the San Andreas fault. Such wells generally produce showings of oil but not enough to make them successful.

"Well No. 4 indicates the location of the Middle Ridge Oil Company's derrick. No drilling has been done here and there is little chance of obtaining oil at this locality.

"Well No. 5, the Tricounty well, is said to have reached a depth of 4160 feet and found showings of oil at several depths. The well starts in upper Miocene sandstone and reaches the underlying Santa Margarita (?) formation near the bottom. Although there was some water trouble, which might account partly for the failure to obtain much oil, this well furnishes a pretty fair test of the west flank of the Parkfield syncline.

"Well No. 6, the Parkfield Syndicate well, was drilled with a portable rig to a depth of 500 feet and got a small amount of gas. It was drilled entirely in the Vaqueros sandstone.

"Well No. 7, the Miller or Raymond well, was the first of the Table Mountain group of wells, as drilling is said to have been started in 1888. The drill is said to have reached a depth between 640 and 800 feet without passing through any oil or tar sands. Sulphur water is now flowing from the casing. Of the wells of the Table Mountain Oil Co., Nos. 8 and 9 are 270 and 600 feet deep respectively. They are said to be in oil or tar sand for most of this depth. Wells Nos. 10, 11 and 12 are shallow, ranging from 100 to 200 feet in depth; they are now abandoned, and when the writer visited them water and a small quantity of oil stood within 25 to 50 feet of the top of the casing in each well. The Table Mountain wells are said to have produced a few barrels of oil per day at the time of their completion. The oil doubtless originated in the Santa Margarita (?) formation and migrated up along the fault which lies east of these wells, saturating the sands for a few hundred feet out from the fault. The base of the upper Miocene sandstone also probably contains some oil which has migrated directly up from the underlying shale, in addition to that which came up along the fault plane.

"Well No. 13, sometimes called the Livermore well, was drilled by the Future Success Oil Co., in 1913–14. It reached a depth of 1810 feet, mostly in Cretaceous shale, but also apparently passing through intrusive sheets of serpentine and possibly reaching Franciscan rocks near the bottom. This well is separated from those on the west by a fault, and the light-gravity oil, showings of which are said to have been encountered, originated in the Cretaceous shale. Wells drilled in the dark Cretaceous shale generally get showings of a light-gravity oil but only a very small quantity.

"Well No. 14, the Dominion well, was drilled in 1912 and is said to be between 150 and 300 feet deep. It is located in an area of serpentine slide, near the contact between the serpentine and the Cretaceous rocks. The bailer dump (consisting of the drill cuttings) appears to be made up entirely of serpentine, but some Cretaceous shale may have been encountered. The location is unfavorable."

Well No. 1 is located about the center of Sec. 32, T. 22 S., R. 14 E.

Well No. 2 is located in the SE. ¼ of Sec. 5, T. 23 S., R. 14 E.

Well No. 3 is located near the north quarter-corner of Sec. 8, T. 23 S., R. 14 E.

Well No. 4 is located in the NE. ¼ of Sec. 18, T. 23 S., R. 14 E.

Well No. 5 is located in the SE. ¼ of Sec. 15, T. 23 S., R. 14 E.

[1]Anderson, Robert, and Pack, R. W. Geology and Oil Resources of the West Border of the San Joaquin Valley, North of Coalinga, Cal. U. S. Geol. Survey. Bull 603. Pp. 167–177, 1915.

Well No. 6 is located in the NE. ¼ of Sec. 26, T. 23 S., R. 14 E.

Wells Nos. 7, 8, 9, 10, 11 and 12 are located in the SE. ¼ of Sec. 13, T. 23 S., R. 14 E.

Well No. 13 is located in the SE. ¼ of Sec. 18, T. 23 S., R. 15 E..

Well No. 14 is located in the NE. ¼ of Sec. 19, T. 23 S., R. 15 E.

San Luis Obispo County.

That portion of the county lying north of San Luis Obispo and west of the Salinas Valley is a rugged mountainous area of the Santa Lucia Range. The rocks along the western portion are mainly sandstones, cherts and serpentine of the Franciscan. On the eastern slope which drains into the Salinas Valley, beds of sandstone and shale of Cretaceous age are exposed together with overlying beds of sandstone and shale of the Monterey Series There is no evidence of petroleum in this district.

In the Salinas Valley proper, between the Monterey County line and Templeton, the formations exposed are beds of sand and gravel of the Paso Robles formation, with an area of granite to the northwest of the town of Paso Robles. The Paso Robles beds are practically flat lying with the exception of an area northeast of San Miguel, where the southeast end of the Bradley anticline is found. The only oil possibilities lie along the axis of this fold (see page 89 for description). However, in view of the fact that the Shell Company's well in Sec. 32, T. 24 S., R. 12 E., Monterey County, located on the axis of the fold, has reached a depth of 4200 feet, with only a small showing, makes the outlook for production unfavorable.

The Salinas Valley from Templeton to Cuesta Pass becomes very narrow, the formations exposed consist of small thicknesses of highly-crushed diatomaceous shale and sandstone of the Monterey Series, overlaid by small patches of fine white sandstone and diatomaceous shale of the Santa Margarita. On the west these formations rest against the Cretaceous and Franciscan and in the east against a granite area. The district is unfavorable for the accumulation of oil.

That portion of the county lying east of the Salinas Valley and north of a line running due east through Atascadero is mainly an area of low, rolling hills drained by Estrella and San Juan creeks. The formations exposed consist mainly of flat-lying beds of sand, gravel and clay of Pliocene age. In the extreme northeast corner near Chalome, there is a small area of Cretaceous and Monterey. In the Red Hills, which lie southeast of Shandon, English[1] has reported that pre-Franciscan rocks are present, and McLaughlin and Waring[2] have reported the presence of Monterey shale and Vaqueros sandstone. Southeast of Creston in T. 28 S., R. 14 E., beds of the Santa Margarita formation, together with sandstone and shales beds of the Monterey Series are reported as overlying the granites of the east slope of the Santa Lucia Range. From these outcrops it is apparent that the Monterey Series is probably present beneath the Pliocene, over a large portion of this area, and therefore this region fulfills two of the conditions for the accumulation of oil: that is, there are porous beds (Pliocene) overlying beds of diatomaceous shale (Monterey). However, other conditions are unfavorable and it is not likely that oil in commercial quantities will be found here. This state-

[1]Geology and Oil Prospects of the Salinas Valley-Parkfield Area. By W. A. English. 1918, p. 246.

[2]California State Mining Bureau. Bull. 69. By R. P. McLaughlin and C. A. Waring. Map folio Plate IV, 1914.

ment is based on the fact that favorable structure is entirely lacking and the basal beds of the Pliocene show no seepages, nor does the Monterey shale show any evidence of petroleum. In addition, the same facts hold true here as elsewhere in the Salinas Valley area; that is, the Pliocene beds do not contain any appreciable amount of oil and the Monterey contains only very small quantities. As stated before, this is due to the uplifting and erosion of the Monterey with a loss of the oil content before the deposition of the Pliocene beds. A map of this area will be found in the folio accompanying Bulletin 69 of the State Mining Bureau.

The area between Atascadero on the north and the Santa Maria Valley on the south and between R. 13 E. and the coast has been mapped in detail by Fairbanks[1].

From San Luis Obispo in a northwest direction this area is covered with metamorphic rocks of the Franciscan, and the Santa Lucia Range east of Santa Margarita is composed of granite. The only possible oil districts consist of two parellel areas of Monterey shale. One in the main Santa Lucia Range, running southeast from Cuesta Pass down Lopez Canyon, and the second located in the San Luis Range which borders the coast south of San Luis Obispo. Both these areas are synclinal in structure and the axis of the anticline which once separated them ran down the San Luis Valley and has been eroded down to the underlying crystalline rocks. The shale in the area around Lopez Canyon is highly tilted, the limbs of the syncline having an average dip of about 50°. Seepages of oil have been reported and there is no doubt but what there is sufficient diatomaceous shale present to have formed considerable oil. This, however, probably collected in the beds that formed the axis of the anticline along the San Luis Valley and which have been removed by erosion. The lack of any reservoir beds overlying the shale and the unfavorable structure, condemns this area as a possible producer of an appreciable amount of oil.

The area of Monterey shale in the San Luis Range runs from Point Buchon, just south of Morro Bay, in a southeast direction to the Arroyo Grande Valley The structure is a syncline with the axis striking south 30° east. The northeast limb rests on the crystalline rock of the Franciscan along the San Luis Valley and the southwest limb rests on similar rocks along the coast line. From Point Buchon, southeast to San Luis Obispo Creek, the Monterey is not overlaid by any younger formation, and there is no noticeable evidence of petroleum. From San Luis Obispo Creek, southeast to the Arroyo Grande Valley, the Monterey is overlaid along the middle of the syncline by the Pismo formation. It is in this area that prominent indications of oil occur and the Arroyo Grande oil field is located.

ARROYO GRANDE OIL FIELD.

The principal development is along Pismo Creek, about three miles north of Pismo. In December, 1920, seventeen wells were pumping in the field, operated mainly by the Associated Oil Company. The average production per well is about nine barrels per day and the total production from the field from July 1, 1920, to December 31, 1920, averaged about 170 barrels per day of 14° Baume gravity oil.

[1]United States Geological Survey. San Luis folio 101. By H. W. Fairbanks, 1904.

The major portion of the wells are located on the north flank of the syncline, the axis of which passes just south of California Oil Company Well No. 3, striking S. 30° E.

The oil has originated in the Monterey shale and has collected in the overlying sands of the Pismo formation. The dips on both flanks of the syncline in the Pismo sandstone average about 20°; the dips in the underlying Monterey are about 60°. The Pismo formation named by Fairbanks[1] consists in this area mainly of coarse loose sands with lenticular beds of shale. It may be correlated with the Santa Margarita formation (upper Miocene). The logs of wells drilled along the axis of the syncline show it to be about 2000 feet thick. The lack of any continuous shale bodies which would confine the oil to certain sands, has resulted in the oil being disseminated throughout the entire 2000 feet of sand in a lean saturation. This, together with the fact that the structure consists of an unsealed syncline, accounts for the small production. It is not likely that the production or the limits of the field will ever be greatly increased over their present status.

There, however, is present another possibility which may prove profitable in time. That is the mining and distillation of the bituminous sands of the Pismo, which are to lean to give profitable wells but which might in time be worth distilling. These sands outcrop along the north limb of the syncline just south of Edna and have at various times been mined for asphaltum. A recent test shows that they yield about twenty-five gallons of 20° Baume gravity oil per ton. In addition to San Luis folio 101,[1] reports on this area have been made by Eldridge[2] and the Mining Bureau.[3]

The country lying south of Arroyo Grande to the Santa Barbara County line consists mainly of low rolling hills, with the Nipomo Valley in the eastern portion. The rocks exposed consist of loose sands and gravels of the Paso Robles formation, together with recent terrace deposits. Neither of these formations has a thickness of more than a few hundred feet and the underlying Franciscan serpentine outcrops frequently over the area. The region offers no possibility of having oil. The hills that form the northeast edge of the Nipomo Valley and which are known as the Nipomo Hills consist of rhyolite tuff and diatomaceous shale of the Monterey Series. These hills will be discussed in the article on the Huasna District.

HUASNA DISTRICT.*

This area lies to the south and east of Arroyo Grande and consists of the territory around Tar Spring Creek, Arroyo Grande Creek, Huasna Valley, Alamo Creek and Suey Creek. The Nipomo quadrangle of the United States Geological Survey covers the major portion of the area.

The formations exposed consist mainly of the Monterey Series. The two areas of Monterey shale described in the preceding paragraphs and which form the two synclinal structures along Lopez Canyon and

[1]United States Geological Survey. San Luis folio 101. By H. W. Fairbanks.

[2]Twenty-second Annual Report of the U. S. Geological Survey. Part I. Pages 412-424. Asphalt and bituminous rock deposits. By G. H. Eldridge. 1900.

[3]California State Mining Bureau. Bulletin 69. Pages 430-432.

*The writer is indebted to Mr. F. Tickell of the Southern Pacific Company for the major portion of the data in this area.

in the Arroyo Grande field merge in the Huasna District. The body of the Franciscan formation which separated them along the San Luis Valley is faulted out of sight at a point on Tar Spring Creek about one mile southwest of the Tar Springs Ranch. In the Nipomo Hills, which form the southwestern portion of the district and which lie between the Huasna Valley and the Nipomo Valley, the basal beds of the Monterey are exposed. These consist of silicified rhyolite tuff, overlying the Franciscan on the western slope of the hills. Above the tuff beds and forming the top of the ridge are beds of diatomaceous shale, with some sandstone. The general dip is about 40° to the northeast, although there are numerous sharp minor anticlines along the north slope of the hills, where they descend into Tar Spring Creek and the Huasna Valley.

The general structure in the upper portions of the Huasna Valley is synclinal and the Monterey beds dip under the Santa Margarita sandstone, which occupies an area of about five square miles between Musick and the Huasna School On the east side of this synclinal trough, the Monterey along the Huasna River rests upon a small thickness of Vaqueros which in turn rests on the Cretaceous, which forms the core of the Santa Lucia Range in this district

While the general structure of the Huasna Valley is synclinal the following minor folds occur, beginning from the west: A syncline in the Santa Margarita running northwest through Tar Spring Ranch; an anticline in the Santa Margarita running northwest along the high ridge north of the Tar Springs Ranch; a syncline in the Santa Margarita running northwest from the Park Ranch, and finally an anticline partly in the Vaqueros and partly in the Monterey running northwest in the hills east of the Huasna River

Indications of oil are found in seepages in the Monterey along Suey Creek, Tar Spring Creek and in the Nipomo Hills. In the Santa Margarita north of the Tar Springs Ranch there are outcrops of bituminous sands. The following wells have been drilled in this area:

The Doheny Well No. 1, located on Tar Spring Creek, about one-fourth of a mile southwest of the Tar Spring ranchhouse. A depth of 875 feet was reached and a showing of gas obtained. The Stow Well of the Associated Oil Company, located on Suey Creek, reached a depth of about 1500 feet in the Monterey, at which point serpentine was encountered. The Associated Oil Company drilled a well in the NE. ¼ of Sec. 1, T. 32 S., R. 14 E.; a depth of 3675 feet was reached without obtaining production. In the SW. ¼ of Sec. 7, T. 32 S., R. 15 E., is an old abandoned hole know as the McKay Well.

The Stieger Well was drilled on the Porter Ranch in what would be the SW. ¼ of Sec. 35, T. 31 S., R. 15 E. A depth of 1100 feet was reached without any showings.

The Harkness wells No. 2 and No. 3 are located about one and one-fourth miles south of the Porter ranchhouse on the east side of the Huasna River. A depth of 1000 feet was reached without any showings.

The Harkness-Squires wells No. 4 and No. 5 are located about one mile northeast of the Porter Ranch. A depth of about 800 feet was reached and a little gas was encountered.

The Downer wells No. 1 and No. 2 were drilled in the SE. ¼ of Sec. 31, T. 32 S., R. 16 E. No oil was encountered.

The sharply tilted condition of the Monterey shale, together with the lack of any large amount of reservoir beds overlying the diatomaceous shale, make this area unfavorable for the accumulation of oil in any appreciable amounts. If any further drilling is done, the most favorable locality for the location of a well is along the axis of the anticline in the Santa Margarita sandstone which marks the high ridge to the northeast of the Tar Springs ranchhouse.

The general mountainous region that lies east of San Luis Obispo, Arroyo Grande and the Cuyama Valley and west of San Juan Creek and the Carrizo Plains may be regarded as the extreme southeast extension of the Santa Lucia Range. The northern portion in the vicinity of Poso and La Panza is known as the La Panza Range. The southern end, which forms the divide between the Carrizo Plains and the Cuyama Valley, is known as the Caliente Range. The areas around Arroyo Grande, Lopez Canyon and the Huasna District, may properly be considered as belonging to the western portion of the region, but on account of indications of petroleum they are discussed separately in the preceding paragraphs.

Aside from these areas the region contains no indications of petroleum. The major portion has been mapped by the state[1] and a portion of the southwestern slope of the Caliente Range by the Geological Survey.[2] The general geology is as follows: In the northern portion between La Panza, Pozo and Atascadero the formations are granite. The core of the range south of Pozo and east of Musick is composed of sharply-dipping Cretaceous rocks. In the southern portion, the core of the Caliente Range is mainly Cretaceous and the east and west slopes are composed of highly tilted areas of Vaqueros sandstone, Monterey shale and Santa Margarita sandstone and shale.

The highly-tilted and faulted condition of the sedimentary rocks in the southern and central portion and the crystalline character of the rocks in the northern portion make the district an unlikely place for the accumulation of oil.

DISTRICT OF THE CARRIZO PLAINS AND SAN JUAN CREEK.

This district occupies the eastern portion of the county and forms an area of low rolling hills and plains between the Santa Lucia Range on the west and the Temblor Range on the east.

The western and southern portions have been mapped by McLaughlin and Waring[3] and the eastern and northern parts by Arnold.[4]

The geology according to these reports is as follows: Along the upper portion of San Juan Creek, north of the San Juan Ranch, the beds exposed consist of loose sands and clays of the Paso Robles formation, practically flat lying. The country is similar to the region around Shandon. From the San Juan Ranch south along San Juan Creek to a point on a line between La Panza and Simmler, the principal formation exposed

[1]California State Mining Bureau. Bull. 69. Map folio Plate IV, 1914. By R. P. McLaughlin and C. A. Waring.

[2]United States Geological Survey. Geology and Oil Prospects of the Cuyama Valley. Bull. 621-M, 1916. W. A. English.

[3]California State Mining Bureau. Bull. 69. Petroleum Industry of California, 1914. By R. P. McLaughlin and C. A. Waring. Pp. 429–430, map folio Plate IV.

[4]United States Geological Survey. Bull. 406. Preliminary Report on the McKittrick Sunset Oil Region, 1910. By R. Arnold and H. R. Johnson.

is the Santa Margarita. It is overlaid in small areas by patches of the Paso Robles formation and occasionally the underlying Monterey shale is exposed. The structure consists of a number of rather sharply-folded northwest and southeast striking anticlines. A seepage of oil is reported in the basal sands of the Santa Margarita near the north line of Sec. 23, T. 29 S., R. 17 E. In the center of Sec. 29, T. 28 S., R. 17 E., a well, known as the Cedar Spring Well, was drilled to a depth of 1960 feet in 1914 and no oil was encountered. At the present time the well is being deepened. It is located approximately on the axis of an anticline in the Santa Margarita and should offer an excellent test of this region.

The west side of the Carrizo Plains from Simmler south is composed mainly of beds of the Monterey Series, with the Vaqueros sandstone predominating. The shale beds of the series are best exposed in the hills west of the Painted Rock ranchhouse. In the extreme southwestern portion, the McKittrick sands and gravels are lying directly on the Vaqueros. The entire region is sharply folded into a number of anticlines. On Sec. 12, T. 11 N., R. 26 W., E. G. Lewis is now drilling a well.

The flat central portion of the Carrizo Plains is covered by loose sands and conglomerates, probably corresponding to the Paso Robles formation.

The dominant feature of the eastern side of the plains is the San Andreas Fault. In the southern end, it is marked by the sharp fault scarp on the west edge of the Elkhorn Hills and in the north end it forms the Bitterwater Valley and Palo Prieto Pass.

The area between the fault zone and the ridge of the Temblor Range which marks the eastern border of the county, is intensely crushed and broken. The formation consists of Vaqueros sandstone, Monterey shale and Paso Robles sands. South of San Diego Joe's Ranch there are innumerable small sharply-folded anticlines in the Vaqueros and Monterey; and in the outcropping beds of these formations there are numerous seepages The oil probably originated in the Monterey shale and has collected in the interbedded sands of this formation and in the Vaqueros sandstone by reason of faulting.

North of San Diego Joe's Ranch the structure is not so broken and there are no seepages. In Sec. 20, T. 29 S., R. 19 E., the Associated Oil Company drilled a well to a depth of about 3400 feet in 1918 and failed to obtain any indications of oil. The well is apparently located close to the fault zone. The general possibilities may be summed up as follows: Along San Juan Creek and the west side of the Carrizo Plains the general geological conditions are not very favorable for the accumulation of petroleum and there are no indications of oil except in Sec. 23, T. 29 S., R. 17 E., as noted above. However, the region is worthy of being examined further in detail before absolutely condemning it.

Along the east side of the plains, south of San Diego Joe's and east of the fault zone, it is probable that small amounts of oil can be obtained from wells drilled along the axis of the numerous folds of this area; but whether any well would be of commercial value, can only be told by drilling.

In the country north of San Diego Joe's there is apparently no indication of oil. Following is a portion of McLaughlin and Waring's report:

"The two Smith wells were drilled along an anticline of Monterey sandstone, southeast of San Diego Joe's. One of these is near the northwest corner of Sec. 22, T. 30 S., R. 20 E., and the other near the northwest corner of Sec. 16, T. 30 S., R. 20 E. Only traces of oil were struck.

"The Erume well was drilled 200 feet into the faulted zone, near Sulphur Spring fault, through the Monterey shale into the Monterey sandstone of Sec. 15, T. 31 S., R. 21 E. Some light oil was obtained but not in paying quantity.

"The Recruit well was driled 1530 feet into the Monterey sandstone, or possibly in faulted formation. No oil was obtained.

"The Humauma well was drilled 2300 feet into the Monterey sandstone. Only a trace of oil was obtained.

"The Vishnu, or Sperry well struck some oil but has never produced enough oil to market. It is driled on a monocline in the Monterey formation.

"On the southwest flank of the Temblor Range some oil has been obtained by wells in the Monterey sandstone. The oil is of good gravity, but probably will not be found in commercial quantities, owing to intense folding and faulting. Some oil may possibly be found east of the San Andreas rift in the region of the Panorama Hills; however, the Humauma well was unsuccessful, although located in a favorable locality to test the neighborhood."

Following are portions of the Arnold and Johnson report:

"The region generally known as the 'Carrizo Plain District' embraces Carrizo and Elkhorn plains and the adjacent southwestern flank of the Temblor Range. The supposed oil territory occupies the flanks of the hills toward the base of the range and the edge of the Carrizo and Elkhorn plains.

"Geology.

"The oil in the Carrizo Plain District occurs in sandstones interbedded with the base of the Monterey shale, or at the top of the Vaqueros, or in beds unconformably overlying the Monterey and Vaqueros. The Vaqueros sandstones are coarse and consist largely of quartz grains, with occasional granite and black to varicolored quartzite pebbles. The sandstone is roughly concretionary, the concretions sometimes attaining a diameter of 10 or 15 feet. The beds carrying oil, which unconformably overlie the Vaqueros and Monterey, consist of granitic debris and rounded shale fragments. The shallow wells, of which all the successful ones penetrate the base of the Monterey, or the top of the Vaqueros, have in most instances been put down close to the axis of those anticlines which have an arched top and steep-dipping sides. There are several of these anticlines (shown on the map, plate 1) which expose the Vaqueros sandstone or bring it close to the surface. Faults accompany most of the anticlines, and so complicate the structure that predictions concerning the territory a short distance away from the axis of an anticline are extremely hazardous.

"An oil sand consisting of shale and other pebbles associated with granitic sand, and believed to be of later age than the Monterey, is exposed in the southern part of the area. A particularly advantageous place for studying this is about one-half mile west of the Vishnu well, in the southern part of Sec. 22, T. 32 S., R. 22 E. The sand here is probably over 15 or 20 feet thick, and is overlain by fine-grained brown shales. This oil sand lies in a syncline, near the eastern edge of which the Vishnu well has been put down. It is believed that the Vishnu well obtains its oil from the Monterey or Vaqueros many hundreds of feet below the sand just described.

"Oil Wells.

"No commercially productive wells have been drilled in the district, but several prospect wells have. Among these, beginning at the northwest, are the R. M. Smith well No. 1, in the northeast corner of Sec. 21, T. 30 S., R. 20 E., the seven wells of the R. M. Smith Oil Company, near the corner stake of Secs. 22, 23, 26 and 27, T. 30 S., R. 20 E.; the Cree well, in the southwest corner of Sec. 22, T. 31 S., R. 21 E.; the Erume test holes in the southern part of the same section; the Schwartz well of the Union Company, near the southeast corner of Sec. 6, T. 32 S., R. 22 E., and the Sperry or Vishnu well, in the southeast corner of Sec. 22, T. 32 S., R. 22 E.

"The R. M. Smith wells in Secs. 22, 23, 26 and 27, T. 30 S., R. 20 E., the Erume wells in Sec. 22, T. 31 S., R. 21 E., and the Vishnu well, in Sec. 22, T. 32 S., R. 22 E., have yielded traces of oil. The Smith and Erume wells are shallow and have yielded oil only in small quantities. The oil is of a good quality, and is said to test about 28° Baumé gravity, although occurring within less than 100 feet of the surface. It is brownish to greenish in color and has very little viscosity. It is said that this oil is used in its native condition in lamps, making a somewhat smoky flame, however. Nothing definite is known concerning the quality of the oil encountered in the Sperry well, but it is said to have been of very good quality and of about 30° Baumé gravity.

"The Carrizo Plain District includes the region southwest of Palo Prieta Pass as far as the southeast corner of T. 28 S., R. 18 E., and the region southwest of the crest of the Diablo Range southeastward from the same corner. It embraces the Carrizo and Elkhorn plains, the northeastern flank of the Caliente Mountains, and the fringe of hills along the southwestern edge of the Carrizo Plain. A very hasty reconnaissance of the hills southwest of the Carrizo Plain as far south as Painted Rock Ranch, in Sec. 30, T. 31 S., R. 20 E., discloses evidence of petroleum at only one point. This was in the northern part of Sec. 23, and the southern part of Sec. 14, T. 29 S., R. 17 E., where an oil sand outcrops at the base of the Santa Margarita (?) formation. The sand here was not over 10 feet thick, consisted of coarse quartz grains, and showed a tendency toward concretionary structure. It immediately overlies the Monterey shale, which outcrops in the axis of an anticline passing through the locality mentioned. This occurrence of oil sand indicates that petroleum in small amounts occurs at the base of the Santa Margarita (?) formation throughout at least a portion of the Carrizo plain region, north of the southern part of T. 29 S., R. 18 E.

"It is not thought probable that deposits of economic importance will be encountered in this region, as the structural conditions are more or less unfavorable owing to the numerous faults that affect the formations adjacent to the plain. No other indications of petroleum were found on the southwestern flanks of Temblor Range north of an east-west line through the mouth of San Diego Canyon. Numerous indications of petroleum are found in the Vaqueros and overlying formations southeast of San Diego Canyon, along the flanks of the Temblor Range, and it appears highly probable that commercial deposits of petroleum occur at many places along the anticlines in this region. The anticline which begins about half a mile south of San Diego Joe's—that is, at the southeast corner of Sec. 8, T. 30 S., R. 20 E.—and passes southeastward along the flanks of the range (see map, Pl. 1) has been tested at two different localities over a mile apart, at the Smith wells near the corner of Secs. 22, 23, 26 and 27, T. 30 S., R. 20 E., and a mile northwest of that point.

"The Vaqueros also yields oil near the surface at the Erume wells in the southern part of Sec. 22, T. 31 S., R. 21 E. The peculiar pinkish color indicative of petroleum is also found at practically all the outcrops of the Vaqueros in the anticlines along this part of the range.

"Bearing in mind these favorable indications, it appears probable that wells sunk through the overlying Monterey shale and tapping the Vaqueros sandstone at advantageous localities will yield petroleum. As the petroleum produced by the shallow holes so far sunk is particularly good, ranging as high as 28° Baumé, it seems probable that oil wherever obtained from the Vaqueros will be excellent. As the conditions here mentioned as favorable continue practically uninterrupted along the range as far southeast as the region back of Sunset, it seems likely that prospecting in favorable localities in the Carrizo Plain District should secure positive results. Owing to the complex folding and accompanying faulting which affects this region, even to a greater extent than the northeastern flank of the range, detailed examinations of any particular area should be made before predictions are attempted. On the accompanying map (Pl. 1) the principal lines of structure are indicated. It is thought by the writers that the anticlines with low-dipping flanks offer the best inducements for exploitation."

The area of the Cuyama Valley is described in Chapter IX in the article on Santa Barbara County.

CHAPTER IX.

Coast Area from the Santa Maria River to the Santa Monica Mountains.

(Includes the counties of Santa Barbara, Ventura and Northwestern Los Angeles.)

Santa Barbara County.

The principal topographic features of Santa Barbara County consist of the San Rafael and Santa Ynez ranges. These two ranges, starting from a common point on the east line of the county, spread out fan-like to the west, the Santa Ynez group running due east and west along the coast line and the San Rafael group running northwest and forming the northern boundary of the county. This fan-like arrangement has resulted in an area of about twenty-four miles in width between the two ranges in the western portion of the county and which is occupied by a series of low hills and river valleys.

Beginning on the north flank of the Santa Ynez and going north to the San Rafael Range, these hills and valleys are as follows: the Santa Ynez Valley; the Purisima Hills; the Los Alamos and San Antonio valleys; the Solomon and Casmalia hills and the Santa Maria Valley.

In the high ranges of the San Rafael and Santa Ynez mountains, the rocks are principally of Cretaceous and Eocene age, highly folded and crushed and with little or no oil possibilities. In the broad depression in the western portion of the county between these ranges, there have been deposited, great thicknesses of gently-folded Miocene and Pliocene rocks in which large deposits of petroleum have formed and accumulated. This entire area has been thoroughly mapped and the oil resources reported on by Arnold and Anderson.[1]

In this report therefore only a brief description of the fields will be given, together with the possibilities of their extension to outlying areas.

Proven Fields and Adjoining Areas.

Beginning at the west end of the county, the first proven field is the Casmalia Hills, just east of Schumann Canyon and Casmalia Station. The structure consists of the broad plunging Schumann anticline, which has its beginning on the coast between Point Sal and Mussel Rock and runs thence southeast along the ridge of the Casmalia Hills, crossing Schumann Canyon about one-half mile south of Schumann Station and continuing southwest down the canyon, where the principal wells are now located, and finally plunging out of sight at a point on the state highway, about one mile south of Divide Station.

The formations exposed consist of Monterey shale along the axis of the anticline, and on the north flank that slopes to the Santa Maria Valley the Monterey is overlaid by Fernando sands and clays. On the south flank near Casmalia station the Monterey is overlaid by recent terrace deposits

[1] U. S. Geological Survey. Bull. 322. Geology and Oil Resources of the Santa Maria Oil District, 1907. By Ralph Arnold and Robert Anderson.

The dips on the flanks of the folds vary from 8° to 40° in the area east of Schumann Canyon and in the territory to the west they run from 20° to 80°. The plunge to the southeast averages about 5°.

The oil originated from the diatomaceous shale of the Monterey and has collected in the hard, flinty, fractured areas of the shale. The field has no true oil sands.

An examination of the Monterey shows that only the lower half is present, the upper portion having been removed by erosion. The large deposit of tar and the burnt shale areas in the hills west of Schumann Canyon probably represent the basal oil measures of the Monterey formation. On the axis of the fold south of Waldorf, the Vaqueros sandstone is exposed. East of Schumann Canyon the plunge of the anticline has covered the oil measures with a thickness of about 1600 feet of Monterey shale, which acts as a capping for the oil.

The proven areas consist of approximately 1940 acres, which lie between Casmalia and Schumann Stations and east of the Southern Pacific Railroad. In December, 1920, the total daily production from the field was 4517 barrels of oil. The average number of wells producing during this period was 87 with an average daily production per well of 52 barrels of oil and 150 of water. This large water production is due to the failure to exclude bottom water and to the fact that the lower oil measures contain both oil and water. The gravity of the oil varies from 9° to 17° Baumé in the western portion of the field, but increases in gravity to the southeast; wells on the Escolle lease of the Union show oil as high as 25° Baumé. Detailed reports on the underground structure and the water conditions may be found in the annual reports of the State Oil and Gas Supervisor.[1]

Drilling has shown that the productive area on the north flank of the anticline is about 1000 feet in width and on the south flank about 3000 feet in width. Efforts to extend the field along the axis of the fold in the hills west of Schumann Canyon and the railroad have resulted in failures, this being due to the fact that the oil measures of the Monterey are exposed on the surface in this area and contain no impervious capping. The most westerly test wells were drilled by the Standard Oil Company, on the steeply dipping north flank of the Schumann anticline southwest of Waldorf Station. The wells failed to show any oil or to penetrate the basal bituminous beds of the Monterey, which outcrops to the south. Outcrops of bituminous sands, probably of Vaqueros age, are exposed on the axis of the fold south of the above mentioned Standard wells and the Vaqueros may possibly contain oil in this area. Wells to test these sands out should be located on the axis of the fold and not on the steep dipping north flank, as selected by the Standard. It is possible that in time the mining and distillation of the bituminous shales of this area will be found profitable.

To the east of Schumann Canyon it is probable that the field may be extended beyond the present southeast limits of the proven area. Recent drilling shows that this extension will probably continue for at least a

[1]Second Annual Report of the State Oil and Gas Supervisor, pp. 204-207.
Third Annual Report of the State Oil and Gas Supervisor, pp. 361-369, 372-384.
Fifth Annual Report of the State Oil and Gas Supervisor. Summary of Operations California Oil Fields, April, 1920. Report on the Casmalia Field. By H. W. Bell. Pp. 10–40.

mile along the axis of the fold southeast of Well No. 13, Escolle Union Oil Company.

The Santa Maria field proper, known as the "old field," lies to the east of the Casmalia field in a group of low hills known as the Solomon Hills.

The structure consists of a series of small, sharply-folded anticlines lying to the south and west of Mount Solomon. The greater part of the surface of the field is covered by a small thickness of sands and clays of the Fernando formation, which bear no relation to the accumulation of the oil and serve only to obscure the real structure. Beneath the Fernando is found the Monterey formation, the upper portion of which outcrops in Pine Canyon and on the Newlove lease of the Union Oil Company. At both of these localities, the Monterey is bituminous and numerous seepages and burnt shale areas are in evidence. The upper portion of the Monterey contains what is known as the '1st zone,' which is productive to the extent of about ten barrel wells in certain portions of the field. The oil runs in gravity from 16° to 20°.

Beneath the 1st oil zone, the Monterey is composed of a thickness of about 1600 feet of blue shale, which serves as an impervious capping for the 2nd oil zone, which lies at the base of the Monterey. The oil of the 2nd zone has collected in the fractured flinty shale that makes up this portion of the Monterey. The gravity varies from 20° to 38°. This zone was formerly the chief source of production in the field. The 3rd zone, now the chief source of production, is probably in the uppermost Vaqueros, at its contact with the Monterey. The oil measures in this zone are true sands. Underground contour maps indicate that this contact between the Monterey and the oil sand of the Vaqueros may be a fault contact, particularly in the vicinity of the Newlove lease of the Union Oil Company. Fig. 2, Section 2, shows the general structure of the field.

Detailed reports covering the underground structure and water conditions can be found in the various annual reports of the State Oil and Gas Supervisor.[1]

The total proven area in March, 1921, was 4620 acres. The total daily production in December, 1920, was 8006 barrels of oil. The average number of wells producing during this month was 232, with an average daily production per well of 34.5 barrels of oil and 29.5 barrels of water. The limits of the field have been defined by past drilling and there will probably be no appreciable extension of these limits. There, however, remain extensive areas, particularly in the western portion of the field, that have not been drilled up to date.

The Cat Canyon field lies along the canyon of that name, north and east of the Santa Maria field. The formations exposed on the surface consist of terrace deposits and Fernando sands and clays. The total thickness of the terrace deposits is about fifty feet and the Fernando outcrops from 600 to 800 feet. The Monterey shale is present beneath the Fernando and it is both the source and reservoir for the oil, which averages about 15° in gravity.

The structure, according to Arnold and Anderson,[2] consists of two parallel anticlines, about two miles apart, with a northwest-southeast

[1]First Annual Report of the State Oil and Gas Supervisor, pp. 198-203, 205-211.
Second Annual Report of the State Oil and Gas Supervisor, pp. 202-204.
Third Annual Report of the State Oil and Gas Supervisor, pp. 370-371.

[2]U. S. Geological Survey. Bull. 322. Geology and Oil Resources of the Santa Maria Oil District. By R. Arnold and R. Anderson, 1907.

trend. The most southerly fold, known as the Gato Ridge anticline, according to surface dips runs along the top of the ridge on the south side of Cañada del Gato. Drilling, however, has shown that the actual productive fold in the underlying Monterey lies about one mile north of where Arnold and Anderson located the axis, from dips in the Fernando. The axis, as determined by drilling, apparently runs through Palmer Union No. 1 in Sec. 26, T. 9 N., R. 33 W., S. B. M., and thence southeast, passing near the location of the Associated Oil Company's well, Recruit No. 1, on Sec. 31, T. 9 N., R. 32 W., and from there continuing southeast to the head of Howard Canyon. The principal area of production lies at the northwest end of this fold in Sec. 26. The Bell wells of the Pan-American Company, located on the Bell Ranch and on the axis of the fold, as shown by Arnold and Anderson, have failed to produce any appreciable amount of oil and the majority of them have been abandoned. The second anticline runs along the ridge marking the north side of Cañada del Gato and its location on the surface in the Fernando beds is slightly north of its location in the underlying Monterey. The principal area of production on this fold centers around Sec. 30, T. 9 N., R. 32 W., S. B. M. The oil measures in the Cat Canyon field are true sands and probably represent sandstone beds in the middle Monterey. The wells vary in depth from 2400 to 3100, according to their position on the fold. The total area of proven land in March, 1921, was approximately 1850 acres. The total daily production in December, 1920, was 2333 barrels of oil. The average number of producing wells during this period was 40, with a daily average production per well of 56.3 barrels of oil and 8 of water. It is probable that the limits of the proven areas may be extended to the southeast along the axes of both folds. Detailed reports on the underground structure may be found in the annual reports of the State Oil and Gas Supervisor.[1]

The Purisima Hills field lies to the south of the proven area above described. That portion of the field which may be considered as proven occupies the western end of the Purisima Hills, in the vicinity of the Lompoc grade, and the area has been frequently called the Lompoc field.

The dominant structure of this region is a broad anticline running west from Red Rock Mountain to the Lompoc Grade, where it disappears under the terrace deposits of Burton Mesa. At the west end, near the Hill wells of the Union Oil Company, the south flank of the fold is faulted. This fault appears to have influenced the accumulation of the oil, as the wells in the vicinity of the fault zone have been the best producers. The formations consist of the Fernando and the Monterey, the latter being both the source and reservoir for the oil.

The total proven area in March, 1921, was 1193 acres. The total daily production in December, 1920, was 1367 barrels of oil. The average number of wells producing during this period was 27, with an average daily production per well of 50 barrels of oil and 70 of water.

Surface geology indicates that the field may possibly be extended. That portion of the Purisima Hills between the Lompoc field and Red Rock Mountain, a distance of approximately ten miles, may be considered as possible oil territory. The most favorable localities would be along

[1]First Annual Report State Oil and Gas Supervisor, pp. 203-204.
Second Annual Report of the State Oil and Gas Supervisor, pp. 210-219.

the axis of the anticline above mentioned and along an eastward continuation of the fault zone noted. There are large deposits of asphaltum in the Monterey near Red Rock Mountain, indicating that the Monterey carries petroleum in the eastern end of the Hills. The possibility of finding production in commercial quantities depends on the presence of the thick blue shale zone, which acts as a capping for the 2nd and 3rd oil zones of the Santa Maria field. If this blue shale is present in the Purisima Hills, overlying the fractured flinty bituminous shale zone as exposed in the vicinity of Red Rock Mountain, then the possibility of a large area in the eastern portion being productive is good.

Five wells are now being drilled to test out this area. Harris No. 1 and Careaga No. 87 of the Western Union Company are located on the axis of the anticline about one mile east of the proven area. Pinal Dome No. 1 is located on the eastern extension of the fault zone and has apparently the best chance. At the eastward end of the Hills, the General Petroleum Corporation is drilling a well in Drum Canyon on the axis of the fold and about two miles farther east, near Red Rock Mountain, the Standard Oil Company is drilling a well.

The territory west of the Lompoc field is known as Burton Mesa. The surface formation is mainly terrace deposits, with some underlying Monterey exposed in the canyons. On account of the overlying terrace deposits the true structure of the region is obscure. Wherever the Monterey is exposed it apparently is folded into a number of small anticlines. At the western end of the Mesa, along the coast line, hard flinty Monterey shale with numerous seepages is exposed. The area might be considered as worthy of further investigation.

Outlying Areas.

The general area of the Santa Ynez Mountains west of the town of Santa Barbara offers no inducement for drilling. The core of the range is composed mainly of Eocene and Oligocene sandstones and Vaqueros sandstone. Along the edge of the Santa Ynez Valley there are small areas of highly-folded Monterey shale, and along the coast there is a very small thickness of Monterey shale exposed along the sea cliffs, overlying the Vaqueros sandstone and dipping about 40° to the south. The Monterey here is slightly bituminous in places. The general structure of the range is that of a great monocline, which dips from the high central ridge at an angle of about 45° to the south.

The San Rafael Range is composed mainly of Cretaceous and Eocene sediments, all highly folded and containing no evidence of petroleum. On the south flank, north of the Santa Maria Valley, there is a large area of highly-folded Monterey shale, probably representing the lower portion of this formation. In the southeastern portion of this area, between Foxen Canyon and Sisquoc River, the Monterey is overlaid by thin patches of Fernando, at the contact of which there are large deposits of asphaltum as well as in the shale itself. The asphaltum deposits are located along Asphaltum Creek and Zaca Creek and on Labrea Creek, north of the Sisquoc River. The territory is not favorable for well drilling, but offers a possibility of mining and distilling the bituminous deposits. In the hills due north from Los Olivos, the Fernando is exposed in a broad anticline, which has been tested by the Standard Oil

Company, in two wells. No oil was encountered and the drilling demonstrated what is evident from a study of the territory to the north, that is, the Monterey is missing on this fold, the wells penetrating Franciscan serpentine after going through the Fernando.

In prospecting for oil in the Santa Maria district the following facts must be borne in mind: (1) All production is in the lower portion of the Monterey and in one instance in the uppermost Vaqueros. (2) Commercial production is only found when the lower flinty productive zone of the Monterey is capped by the impervious blue shale body. (3) The Fernando is not productive, nor do folds in the Fernando reflect the structure in the underlying Monterey.

Area of the Cuyama Valley.

The Cuyama Valley lies along the north flank of the San Rafael Mountains, which locally are sometimes known as the Cuyama Mountains. Along its western portion the valley forms the dividing line between Santa Barbara and San Luis Obispo counties. The extreme eastern portion lies in Ventura County. The geology and oil resources of the major portion of the valley have been reported on by the United States Geological Survey[1] and the conclusion of English's report is as follows:

"Conditions in Cuyama Valley.

"As the association of sandy beds with the shale which was the original source of the oil is one of the most important conditions in productive fields, the discussion of the Cuyama Valley area will be based on the areal distribution and character of such shale. The shales present in the Cuyama Valley are the thick mass of pre-Monterey shale, the shale in the Vaqueros formation, the Maricopa shale, and the locally well-developed Whiterock Bluff shale member of the Santa Margarita formation.

"There appears to be little possibility of obtaining oil from beds associated with the dark clay shale of the pre-Monterey rocks, which crops out over considerable areas in the rugged mountains on the south side and in the western part of the Cuyama Valley. Lithologically similar shale of Cretaceous age on the west side of the Sacramento Valley contains oil seeps, and in the Santa Clara River valley some of the oil probably originated in the Topatopa (Eocene) shale, which is of much the same type and possibly of the same age as the shale of the pre-Monterey in this area. However, in the area examined no seeps or other evidence of the presence of oil were found or were reported in this shale, or in overlying beds, so that it seems unlikely that any appreciable amount of oil derived from it is present either in the interbedded sandstones or in porous overlying formations. Much the same reasoning may be applied to the dark clay shale and interbedded sandstone of the Vaqueros formation, which constitutes the main mass of the Caliente Range.

"Of the other formations, the pearl-gray shale in the vicinity of Montgomery Potrero, the pinkish Maricopa shale on the flanks of the Caliente Range, and the "chalky" Whiterock Bluff shale member of the Santa Margarita are the only beds that are of a lithologic type in which it seems likely that oil may have originated, and only those general areas in which one of these shales crops out or is believed to be present below the surface are thought to be likely to produce oil.

"The gray diatomaceous shale which is mapped as a part of the Pato red member of the Vaqueros and which underlies the prominent white sandstone of the Vaqueros at Montgomery Potrero has a very irregular distribution, being absent along the Monterey and pre-Monterey contact west of Branch Canyon and on the south side of the tilted block of pre-Monterey rocks at the head of Castro Canyon. It probably underlies the western part of the prominent anticline north of Salisbury Potrero, but its slight thickness and meager content of diatomaceous material make it insignificant in comparison with the great mass of diatomaceous shale in productive fields. No seeps are known to occur in this shale or in associated porous rocks. The chance of obtaining commercial quantities of oil from beds overlying this shale in the area mapped is therefore probably slight.

"The Maricopa shale, in the upper part of the Monterey group of the Caliente Range, has a maximum thickness of about 2000 feet, and although less diatomaceous than the typical "Monterey shale," it may have been the source of considerable quantities of petroleum. Two or three oil seeps have been reported in this shale.

[1]U. S. Geological Survey. Bull. 621-M. Geology and Oil Prospects of the Cuyama Valley. By W. A. English, 1916.

"The white diatomaceous shale in the Whiterock Bluff shale member is locally over 1000 feet thick and may have been the source of considerable quantities of oil. It is significant that the seep south of Whiterock Bluff occurs at a point where this shale is thickest as well as most diatomaceous. Areas of favorable structure underlain by either this or the Maricopa shale would deserve very careful consideration as being possibly productive. Unfortunately no such areas of favorable structure were found.

"The structure in the Caliente Range is unfavorable for the collection of oil from either of these formations, as they are overlain by porous beds only on the flanks of the anticline, where the beds stand nearly on edge. The Whiterock Bluff shale member of the Santa Margarita west of the fault that trends northwest from the mouth of Morales Canyon is thin but very diatomaceous. However, the broad syncline in which it lies is not a favorable structure for the accumulation of oil.

"Between Whiterock Bluff and the outcrop of the Santa Margarita formation, west of Salisbury Canyon, and northward to Cuyama River is an area in which a determination of either the structure or the distribution of the formations that may have been a source of oil is uncertain because of the presence over most of the surface of the Cuyama formation and terrace gravels. As the underlying structure is unknown this area cannot be classed as definitely barren of oil, although there is no positive evidence to recommend it as an area favorable for oil accumulation. The small area of pre-Monterey rocks overlain by the Morales member of the Santa Margarita south of Whiterock Bluff is important as showing that the diatomaceous shale does not extend directly south from Whiterock Bluff to the edge of the valley. In the absence of more definite evidence it may be assumed that the diatomaceous shale is absent south of a line drawn from the small area mentioned to the point where Aliso Canyon enters the main body of pre-Monterey rocks. Northeast of that line the Cuyama River, and the Whiterock Bluff shale between Salisbury and Aliso canyons is less diatomaceous than at Whiterock Bluff. If one may judge of the amount of oil formed in the shale by its thickness and the amount of diatom skeletons present in it, then only a comparatively small quantity of oil should be expected to occur in this area. Any oil which may have originated in these shales might have collected either in interbedded sandstones or at the base of the Cuyama formation, having seeped up from the eroded edge of the underlying shale. A well of comparatively shallow depth located on any one of a number of low local anticlines in the Cuyama formation would test the sands at the base of that formation, as the Cuyama formation in this area is probably not over 200 or 300 feet thick. This thickness of beds would probably not give sufficient covering to retain any large quantity of oil, and the very marked unconformity between the Santa Margarita and Cuyama formations suggests that a large part of the oil might have escaped from the lower beds before the overlying beds were deposited, so that on the whole the prospect of obtaining more than small quantities of oil, if any, in this area is not promising.

"Oil Seeps.

"The largest seep reported, and the only one seen by the writer, occurs in the bed of the Cuyama River south of Whiterock Bluff. The river has cut down about twenty feet through Quaternary stream deposits and is flowing on bedrock, here diatomaceous shale of the Whiterock Bluff member of the Santa Margarita. During an earlier epoch the river cut down to the same level and formed a much wider valley in which the stream gravel and sand that form the vertical banks of the present stream were deposited. It was during this earlier epoch in which the river flowed upon bedrock that most of the oil now seen at this locality seeped up from the underlying shale of the Santa Margarita. While the river was flowing on bedrock and while it was depositing three or four feet of sand a number of pools of oil were formed here, some not less than 100 yards across. The oil in these pools saturated the surface sand, which was later covered by sediment and preserved and which is now traceable along the vertical river banks as thin strata of oil sand interbedded with white sand and clay. At one place, which may have been the original seep, an asphalt-like oil has escaped from the underlying shale very recently. The shale near this seep has irregular dips and the oil may have come up along or close to a fault.

"At least three seeps of oil are reported in areas of Maricopa shale of the Monterey group in the Caliente Range, but at the time of the writer's visit, they could not be located and had probably ceased to flow. A reported seep in a small canyon in the NW. ¼ Sec. 15, T. 11 N., R. 28 W., could not be found. There is said to be a small brea deposit on a ridge in the SE. ¼ Sec. 14, T. 11 N., R. 28 W. A seep reported in the creek bed near the forks of Taylor Canyon, in the SE. ¼ Sec. 24, T. 32 S., R. 19 E., has also apparently ceased to exist.

"Wells Drilled for Oil.

"The Webfoot well, in a narrow gulch on the north side of Ballinger Canyon, in the SE. ¼ Sec. 2, T. 9 N., R. 24 W., was started about 1905, and drilling continued intermittently for a number of years. It is said to have reached a depth of 1800 feet without encountering any oil. This well starts in nearly vertical beds of brown sandy shale of the Monterey group.

"The Grand Prize Oil Company, composed of Bakersfield and local people, drilled a well in Sec. 6, T. 11 N., R. 28 W., at about the same time as the Webfoot well was drilled. This well is said to have reached a depth of 600 or 700 feet without obtaining any oil. It starts in the "chalky" white shale of the Whiterock Bluff shale member of the Santa Margarita and probably reaches the underlying pre-Monterey rock. It is located on the south flank of a broad syncline."

It is apparent from the above report that the possibility of any appreciable production of oil in the Cuyama Valley is slight.

Coast Area of Santa Barbara County.

The only other area in the county, outside of the Santa Maria District, that contains any oil possibilities is the narrow coastal strip, from Goleta to the Ventura County line. The territory contains one small proven district, namely the Summerland field, located about eight miles east of Santa Barbara. There are possiblities, however, that other similar fields may be developed in this area.

The coastal strip, with an average width of almost five miles, lies between the rugged, steep Santa Ynez Range and the Pacific Ocean. The Santa Ynez Range at this point is composed of highly-tilted rocks of Eocene and Oligocene age, corresponding to the Topatopa and Sespe formations of Ventura County. The organic shales of the Topatopa have been the source of some oil which has collected in beds along the contact with the Sespe. In the area under discussion, this condition exists in the foothill area of the Santa Ynez, east of Summerland, in Toro, Oil and Santa Monica canyons

Along the coastal strip, the oil is found in the Fernando sandstone, having accumulated there from the underlying Monterey. This is the condition that exists in the Summerland field, the structure of which is a steep monocline in the underlying Monterey with small minor folds in the overlying Fernando. The field is located along the water's edge and the majority of the wells are drilled from wharves extending out into the sea. The depths range from 100 to 600 feet and the gravity from 14° to 16° Baumé.

In December, 1920, the total number of wells producing was 120. The average production per day per well was 1.4 barrels of oil and 14.2 barrels of water. The total daily production from the entire field was 168 barrels of oil.

The most favorable location for new fields in the coastal area would be where the Fernando is folded in anticlines, overlying the Monterey. Two such areas are apparently present; one lying in the hills between Santa Barbara and Goleta and the second between Santa Barbara and Montecito. In the first area a well was drilled some years ago on the Hope Ranch by the Associated Oil Company, called the Recruit well. A depth of 2800 feet was reached and considerable gas was encountered.

The foothills of the Santa Ynez Mountains, northeast of Summerland, in the vicinity of Toro and Santa Monica, offer a possibility of small production of Eocene oil.

At Rincon there are some shallow wells which have obtained slight showings. The region between Santa Barbara and Carpinteria, including the Summerland field, has been reported in detail by the United States Geological Survey.[1].

[1]U. S. Geological Survey. Bull. 321. Geology and Oil of the Summerland District. By R. Arnold, 1907.

Following is a portion of the report regarding the old wells in the outlying areas and future possibilities of these areas:

"Wells Near Loon Point.

"Several prospect wells have been put down in the Fernando formation near Loon Point, about a mile east of the Summerland field, but none were successful, although oil sands with traces of oil were penetrated in most of them It is the opinion of the writer that the paucity of petroleum is due to the position of the Fernando beds, which are believed to overlie here the nonbituminous Vaqueros rather than the petroliferous Monterey as they do farther north in the Summerland field. The position of the Loon Point wells relative to the anticline is apparently advantageous and the only reason that can be assigned for their nonproductiveness is that stated above.

"Wells Near Carpinteria and Rincon Creek.

"Several wells, at least one attaining a depth of over 3000 feet, have been sunk on the lowlands in the region near Carpinteria and the mouth of Rincon Creek, five to eight miles east of Summerland. Traces of oil were found in all of them, but none so far have been highly successful. In all the wells the strata penetrated beneath the superficial Pleistocene deposits have been the Monterey (middle Miocene) bituminous shale, which lies in steeply dipping positions throughout this coastal belt.

"The most important and deepest well is that of the Columbia Oil and Asphalt Company, located on the north side of the railroad one-half mile east of the asphalt mine at Carpinteria. It is put down in line with the axis of a sharp auticline which extends into the ocean about a mile east of the mouth of Carpinteria Creek, near the edge of the area shown on the map. No definite information concerning the well was obtainable at the time of the writer's visit (October, 1906), but the following notes were gleaned from various sources: The well penetrates shale throughout the greater part of its depth, is about 3000 feet deep, and encounters artesian water with a head of 12 feet at 100 to 150 feet, asphaltum at 1200 to 1400 feet, and oil in sandy layers in the lower 100 feet. The oil in the sump is black and heavy, although it is said by the operators that oil of 37° gravity was struck near the bottom. The oil is accompanied by a strong gas pressure. Gas was also encountered with the asphaltum between 1200 and 1400 feet, forcing the asphaltum up in the hole for a distance of 180 feet when first struck. Only a small amount of oil was on the sump, indicating that the production of the well is probably not large.

"Several years ago a well was sunk in the shale at the edge of the bluff about one-fourth mile east of the asphalt mine. Heavy oil was struck, but it was too viscous for pumping, and the well was abandoned. The casing of this hole still protrudes from the ground, and a heavy oil, accompanied by considerable gas, is slowly escaping from it. It is said that a second well was sunk a short distance farther northeast, but that no oil of consequence was encountered in it. As the first well is near the northern limit of a highly disturbed zone, it seems very likely that the reason no oil was encountered in the second well was because it penetrated beds which were so little fractured that the oil had no channels of migration through them.

"In 1894 a 4 by 6 foot well was dug to a depth of 354 feet by P. C. Higgins, on the seashore one-half mile west of the asphalt mine. Purplish bituminous shale, with casts of the fossil *Pecten peckhami* Gabb, was the only formation penetrated, and no oil was encountered.

"A 400-foot well was drilled by J. Heath on the Hill ranch just north of the mouth of Rincon Creek, oil being struck in small quantities from 150 feet downward.

"Watts[1] gives the following reference to prospect wells of the Arctic Oil Company, east of Carpinteria:

" 'Well No. 1, seven miles south of Rincon Creek. 1825 feet deep; formation, red sandstone; no oil. Well No. 2, 50 feet distant from Well No. 1, 2100 feet deep; formation, red sandstone; no oil. Well No. 3, on Southern Pacific Railroad, 1½ miles east of Carpinteria; conglomerate and sandy shale to 700 feet; shale and sandstone to 1200 feet; liquid asphaltum; well abandoned.'

"The conglomerate here mentioned is probably the Pleistocene gravel and sand, which overlies the Monterey shale to a depth of over a hundred feet in the region northeast of Carpinteria.

"At the time of the writer's visit to Carpinteria (October, 1906), it was reported that a well was being sunk at Shepards, two miles northeast of the mouth of Rincon Creek, but no data concerning its depth or the formation penetrated were obtainable.

"Wells in the Mountains Northeast of Summerland.

"Several wells have at different times been put down in the Topatopa formation (Eocene) in the mountains east and northeast of Summerland. The wells have all been located near oil springs or seepages, and have without exception yielded traces and some of them commercial quantities of oil. Light yields and lack of proper transportation and market facilities have discouraged development, and at the present time none of the wels are being operated. Among the wells are those of the Santa Barbara Oil Company in Oil Canyon, the Occidental Mining and Petroleum Company in Toro Canyon, the Santa Monica Oil Company in Santa Monica Canyon, and the Pinal Oil Company at the mouth of Arroyo Parida. These will be briefly described.

"Two wells were drilled by the Santa Barbara Oil Company in Oil Canyon about 3¾ miles northeast of Summerland. The rocks here exposed are the overturned upper Topatopa shale, which dips steeply at angles ranging from 60° N. to vertical; oil springs occur in them in the immediate neighborhood of the wells. The wells start down in

[1]Bull. California State Mining Bureau. No. 19, 1900, p. 104.

the shale, but may penetrate to the stratigraphically higher, but actually lower upper sandstone belt. The wells are between 500 and 600 feet deep, and yielded small quantities of oil and much gas.

"Seven wells and one tunnel have been sunk by the Occidental Mining and Petroleum Company in Toro Canyon, about 3¼ miles northeast of Summerland and three-fourths of a mile west of those of the Santa Barbara Oil Company just described. The formation at the Occidental wells is the same as that in Oil Canyon, and the wells doubtless derive their oil from the same zone. The wells range in depth from 200 to 1100 feet. Four of them were classed as productive and three dry, although the latter contained traces of oil. No. 1 is said to have produced a total of 5000 barrels and No. 5 was rated as a five-barrel well; the average for the productive wells was about two to three barrels a day each. In August, 1895, only one well was pumping, and the oil from this was largely mixed with water. The oil is black and of 17° Baumé gravity when it first comes from the wells, but on standing for a little while drops to 14°. The tunnel is 511 feet long and runs in a N. 10° E. direction into the mountains. It penetrates sandstone composed of quartz, feldspar and green and reddish minerals, interbedded with the greenish shale. It yielded little oil but much water, and the latter is now being used in Summerland. An analysis of this water is given on page 24.

"The well of the Santa Monica Oil Company is located two miles north of Carpinteria, near the mouth of Santa Monica Canyon. It starts down in the lowest Sespe sandstone, which here dips 60° S., 10° W., and penetrates the alternating sandstone and shale of the uppermost Topatopa. A yield of eight barrels a day of 18° amber-colored oil accompanied by strong gas pressure was encountered at 400 feet. At 700 feet a strong flow of sulphur water 'drowned out' the oil and the well is now abandoned.

"The Pinal Oil Company is putting down a well at the mouth of Arroyo Parida Canyon, about 3¼ miles east of Summerland. It penetrates the lowest Sespe sandstone and the uppermost Topatopa alternating sandstone and shales, which here dip 60° S. It is thought that the well will reach the oil in sands under a certain shell at a depth of something more than 1000 feet.

"General Conclusion.

"The conditions of structure do not appear to favor the probability of striking remunerative deposits of oil by deep drilling. It is true that oil would probably be encountered in wells 2000 or more feet in depth put down almost anywhere over the territory underlain by the Monterey shale, but the steep dips and close texture of the shale apparently preclude the accumulation of such great deposits of oil as are found in fields where the rocks are less steeply inclined and more porous.

"Region Near Carpinteria.

"The last paragraph is as applicable to the region about Carpinteria and to the east as far as the contorted condition of the shale extends as it is to that territory about Summerland which is underlain by the Monterey. More or less oil is inclosed in the shale and in local interbedded sandstones, but it does not appear likely that heavy producers will ever be encountered in a region of such distortion and fracturing as is prevalent in the Monterey shale all along this part of the coast, although in certain facies of the shale fracturing seems to be essential to the migration of the oil within or through it.

"Region West of Montecito.

"It is thought that wells sunk deep enough to penetrate the basal beds of the Fernando formation in the region of the Montecito anticline, which extends indefinitely west-northward from the coast one mile west of Montecito Landing, will strike deposits of oil of about the same quality as the best of that encountered at Summerland.

"Region of the Topatopa Formation (Eocene) Northeast of Summerland.

"In the light of the development which has already taken place in Toro, Oil, Santa Monica and Arroyo Parida canyons, it seems almost certain that light producers (averaging from two to six or eight barrels a day of 14° to 18° oil), 1000 feet or less in depth, could be put down at many places along the contact between the upper Topatopa shale and sandstone zones or the contact between the Topatopa and Sespe formations in the region northeast of Summerland. The oil-bearing strata in both of these belts are apparently confined to the upper part of the Topatopa, and to obtain productive wells is simply a question of locating places where the structure appears most advantageous for the accumulation of the petroleum. The region near the Arroyo Parida fault, toward the east end of the area covered by the map, appears promising, although the wells here, especially on the north side of the fault, would have to go much deeper to strike the oil zone than they do at the tested localities."

In Bulletin 63, California State Mining Bureau, "Petroleum in Southern California," by Paul W. Prutzman, 1913, pages 339–415, a complete list of all wildcat wells in the county and their results up to 1913 is given. McLaughlin and Waring[1], in their bulletin, give a somewhat briefer account of Santa Barbara County.

[1]California State Mining Bureau. Bull 69. Petroleum Industry of California, 1914. By R. P. McLaughlin and C. A. Waring.

ʻeological Survey. Bull. 309. The Santa Clara Valley, Puente Hills and Los
il Districts. By G. H. Eldridge and Ralph Arnold.

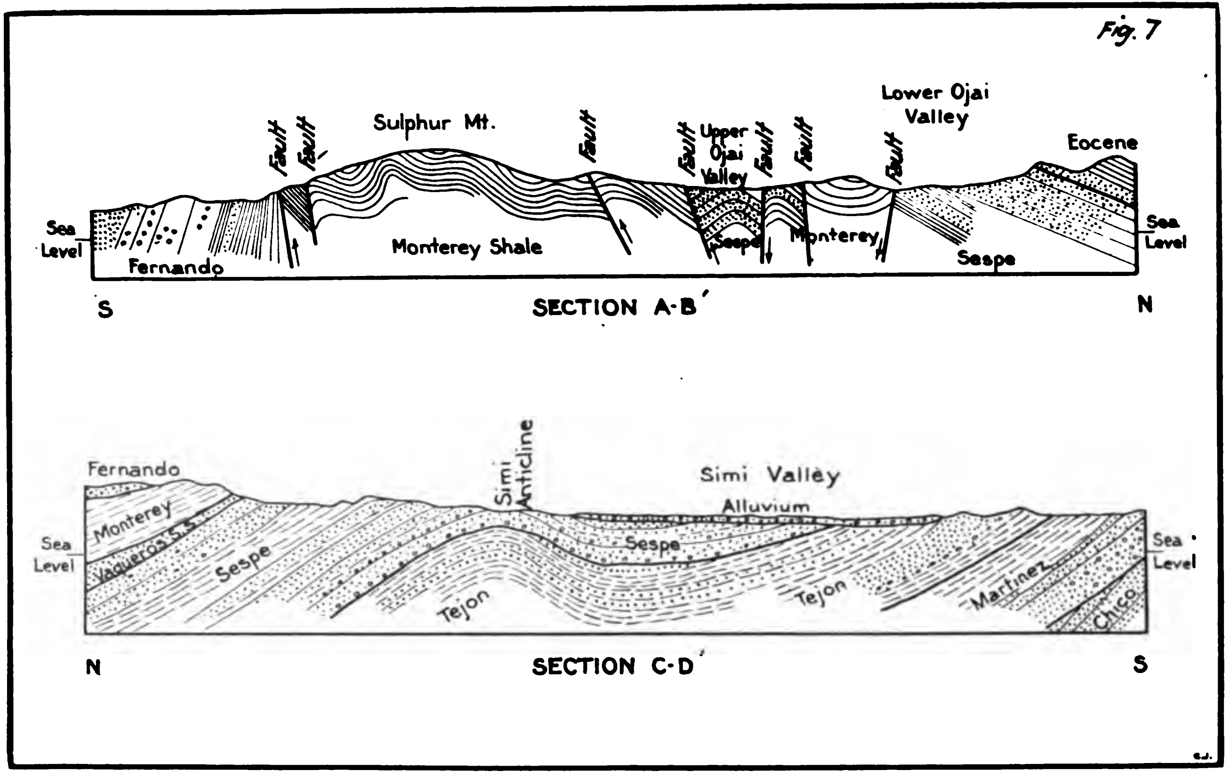

FIG. 7. Section A-B—North-south section across Sulphur Mountain and Ojai Valley, in the vicinity of the Upper Ojai fields, Ventura County (adapted from the U. S. G. S. Bull 309). Section C-D—North-south section across the Simi Valley, Ventura County, in the vicinity of Simi (adapted from the U. S. G. S. Bull. 691-M).

of the upper Ojai Valley merge about one-fourth of a mile north and east of the point where Sisar Creek turns from a south direction and flows east. From this point east the structure consists of a single overthrust fault, in which the older Sespe and Topatopa beds on the north side of the fault have been thrust over the Monterey beds of Sulphur Mountain region. The oil has migrated from the diatomaceous shale of the Monterey and collected in the sandstone beds of the Sespe along the contact. The majority of wells are located north of the fault line and start down in the Sespe, penetrating the oil sands along the fault contact. The wells are small and there is little possibility of any considerable increase in production. However, the eastward limits of the field towards Santa Paula Canyon can probably be extended with profit.

In March, 1921, the total proven area in the Ojai Valley fields was 297 acres. In December, 1920, the total daily production was 192 barrels of oil. The average number of wells producing at this time was 42 and the daily average production per well was 4.4 barrels of oil and 3.9 barrels of water.

SANTA PAULA FIELD.

This name is applied to a number of isolated areas of production lying along the south side of the Sulphur Mountain and Santa Paula Ridge. Those areas on the south side of Sulphur Mountain and west of Santa Paula are found at the heads of Aliso, Wheeler and Adams canyons and those on the south side of Santa Paula Ridge and east of Santa Paula are found at the head of Onlauf and Timber canyons.

The structure that has caused the accumulation of the oil is a great overthrust fault, which starts at the extreme western end of Sulphur Mountain on the Ventura River and runs east along the south flank of the mountain, crossing Santa Paula Canyon about one mile south of Sulphur Mountain Spring and thence continuing to the east along the steep south flank of Santa Paula Ridge to Timber Canyon. At this point it merges with the fault from the Sisar Canyon field and the two continue as a single fault, running northeast around the base of Mount San Cayetano to Sespe Creek. The fault zone is clearly visible, being marked by a steep escarpment, along Sulphur Mountain and Santa Paula Ridge and it abruptly terminates the headwaters of the various canyons above mentioned.

The formation lying to the south of the fault, and which has been overthrust by the older formations to the north, consists of Fernando sands, clays and gravels. The formations to the north of the fault consist of the broad area of Monterey shale, occupying the Sulphur Mountain region. Owing to the convergence of the two faults at Timber Canyon, this Monterey area gradually thins and becomes wedge shaped towards the east and finally disappears entirely at Timber Canyon. From Timber Canyon east, the formation north of the fault is the Topatopa sandstone and shale. The magnitude of the faulting has thrust this formation over the Fernando, and the Monterey is entirely lacking on the surface but is undoubtedly present beneath the Fernando. The south end of Sec. AB, Fig. 7 shows the structure on the south side of Sulphur Mountain. The oil has formed in the Monterey and has collected in the Fernando sands along the fault contact. The oil runs in gravity from 24° to 28° Baumé in the Sulphur area and averages about 32° gravity in the Timber Canyon area. The total proven area of the Santa Paula field in March, 1921, was approximately 170 acres. The total daily average production in December, 1920, was 139 barrels of oil. The average number of wells producing during this period was 65, with a daily average production per well of 2.2 barrels of oil and 0.7 of water.

The wells start down in the area of the fault zone and penetrate to the plane of contact, the average depth being about 1000 feet. The width of the field north and south of the fault is limited to a distance of about one-fourth of a mile, and there can be no appreciable extension in this direction. In an east and west direction, along the axis of the fault, there is much room for development and there is apparently no reason why there should not be a continuous line of small wells joining up the now isolated groups. There has been no development along the fault east of Timber Canyon and this area affords a possibility of small well development. The possibility of commercial returns depends upon whether the overthrust faulting has not buried the oil sands at too great a depth.

VENTURA FIELD.

This field lies along the Ventura River and consists of two proven areas. The most southerly area is about two and one-half miles northeast of the town of Ventura and is commonly known as the Ventura Avenue field. The structure consists of a simple anticlinal fold, known as the Ventura anticline, trending approximately east-west, and crossing the Ventura River at right angles. This fold continues westward from the river for a distance of about eight miles, finally striking out to sea about one-fourth of a mile northwest of Sea Cliff Station. Eastward from the river it extends a distance of about six miles, dying out on Aliso Creek. The proven area consists of about 300 acres on the axis of the fold at the point where it crosses the Ventura River. The formations exposed on the anticline consist of Fernando sands, clays, shales and gravels. This formation acts as the reservoir for the oil, which was probably formed in the underlying Monterey. To date, two oil zones have been recognized—an upper or light oil zone, extending from 1900 to 3000 feet and yielding oil of from 48° to 56° Baumé gravity; the second, or heavy oil zone, is found below 3000 feet and yields oil of from 30° to 38° Baumé gravity. The light oil zone at one time gave promise of being capable of producing wells as high as 150 barrels per day, but careless drilling by some of the pioneer companies has resulted in this zone being flooded by water, so that the present production is extremely small. The second zone has not to date been thoroughly explored, but it is apparent that it is capable of yielding from 200- to 300-barrel wells and possibly more in deeper sand yet to be encountered. The limits of the field have not been defined and it is probable that they can be extended for some distance westward from the Taylor wells of the Shell Company, along the axis of the fold, and a similar extension may be made to the east beyond the Lloyd wells of the Associated Oil Company. A detailed report on the underground condition may be found in the fifth annual report of the State Oil and Gas Supervisor.[1]

The second proven area on the Ventura River consists of a small section on the east side in the vicinity of Fresno Canyon and east of La Crosse Station, covering about fifty acres. It may be considered as a continuation of the small proven areas along the south side of Sulphur Mountain, which were described under the article on the Santa Paula field. The geology and method of accumulations are similar. The yield of the wells is small and the commercial value of the district is somewhat doubtful. There is no doubt but what the area could be extended eastward along the fault zone as far as the producing wells in the Aliso Canyon, a distance of six miles.

Outside of the two areas above mentioned, there is apparently no other district along the Ventura River that offers any inducement for drilling.

In the district lying west from the Ventura River to the Santa Barbara County line, there is only one possible area of development, and that has been described under the article on the Ventura Avenue field, namely an extension of this field along the axis of the fold, westward from the Taylor wells of the Shell Company. It is most probable, however, that this extension can not be carried much more than a mile west of the river. The extreme westward end of the Venture Avenue anticline has been tested in two wells by the General Petroleum Corporation and found unproductive. These wells were known as the Hobson wells. Hobson No. 1 was located on Padre Juan Canyon and Hobson No. 2 on Madranio Canyon. The general geology of the remainder of the district is as follows: The Fernando, which outcrops along the axis of the Ventura Avenue anticline, continues northward for about one and one-half miles to a point just south of Red Mountain, where it is abruptly faulted against the Monterey. This Monterey consists of a narrow area of shale, overlying the Sespe beds of Red Mountain. It continues westward, coming out on the coast between Punta Gorda and Rincon Point, at which place it is slightly bituminized. From Red Mountain northward, the principal formation exposed is the Sespe, consisting mainly of red and white sandstone beds. At the base of the Santa Ynez Range, north of the Santa Ana Valley, it rests against the Topatopa. This area of Sespe contains neither favorable structure or any indication of oil.

District Along the North Flank of South Mountain and Oak Ridge.

This area includes two proven areas, the South Mountain field and the Bardsdale-Montebello district. The structure may be considered, in a broad sense, as that of a great anticlinal fold running east and west along the north flank of the mountain, from Santa Paula to Wiley Canyon. The axis of the fold, however, plunges and emerges at several different points, with the result that the actual structure consists of a series of isolated domes, an ideal condition for the accumulation of oil. Beginning at the west, these domes are four in number: One in the

[1]California State Mining. Fifth annual report of the State Oil and Gas Supervisor. Summary of Operations, February, 1920. Report on the Ventura Oil Field. By Lawrence Vander Leck.

vicinity of Morgan and Willard Canyon, forming the South Mountain field; the second at the mouth of Grimes Canyon, forming the Bardsdale area; the third in the vicinity of Guiberson Canyon, forming the Montebello area; and finally, the fourth in the vicinity of Wiley Canyon, this last area being unproven to date. The oldest formation in the district is composed of medium coarse sandstone, conglomerate shales and clays of vivid red, purple and white colors. These beds are of Sespe age and are exposed in the highest points of the several domes. From an economic standpoint it is the most important formation, as it contains the commercial oil sand of the district.

Overlying the Sespe red beds is found the Monterey series, consisting of Vaqueros sandstone and Monterey shale, and called by Eldridge and Arnold the Modelo formation. This formation is present mainly along the high, steep ridge that marks the top of South Mountain and Oak Ridge; it also covers the axis of the anticline in the low places between the several domes. The Monterey shale is bituminous, and burnt shale areas are frequent, especially in Grimes Canyon. These areas, however, have no connection with the proven sands of the district, being stratigraphically several thousand feet above them, and any oil formed by the Monterey would collect in the Fernando sands of the Las Posas area to the south. Along the top of the mountain, the Monterey is overlaid by the Fernando, which dips southward to the Las Posas area of the Simi Valley.

The oil sands of the proven area are found in the middle and lower Sespe and possibly in the uppermost Tejon. The exact origin of the oil is not entirely clear, but it is generally held that it is of Eocene origin, having formed in the carbonaceous shales of the underlying Tejon and Meganos formations. The extremely light gravity of the oil suggests an Eocene age.

The South Mountain field, lying just south of the town of Santa Paula, is at present the chief productive area of Ventura County. The wells start down in the Sespe and shut off water at depths from 400 to 800 feet. From this point on, oil sands are encountered to depths below 3000 feet. The highest point of the dome is in the vicinity of the west line of the Willard lease. From this point the axis plunges to the east and west. A photograph of this area is shown opposite page 112. The dip of the north flank of the dome is rather steep and the outlook for extending the field to the north is doubtful. The south flank, however, is more encouraging, owing to the gentler dips, and it is probable that the field can be extended as far south as the top of the high ridge. The plunge of the dome has limited the field in east and west directions and it is not probable that commercial wells will be found beyond the west line of Sec. 13, or beyond the east line of Sec. 18. The field has no water trouble, due mainly to the excellent protective work of the Oak Ridge and Santa Paula Oil Companies, who operate the major portion of the area. The total proven area in March, 1920, was 330 acres, and it is probable that future drilling will cause the figure to be doubled. The total daily average production in December, 1920, was 3042 barrels of oil. The average number of wells producing was 23, with a daily average production per well of 130 barrels of oil and no water. The gravity of the oil averages about 30° Baumé.

The intervening area between the South Mountain field and the Bardsdale area is about four miles. This district offers no inducement for drilling, as the sharp plunge of the anticline has buried the Sespe sands beyond reach of the drill over the greater portion of the area. The Schieferle wells of the United Oil Company, on Sec. 17, T. 3 N., R. 20 W., have demonstrated that even when they are accessible to the drill west of Sec. 18, their oil content is small.

The Bardsdale area consists of a dome in the Sespe at the mouth of Grimes Canyon. This field is the least productive of the South Mountain group. Its limits are practically set and no increase in the production is likely. The total proven area in March, 1921, was 130 acres. Two miles east of the Bardsdale area is the Montebello area (this should not be confused with the Montebello field of Los Angeles County), which, previous to the opening up of the South Mountain field, was the principal producing area of Ventura County. The field is centered about a gently dipping dome in the Sespe. The proven area lies in the middle of Secs. 3 and 4, T. 3 N., R. 19 W. Three well-defined oil zones and two intervening salt-water zones are recognized. The first oil zone is shallow and the yield is small. The second oil zone, encountered from approximately 1600 to 2500 feet, is the chief source of production and is located near the base of the Sespe.

The third zone, of which little is known to date, yields light oil and may be in the Tejon. While the limits of the field have been fairly well defined, there is still room for considerable development work around the edges. The total proven area in March, 1921, was 310 acres.

Between the Bardsdale and the Montebello area there is at least one fair chance for development. This consists of a plunging anticline running across the northeast corner of Sec. 6 and the NW. ¼ of Sec. 5, T. 3 N., R. 19 W. The general trend of the anticline is to the southeast, with a sharp plunge in that direction. The highest part of the structure is apparently along the north line of Sec. 6. The Petroleum Midway, in the northwest corner of Sec. 5, drilled a well and encountered a fair showing of oil between 2500 and 3000 feet. The well, however, was abandoned on account of mechanical difficulties. The Oak Ridge Oil Company has a well about one-fourth of a mile south of the Petroleum Midway location, and has to date only encountered gas. The Amalgamated Oil Company is also testing the area out with a well in the northeast corner of Sec. 6. The Bardsdale and Montebello areas are regarded as one field and the district is commonly known as the Bardsdale field. The total daily average production in December, 1920, was 1340 barrels of oil. The average number of wells producing was 134, with a daily average production per well of 10 barrels of oil and 1.1 of water. The gravity of the oil averages about 25° Baumé. About two miles east of the Montebello area occurs the last and most easterly dome in the Sespe, along the north flank of Oak Ridge. This dome is located on Sec. 1, T. 3 N., R. 19 W., and may be called the Wiley Canyon dome. This area remains unproven today. Two wells have been drilled here and abandoned, but the records and results are lacking. The surface evidence indicates conditions similar to the Montebello area, and it may be considered worthy of testing.

SESPE CANYON AREA.

This district includes the territory drained by the Big and Little Sespe and their branches. Some of the first development work in Ventura County took place in this area. Of late years, however, on account of the small yield, development work has lagged. At the present time the producing areas are confined to the E. ½ of Sec. 1, T. 4 N., R. 20 W., at the junction of the Big and Little Sespe Creeks; and to an area on the Little Sespe in Sec. 6, T. 4 N., R. 19 W., and finally on the headwaters of Tar Creek, in Sec. 33, T. 5 N., R. 19 W.

The geology and structure are more or less complicated. The formations exposed consist mainly of the Vaqueros, the Sespe and the Topatopa beds.

The structure consists of a number of sharply-folded, plunging anticlines and synclines, in some cases overturned. The oil apparently has been formed in the shales of the Topatopa formation and has migrated and collected in the sandstones at the base of the overlying Sespe. The gravity of the oil varies considerably. Wells on the Big Sespe showed heavy black oil of about 13° Baumé. The Tar Creek wells produce medium gravity oil of about 26° Baumé. The Kentuck wells also average about 26° Baumé. The wells on the Little Sespe run about 20° Baumé. The average depth of the wells is about 900 feet. There is no water trouble. The total proven area in March, 1921, was 440 acres, this figure being based on the actual present production. It is probable, however, that if the old abandoned properties which could easily be made productive were considered, the proven area would be doubled. The total daily production from the field in December, 1920, averaged about 100 barrels of oil. The total number of wells producing was 21, with an average daily production per well of 4.5 barrels of oil and 0.8 of water. There is still considerable room in the field for small well-development. The most favorable locations are along the axis of the anticline in the vicinity of the Los Angeles Oil Company wells, on Little Sespe Creek; on Secs. 21, 28, 32 and 33, T. 5 N., R. 19 W., all located about the headwaters of Tar Creek; on Sec. 1, T. 4 N., R. 20 W., in the vicinity of the plunging overturned syncline from which the Kentuck wells are producing, and in the northern portion of the same sections along the axis of an anticline running through the Big Sespe Oil Company's wells. The area along Big Sespe Creek is not so encouraging, on account of the heavy oil produced. On Coldwater Creek, just above Devil's Gate, there is a well-defined anticline which is probably capable of yielding heavy oil. Many of the old abandoned properties are also capable of being repaired and put on a producing basis.

PIRU FIELD.

This name is given to a group of proven areas lying north and south of the Santa Clara River in the vicinity of the towns of Piru and Camulos. The proven areas north of the Santa Clara are located between Hopper Canyon and Piru Creek. South of the Santa Clara they are located along Torrey, Eureka and Topo canyons. The unproven area between Hopper Canyon and Sespe Creek and between Piru Creek and the Los Angeles County line will also be considered here.

The general structure of these areas consists of sharply-folded anticlines and synclines. The oil-bearing formation is the Monterey (Modelo), the production coming from sandstone beds (probably Vaqueros) interbedded in the organic shale. From Piru Creek east to the Los Angeles County line, the principal formation exposed is the Fernando, which, however, appears to be barren of any appreciable amount of oil.

Following is a portion of McLaughlin and Waring's report on this region:

"East of the Sespe and Fourfork creeks the geologic formations are folded along northwest-southeast axes which, with a few exceptions, turn to an east-west direction east of Hopper Canyon. The Vaqueros and Monterey are the important oil formations in this region. Most of the drilling has been done in the canyons where they cut across likely anticlines.

"Probably the most favorable drilling territory in this vicinity is along the north flank of the Nigger Canyon anticline and along the Hopper Canyon anticline. There are exposures of oil sand in the Vaqueros formation on the west face of Oat Mountain, and also in the Monterey formation from the mouth of Pole Canyon to Fairview Canyon.

"The principal oil zones are those of the Monterey (lower Modelo) formation, consisting of shallow sand interbedded in the Monterey shale, and those of the Vaqueros sandstone interbedded in the Vaqueros shale. The oil zones of the Monterey range to 1000 feet below the surface, while those of the Vaqueros range usually from 1500 to 2000 feet.

"The maximum initial production per day for some of the older wells of the Sunset, Modelo and Harris Oil Company was 75 barrels. Wells as a rule drop off rapidly for the first few months and then maintain a more steady production for many years at rates of from 5 to 25 barrels. The oil varies from 14° Baumé in the shallower Sunset and Harris wells to over 30° Baumé in some of the Modelo wells. The deepest Harris well obtained the lightest oil and the largest production of the group. In the long run wells over 2500 feet deep are said to be no more profitable than shallower ones.

"A few wells have been drilled as far east as San Martinez Chiquito Canyon and Castaic Valley. These wells started in the Fernando formation and drilled to depths ranging from 500 to 2500 feet. Traces of oil and asphalt are reported from some of these wells. Probably if oil in paying quantities is struck in this region it will be deep because of the eastward plunging of the geologic structural axes."

Following is a portion of Eldridge and Arnold's report on the Torrey, Eureka and Tapo canyons group of wells:

"The productive territory of the Torrey anticline, forming what is known as the Torrey field, embraces an area of about one square mile, the length being twice the breadth and lying with the strike of the rocks, which gradually bend from N. 65° W., the direction prevailing on the side of the flexure, to northwest, north-northwest, and north as the strata round its end. The axis of the anticline passes close to the northern edge of the field, the wells, with a few exceptions, having been drilled in the strata of gentler dip, 30° to 40°, south of the axis. In all there are between 50 and 60 wells, aligned in seven or eight concentric arcs, in accordance with the curves assumed by the outcropping strata. The wells nearer the axis penetrate the red and gray banded argillaceous sandstone that has been correlated with a portion of the Sespe formation, while those more distant are perhaps entirely confined to the sandstone and shale of the Vaqueros.

"It is said to be usually impossible in this field to identify horizons in one well with those in another, even though the two locations are adjacent. The oil sands also vary in thickness from a few feet to 150, and even the thicker beds, it is reported, cannot be identified from well to well. It is, however, the opinion of the writer that considerable order might be worked out with the aid of carefully prepared cross sections.

"The oil has a gravity of 30° to 35° Baumé and resembles that derived from the same formation north of the Santa Clara, especially that from the region of Fourfork and Tar creeks. The depth of the wells varies from 600 to 2000 feet, the deeper wells being those farther away from the axis of the fold. North of the Torrey anticline the productive territory is apparently confined to the east end of the field where the distance from the syncline immediately north and from the fracture possibly accompanying it is greatest.

"Concerning the extent of the Torrey field beyond the present developed area, it may be said with some degree of assurance that to the west and north it is likely to be limited by structural conditions to nearly the existing lines. In the other directions no prediction can be made.

"Eureka Wells.

"The wells of Eureka Canyon are located in its lower reaches, most of them being grouped at the sharp turn half a mile above its mouth. The geology of the immediate region is somewhat doubtful, but if the structure is that of a highly compressed compound fold, as suggested on page 82, the locus of the wells is not far from its anticlinal axis; moreover, the developed territory is in the vicinity of a prominent curve in the stratification planes, the axis having been pushed somewhat northward between Eureka and Torrey canyons. The wells penetrate the Vaqueros sandstone, conglomerate and shale, but whether any of the beds are duplicated it is impossible to determine. Such duplication may have taken place, but it has had practically no effect on the productiveness of the territory. The wells are located a little over a mile north-northeast of the Torrey group, the geology of the two fields being quite distinct.

"Twenty-one wells were in operation or drilling at the time of the writer's visit. They vary in depth from 600 to 1200 feet, and the strata passed through according to the logs, embrace sand, arenaceous shale, dark, adobe-like clay, and the usual 'hard shells' of the drillers. The character of the beds varies every 50 to 125 feet in depth, but sandstone predominates. Oil sand, so-called, appears to be encountered at depths of 540 to 620 feet. Water is found both in the upper parts of the wells and beneath the lowermost oil sand recorded. Well No. 20, of the group at the turn of the canyon, is the only one in which pebbles are reported. These are, perhaps, a local development of one of the more prominent sandstones that lie near either the summit or the base of the Vaqueros beds. Usually but a single oil sand shows in a well, and tt is the opinion of the superintendent that the producing horizon is the some throughout the field.

"The gravity of the oil averages, it is said, 24° Baumé, but in some instances rises to 26°. This difference, as compared with the Torrey oil, is inexplicable, for both are believed to be derived from the same formation. Their horizons, however, may be different, and in the Eureka field the sediments appear to be coarser, while the strata are far more fractured, if the interpretation of the geology here given is correct. The latter feature would tend to permit the easier escape of the lighter hydrocarbons, leaving behind the heavier oils, which now constitute the product.

"The yield has been from 1 to 40 barrels per day. The field has, however, never been one of large production, but from the records the wells appear to have maintained their supply with remarkable uniformity.

"No evidence of the red and gray banded series of probable Eocene age has been found in any of the holes in this field.

"Wells have been drilled in the main fork of Tapo Canyon and also in each branch of a westerly tributary. Those at present producing lie along the east fork of this tributary. They are four in number, although from their designation, Nos. 12 to 15 inclusive, it is to be inferred that several others have been in existence in earlier days. Indeed, one or two of these old wells still contain a slight amount of oil. The producing wells are sunk in northward-dipping sandstone and shale a mile north of the axis of the Tapo anticline. They yield at present from 5 to 40 barrels of oil per day. The gravity is 20° to 24° Baumé, the 20° oil being produced by the well highest up in the canyon and lowest as to the strata penetrated. These wells are about 200 feet apart and range in depth from 460 to 1200 feet. The oil sand is encountered at 235, 465, 940 and 865 feet, from the well farthest up the creek to that lowest down, respectively. The wells lowest on the dip are the greatest producers. The dip of the measures is from 50° to 60°, and it is impossible to say that a single bed produces oil for the entire field, although this is suggested by the increasing depths of the wells in the direction of the dip. More or less water is pumped with the oil, and it is the opinion of the superintendent that the two are mined and come from the same bed. The amount of water, however, is slight, the proportion being given as 1 of water to 40 of oil. Inasmuch as water-bearing sands overlie the oil sands it may be that a leak occurs which would account for its presence with the oil. Water was also found beneath the oil sand in the well farthest up the gulch and has been encountered in some of the wells now abandoned.

"The whole of the lower half of the Vaqueros strata exposed in Tapo Canyon shows a greater or less impregnation with petroleum. No unusual amount appears to have been assembled in proximity to the axis of the main anticline, and it may be that the productive territory is a particularly rich portion of the series of beds which, from some cause or other, has held its oil better than the great mass of the beds in the region. From the surface no reason can be seen for the enrichment of one portion of the formation over another portion, and except for strong seepages in proximity to the wells one locality might as readily have been chosen for development as another.

"The logs of the Tapo wells show a succession of blue clay, brown shale, gray sandstone, fine to coarse, and in one instance a trace of conglomerate. The thicknesses of these several materials, which are constantly repeated, vary from 5 to 200 or more feet, the average being, perhaps, between 20 and 75 feet."

In March, 1921, the total proven area was 865 acres. The total daily average production in December, 1920, was 336 barrels of oil. The average number of wells producing was 75, with a daily average production per well of 4.5 barrels of oil and 5.2 of water. The area is not encouraging except for a small well-development.

SIMI VALLEY FIELD.

The Simi field lies along the north side of the Simi Valley between Santa Susana and Simi.

The chief area of production is around the mouth of Tapo Canyon. From there on west to Brea Canyon there are a few scattering wells.

The main structure consists of the Simi anticline. This fold starts about one-half mile east of the mouth of Tapo Canyon and runs due west to a point just west of the canyon, where the strike of the axis changes to a southwest direction, so that it crosses Brea Canyon at its mouth. The dips on the flanks vary from 15° to 30° and there is a plunge to the axis of approximately 3° to the southwest. East of Tapo Canyon the formation exposed on the axis of the fold is of Tejon age. West of the canyon the plunge of the folds has caused the Sespe to overlie the Tejon.

TAPO CANYON WELLS.

In the vicinity of the Tapo Canyon wells (principally of the Pan-American Petroleum Company) the oil has apparently been formed in the carbonaceous shales of the Meganos (Eocene) and has collected mainly in the overlying sands of the Tejon and to a lesser extent in the Sespe formation. The oil is of a light-green color and averages in gravity about 38° Baumé; some wells, however, produce as high as 42° gravity oil. Along the axis of the fold the first oil is encountered at about 300 feet and productive sands are logged down to 1600 feet; wells down the dip are, of course, deeper. The sands are extremely lenticular and no correlation is possible from well to well. The field is apparently limited in a north and south direction to an area of 3000 feet about the axis of the fold. Along the axis, in a westward direction, there is every indication that the field may be extended for a considerable distance. Eastward from Tapo Canyon to the head of the valley, the possibilities may be summed up as follows: There is a chance for small-well production of three to four barrels per day in the areas between Tapo Canyon and the first large canyon to the east (a mile distant from the proven area). The structure consists of the eastward end of the Simi anticline, and in Secs. 29 and 30, T. 3 N., R. 17 W., some oil has accumulated along a fault in the Tejon. At the head of the valley, in the low hills north of the state highway, the structure consists of a monocline dipping about 25° to the west. The formations beginning at the bottom consist of the Chico, Martinez, Meganos and Tejon. It is possible that wells sunk in the Tejon might yield 3 to 4 barrels per day. In the general area north of the Tapo field, including the southern slope of Oak Ridge and the Santa Susana Mountains, the prospects of any development are unfavorable.

Area in the Vicinity of Brea Canyon.

Westward from Tapo Canyon there are three small groups of wells. The first consists of the Simi wells of the Pan-American Petroleum. These are located near the west quarter corner of Sec. 34, T. 3 N., R. 18 W., and consist of five wells, only one of which is producing. The wells start down in the Sespe about three-quarters of a mile north of the axis of the Simi anticline and encounter oil sands from 1600 to 2100 feet. The oil is black and of about 20° Baumé in gravity. The yield is apparently going to average about 20 barrels per well. The axis of the fold has not yet been tested in this vicinity. The second and third groups are located in Brea and Los Alamos canyons, and consist of the Union Oil Company, Cañada del La Brea wells and the

Pan-American Scarab wells. The Union wells are in Brea Canyon, about one mile north of the axis of the Simi anticline, and the Scarab wells are in Los Alamos Canyon about 1½ miles north of the axis of the anticline. Just south of the Union wells there is a prominent line of oil sands and seepages which may be followed to the west of Brea Canyon for about a mile and a half. Both groups of wells are apparently drawing their oil from these outcrops, the dip being about 25° to the north. The beds exposed are red, purple and white sands and clays of the Sespe formation. The oil encountered is black and of about 18° Baumé in gravity, the yield, per well, being about 15 barrels per day.

At the mouth of Brea Canyon, a mile south of the Union wells, are three abandoned dry holes all located approximately on the axis of the Simi anticline. They consist of the Dabney & Roberts well, in the SE¼ of Sec. 5, T. 2 N., R. 18 W., which was drilled to a depth of 2680 feet; the Miley-Buley well of the State Consolidated Oil Company, in the SW¼ of Sec. 4, which reached a depth of 1160 feet, and the Hidalgo, in the NE¼ of Sec. 6, with a depth of 1925 feet. No paying oil sand was encountered in any of these wells, although light showings of oil and gas were reported. The Dabney & Roberts well demonstrates that the Sespe is about 400 feet thick on the axis of the anticline and that the Tejon is apparently not productive along this portion of the fold.

This situation, where wells along the axis of the fold fail to produce, while wells located a mile down the flank show production, is a peculiar one for California fields. The only explanation that the writer can offer is as follows: The heavy black oil produced by the Union and Scarab wells from the Sespe beds is not of Eocene origin, but has accumulated in the upper Sespe sands from the Monterey shale which overlies the Sespe unconformably a short distance north of the Scarab wells. Apparently the oil did not enter the lower 400 feet of the Sespe which covers the axis of the fold. In this connection account must also be taken of an igneous dike which outcrops parallel to the axis of the fold about one-half mile north of the mouth of the canyon. This intrusion may have prevented the oil from accumulating in sands along the axis. The reason for the Tejon being apparently unproductive may be due to the fact that the quantity of oil capable of being formed by the Meganos shales was limited and has collected up the plunge of the axis in the vicinity of Tapo Canyon, leaving the remainder of the fold apparently barren.

It must be noted, however, that there is some reason to believe that the wells drilled at the mouth of the canyon did not give fair tests to the showing reported. The failure of these wells has had the effect of retarding exploration work on the west end of the Simi anticline.

Unproven Areas in the Simi Valley.

The south side of the valley, from Simi to Santa Susana Pass, consists of a monocline in which the Cretaceous, Martinez, Meganos and Tejon formations are exposed. The dip is about 25° to the north. The structure may be considered as the south flank of the Simi syncline. The Tejon beds, which are productive on the north side of the valley, show no evidence of petroleum here. One well has been drilled in this district, that of the Calabasas Oil Company in the NE¼ of Sec. 13, T. 2 N., R. 18 W. The well starts down in the Tejon and a depth of 1900 feet was reached without obtaining any showing of oil, although gas was reported. Sec. CD, Fig. 7, shows the general structure of the valley between Moore Park and Santa Susana.

The north side of the valley west of Moore Park and Happy Canyon is known as the Las Posas district. The structure consists of a great syncline between South Mountain and the west end of the Simi anticline. The formation exposed on the surface is the Fernando. Along the south flank of South Mountain it is underlayed by Monterey shale which is bituminous and contains burnt shale areas. Within the general synclinal structure there are at least two, and possibly more, minor anticlinal folds. The most prominent of these is found about 3 miles north of Somis, crossing Sulphur and Long canyons at approximately right angles. This fold is now being tested by the Standard Oil Company on the Donlon tract. Well No. 1 was drilled to depth approximately 2700 feet and abandoned on account of mechanical difficulties; no showings were encountered. Well No. 1-A is now drilling. In addition the following wells have been drilled and abandoned in this area without obtaining any showings: The Honda Oil Company's well in the SE¼ of Sec. 29, T. 3 N., R. 20 W., was located on the north flank of the great syncline, and at a depth of 1650 feet went out of the Fernando into the underlying Monterey, continuing in that formation to a depth of 1875 feet. This well demonstrated that the Fernando on the south flank of South Mountain is not productive. The California Profit Sharing Oil Company drilled a well about one mile north of Moore Park and a hundred yards east of the Grimes Canyon road. A depth of 2410 feet was reached in the Fernando.

The possibilities that the Las Posas district will produce are not very favorable. That is due chiefly to the fact that the structure is synclinal. The small minor anticlines noted above, one of which is being tested by the Standard Oil Company, are apparently only surface flexures in the upper Fernando, or Saugus, and do not influence the accumulation of petroleum.

West End of the Simi Anticline.

At the mouth of Brea Canyon the Simi anticline crosses the valley to the south side and continues westward along the top of the range of hills between Moore Park and Somis. In the Tierra Rejada district, south of Moore Park, the formation exposed on the axis is Sespe, with a thin covering of a basaltic lava flow which is characteristic of the base of the Monterey in Simi Valley and the South Mountain areas. Further west, in the hills near Somis, the formations consist of sands, clays and gravel of the Fernando. The low range of hills west of Somis is probably a continuation of the fold, though good dips to prove this are rare. J. B. Dabney drilled a well here, on the Perkins property, about 3 miles west of Somis and a mile south of the highway; no oil was encountered. From the log it is evident that the following formations are present: Fernando to about 1700 feet; Monterey shale and Vaqueros sandstone from about 1700 feet to 2885 feet. At that point lava was encountered and the well abandoned. The lava probably represents the flow at the base of the Monterey series. The well may be considered as showing that the Fernando and Monterey are not productive along the lower end of the Simi anticline. At the same time the well was not drilled deep enough to test the Sespe and Tejon which are probably present beneath the lava encountered at 2885 feet. The general possibilities of the Simi anticline, west of Brea Canyon may be summed up as follows: The structure is favorable, but wells at Brea Canyon have demonstrated that the Sespe and Tejon are not productive in that particular region, and the Dabney well at the extreme western end shows likewise that the Fernando and Monterey are barren. It is, however, worthy of being tested by a well located on the axis in the area south of Moore Park with a view to obtaining production from the Tejon. The seepages at the foot of Conejo grade indicate that the Tejon is oil bearing somewhere at the lower end of the Simi Valley.

District Around Oxnard, El Rio and Camarillo.

The area is flat and covered with recent soil. There are no surface indications of petroleum. It, however, possesses the possibilities common to flat areas adjoining productive fields, that it possibly may contain buried anticlinal folds of which there is no evidence on the surface. If such folds are present they would, in all probability, be a continuation of the South Mountain fold in a western direction towards El Rio, and a similar extension of the Simi anticline towards Camarillo. As stated before, the seepage of light-green oil at the foot of the Conejo grade, indicates that the Eocene is oil-bearing in this portion of the county.

District of the Santa Monica Mountains Lying in Ventura County.

This district comprises the mountain region in the southeast quarter of the county, lying south of the Simi Valley. In the vicinity of Santa Susana Pass and Chatsworth Peak, the formation is Chico-Cretaceous, which runs west in a continuous body as far as the vicinity of Simi Peak. Along the lower flank of the Simi Hills this body of Cretaceous is overlayed by the Martinez, Meganos and Tejon. The general dip of these formations is about 25° to the north, and this monocline represents the north flank of the axis of an anticline which was once present just south of Simi Peak. The axis has been faulted, however, so that only the north flank and plunging nose of the fold are left. The strike of the fault is approximately east and west, and it may be seen in the region about one-half mile south of Simi Peak. The plunge of the faulted fold causes the strike of the Eocene formations along the north flank to change from east–west to north–south, so that west of Simi Peak they 'nose around' over the Cretaceous, and they, in turn, give place to the Vaqueros and Monterey in the region just northeast of Newbury Park. The fault apparently ends about a mile west of Simi Peak, so that the Monterey Series is still domed and the axis of the fold may be recognized near the Conejo Oil Syndicate well located about 2 miles northeast of Newbury Park.

The formations exposed south of the Simi Peak fault consist of Vaqueros sandstone and Monterey shale. These continue westward to the vicinity of Newbury Park and the Conejo Valley, and east to the San Fernando Valley in the vicinity of Calabasas.

Two wells are being drilled in this general vicinity and should determine the possibility of this region as they are favorably located on the plunging nose of the faulted anticline. Well No. 1 of the Conejo Oil Syndicate, is located about two miles northeast of Newbury Park and starts down in Monterey shale, which is dipping about 45° to the west. Well No. 1, "Erbe," of the Conejo Oil Syndicate, is located about 4 miles northeast of Newbury Park, and starts down in the Vaqueros close to the Tejon contact. The structure is fairly favorable and the region is underlaid by the Tejon and Meganos which are oil-bearing on the north side of the Simi Valley. However, there is a total lack of seeps along the outcrops of these beds, such as are common in the region north of Simi Valley. It would seem that if the region is oil-bearing there would be some indication of oil at the outcrops.

In the hills just south of the state highway and Newbury Park, the formation is lava, probably belonging to the Vaqueros. From these hills south to the coast the formations consist of highly-tilted areas of Cretaceous and Eocene age, together with some areas of Miocene lava. The region may be considered as unfavorable on account of the sharply-tilted rocks and total lack of any surface indications.

At the foot of the Conejo grade, about 3 miles east of Camarillo, there are seeps and a group of shallow producing wells. This is known as the Conejo field. The oil has apparently collected in the recent valley alluvium of a little basin, lying between two areas of Vaqueros lava flows. The oil is light-green in color and of about 16° Beaumé gravity. It is apparently of Eocene origin. It has no gasolene content and is practically a pure lubricant, indicating that it has migrated a considerable distance and has been filtered. The wells are drilled in the alluvium to depths between 200 and 300 feet, and production has been obtained here for the last twenty years. In 1919 there were 20 wells producing with a total daily yield of 17 barrels of oil and a hundred or more of water. In the latter part of 1920 drilling was started again after a ten-year period of idleness, and the new wells have come in with an initial production of from 30 to 100 barrels of oil, followed by a rapid decline. The origin and method of accumulation of the oil is obscure; it is the opinion of the writer that it was formed in the Eocene shales and has migrated along a fault plane up through the lava and into the alluvial basin, as shown in Fig. 8, lying in the basin in a manner similar to water in a lake. The chief interest it has is in demonstrating that there is Eocene oil at the lower end of the county, with a possible accumulation in the Tejon at the west end of the Simi anticline.

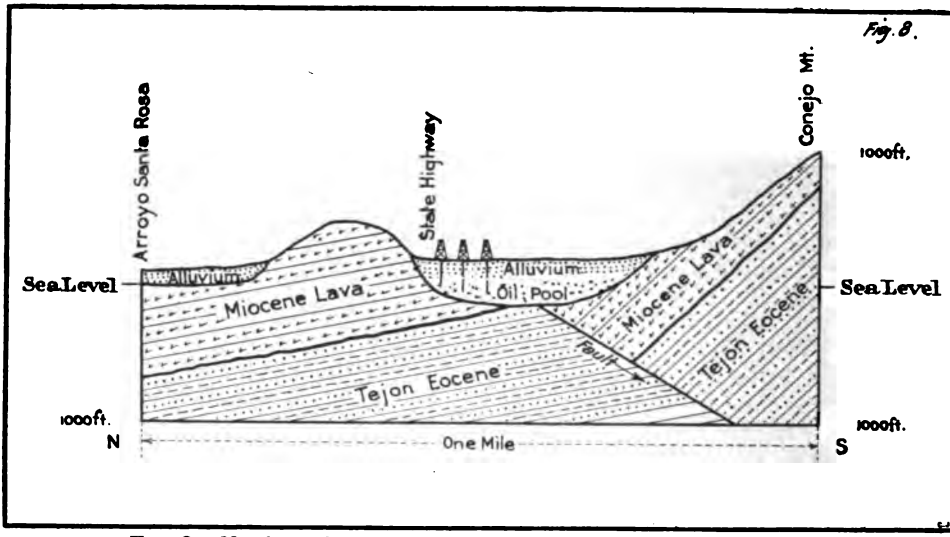

FIG. 8. North-south section through the Conejo Field, Ventura County.

NORTHWESTERN LOS ANGELES COUNTY.

This area comprises, roughly, the territory lying north of San Fernando Pass and west of the Antelope Valley.

The northern portion consists of the Sierra Liebre Mountains, over which the ridge route of the state highway passes. The central portion consists of a valley area, made up of Soledad Pass, Newhall Creek and the Santa Clara River Valley, all of which drain westward to the ocean through Ventura County. The southwest corner consists of the Santa Susana Mountains, and contains the proven fields of the district.

The eastern portion of the Sierra Liebre Range is composed of granite and ancient crystalline schists. The western quarter lying between Castac Creek and the Ventura County line, is composed of sedimentary deposits. These beds have a thickness of well over 10,000 feet. The lower portion consists mainly of shales, with thin beds of sandstone. The upper portion consists mainly of yellow-brown medium coarse sandstone, with some minor beds of shale and conglomerate. They are first exposed along the Ridge Route, about six miles north of Castac Station, and the general dip is about 30° to the north, with occasionally a southward dip. The beds continue as far north along the Ridge Route as the Liebre maintenance of way station, at which point they are sharply faulted against the granites by the San Andreas fault. So far as known, they contain no evidence of petroleum. Their age is uncertain, however, they are apparently continuous with the Eocene beds of Ventura County, and resemble them to a marked degree in lithology and may, therefore, be assumed to belong to the Topatopa Series.

On the southern flank of the Sierra Liebre Range, which forms the northern boundary of the Santa Clara River and Soledad Canyon, in the region north of Saugus, the Eocene beds above referred to are overlain unconformably by the Fernando. These Fernando beds consist of gravels, white and yellow sandstone and yellow clay-shales. They are found up Castac, San Francisquito and Deadman's canyons for a distance of at least six miles from the point where these canyons join the Santa Clara River. They are also continuous up Soledad Pass for a distance of about 10 miles east of Saugus. Westward from Castac they join similar beds in Ventura County in the region northeast of Piru. The region contains a number of well developed folds in the Fernando which might possibly be oil-bearing. A number of old abandoned wells drilled here have reported showings but failed to obtain any commercial production. In view of this the area may be considered as one of doubtful possibilities.

Following is a list of the abandoned wells, taken from Prutzman's Report:[1]

"**Wells in Townships 4–17.**

"East Piru Oil Company—This company was drilling, in the year 1900, just north of Leckler Canyon, near the center of Sec. 6. The results of this work are not known.

"Aetna Oil Company—This company has two wells on the SE. ¼ of the NW. ¼ of Sec. 8, drilled about 1901. Well No. 1 was 845 feet deep, and was abandoned because of collapsed casing, with a good showing of oil in the hole. No. 2, however, a little to the southeast, was carried to 960 feet without finding the sand, and was abandoned as a dry hole.

"**Wells in Townships 5–17 and 5–16.**

"Castaic Oil Company—This well was drilled on the north side of Palomas Canyon, on the east line of Sec. 23, 5–17, in the year 1901. It is reported to have been approximately 1000 feet deep, and had a 20-foot streak of dry asphalt at 600 feet. This hole is said to have been drilled without casing.

"Castaic Oil Association—This company drilled a well on the east side of Castaic Canyon, just below the entrance of Elizabeth Canyon, and on the SW. ¼ of Sec. 18, 5–16, in the year 1899. The depth of this hole was slightly in excess of 1400 feet; no oil was found, but considerable gas.

"Rose Oil Company—In 1904 this company drilled a well just to the south of the foregoing, carrying it to a depth of 1700 feet, and abandoning it owing to mechanical difficulties. This hole developed some high-gravity oil, which is now flowing from the casing head.

"New Castaic Oil Company—This company has been drilling for many months on the NW. ¼ of Sec. 19 in 5–16. In February, 1912, this hole was reported to be down 2500 feet and drilling, with a strong showing of gas and some indications of oil.

"A small but very perfect and well-marked anticlinal fold shows on both sides of Castaic Creek at this point, and reappears in Charley Canyon, about a mile to the east. The Rose well appears to have been almost exactly on the axis of this fold—the New Castaic well is some distance out on the south limb, which at the surface, at least, has a sharp dip."

Following is a list of the wells now drilling in this region, none of which have obtained any commercial showing, at the date of this report:

Walker-Pearson & McGregor, well No. 1, Sec. 32, T. 4 N., R. 15 W., Community Oil Producers' Company, wells No. 1 and 2, Sec. 23, T. 4 N., R. 16 W., Loma Verde Petroleum Company, well No. 1, Sec. 5, T. 4 N., R. 17 W., Fernando Oil Company, well No. 1, Sec. 10, T. 4 N., R. 17 W., Tick Canyon Oil Syndicate, well No. 1, Sec. 35, T. 5 N., R. 15 W., Occidental Petroleum Company, well No. 1, Sec. 35, T. 5 N., R. 16 W.

The eastern portion of Soledad Canyon is composed of granite and crystalline schist, together with smaller areas of gravels, sand, tuff beds and lava flows. This portion of the canyon is unsuitable for prospecting.

The region south of Saugus, known as the Santa Susana Mountains, contains the proven fields of this portion of Los Angeles County. These are generally known as the Newhall fields, and were the scene

[1]California State Mining Bureau. Bull. 63. Petroleum in Southern California. By Paul W. Prutzman, 1913.

of some of the first development work in California. The proven areas consist of a number of isolated groups located at the heads of Pico, Towsley, Wiley and Rice canyons. These wells are located along the axis of a sharp northwest–southeast fold, known as the Pico anticline. The wells apparently start down in the Fernando and draw their oil from sandstone beds in the Monterey Series. These groups of wells lie west of Newhall. In Pico Canyon, on the property of the Standard Oil Company, is located the first producing well obtained in California. This well was drilled in 1870 and is still producing at the rate of 3 barrels per day of 38° gravity oil. At the head of San Fernando Pass, and in the hills southeast of Newhall, are located the Elsmere Canyon wells. The formation here consists of Fernando, which is lying unconformably upon the granite. The oil is found in the basal sands of the Fernando and is of a heavy gravity, ranging from 14° to 19° Baumé. This is in marked contrast to the Pico Canyon wells which run over 30° Baumé in gravity. The structure consists of several sharp anticlines. In Placerita Canyon some oil has been found in an area of crystalline schist, having migrated there from the Fernando. This is a freak occurrence and was referred to in Chapter II.

The general depth of wells in the Newhall area ranges from 1000 to 2000 feet. The oil has probably had its origin in the shales of the Monterey Series, and has collected in the Vaqueros sandstone and overlying Fernando beds. The total proven area in March, 1921, was 205 acres. The total daily average production, in December, 1920, was 308 barrels of oil. The average number of wells producing was 77, with an average daily production, per well, of 4.0 barrels of oil and 1.2 of water. The limits of the proven areas are practically set and it is doubtful if the production can be increased any in the future.

CHAPTER X.

SOUTHERN LOS ANGELES AND ORANGE COUNTY.

This area includes all of Orange County, and that portion of Los Angeles County lying south of the San Fernando Pass and the San Gabriel Mountains. This is the chief producing area of Southern California, and the second in the state. In this report no detailed descriptions will be given of the proven areas, and the reader is referred to the bulletins of the Geological Survey[1] and the State Mining Bureau,[2] for this information.

POSSIBILITIES OF THE VARIOUS DISTRICTS.

Santa Monica Mountains.

The Santa Monica Mountains lie in the extreme southwestern portion of Los Angeles County, and continue west into Ventura County. They offer no inducement for drilling operations. The general geology is as follows: Beginning at a point on the Los Angeles River north of Elysian Park and running westward is a body of crystalline rocks, chiefly granite gniesses and schists, which form the core of the range. Along the north flank, and bordering the south side of the San Fernando Valley, the crystalline rocks are overlayed by the Monterey Series, consisting of white Vaqueros sandstone and diatomaceous Monterey shale. The structure is that of a monocline, dipping about 30° to the north. This body of sediments is continuous from Cahuenga Pass to Calabasas, where it joints the Monterey Series along the Conejo Grade. On the south flank of the range from Elysian Park to Sherman, the crystalline core is overlayed at the edge of the foothills by the Monterey Series and the Fernando. These beds dip to the south and form the Los Angeles City and Salt Lake fields which lie out in the flat area about two miles south of the mountains. In the hills back of the Soldiers' Home at Sawtelle, the formations exposed are beds of sandstone and shale, probably belonging to the lower portion of the Monterey Series (locally known as the Puente). These beds are, in turn, underlayed by the Chico (Cretaceous), which occupies a wedge-shaped area, that gradually widens towards Topango Canyon. Along the Topango Canyon road the Chico consists of massive sandstone and coarse conglomerate, with minor beds of shale. These beds are highly-tilted and have a general dip to the north. Along the beach from Santa Monica Canyon to Topango Canyon the lower Puente (Monterey) is overlaid by bituminous shale probably belonging to the upper Puente (Monterey). The shale is exposed along the sea cliff and the total thickness is not over a few hundred feet.

[1]U. S. Geological Survey. Bull. 309. Santa Clara Valley, Puente Hills and Los Angeles Oil District. By G. H. Eldridge and Ralph Arnold, 1907.

[2]California State Mining Bureau. Bull 63. Petroleum in Southern California. By P. W. Prutzman, 1913. Bull. 69. Petroleum Industry of California. By R. P. McLaughlin and C. A. Waring, 1914. First, Second and Third Annual Reports of the State Oil and Gas Supervisor. Summary of Operations, California Oil Fields. Report on the Montebello Field. By Irving V. Augur. May, 1920.

The geology of the Santa Monica Mountains is chiefly interesting because of the outcrops of Monterey shale along its borders. The outcrops on the northern flank indicate that the San Fernando Valley is underlaid by the Monterey, and those on the southern border and along the coast indicate similar conditions in the region between Los Angeles and Santa Monica.

San Fernando Valley District.

The San Fernando Valley consists of a flat, oblong area, completely surrounded by mountains except for the narrow pass at the southeast corner between the Verdugo and Santa Monica mountains, through which the drainage flows by means of the Los Angeles River.

The flat valley area is covered with soil and recent valley deposits which give no hint as to the underlying formation. The one exception to this consists of an area of crystalline rocks and Vaqueros sandstone which outcrops in the small group of isolated hills just east of Pacoima.

The geology of the foothills surrounding the valley is as follows: Along the southern edge from Cahuenga Pass to Calabasas, the formations consist of Vaqueros sandstone and Monterey shale, dipping in a monocline to the north. From Cahuenga Pass, east to West Glendale, there is some Monterey, but the main formations consist of granite and schist.

At the southwestern head of the valley, in the vicinity of Calabasas and south of Chatsworth, the beds exposed are Vaqueros sandstone and Monterey shale. At Chatsworth, and in the vicinity of Santa Susana Pass, massive Chico sandstone outcrops. In the hills north of Chatsworth and west of San Fernando, Monterey shale and Fernando sands, clays and gravels are exposed. This region contains the most favorable structures in the valley for the accumulation of oil. One of these anticlines starts in the hills between Limekiln and Aliso canyons and runs out into the valley in a southeast direction, terminating in the low group of hills two miles south of the San Fernando Mission. The second fold runs east and west in the hills that surround the San Fernando reservoir. The axis of the anticline passes approximately along the face of the dam at the southern end of the reservoir and continues east towards San Fernando for about a mile, and west as far as Aliso Canyon. These two folds are now being tested by the 'Mission Wells' of the Standard Oil Company, and while depths of 4000 feet and over have been reached, no encouraging results have been obtained. The final results obtained by these wells should prove or disprove the oil possibilities of the valley.

The San Fernando Oil and Gas Company is drilling a well about a mile north of the reservoir dam, a location too far north of the axis of the fold to be an adequate test of the region. The northwest head of the valley, in the vicinity of San Fernando Pass, may be considered as a continuation of the Elsmere Canyon structure (discussed in Chapter IX). It is possible that in the vicinity of Grapevine Canyon, on a continuation of the Elsmere Canyon fold, small wells of heavy oil and doubtful commercial value may be obtained. The Active Oil Company is drilling a well at the mouth of Grapevine Canyon.

In the hills northeast of San Fernando, between Pacoima Wash and the Little Tujunga, the formation consists of Monterey shale and

Fernando sands and gravels. The Monterey is exposed in a narrow strip running east and west at the edge of the hills. Between Lopez Canyon and Pacoima Wash there are several seepages and the shale is bituminized. Overlying the shale are the Fernando beds. The dip of both formations is about 45° to the north. Two wells have been drilled at the edge of the hills and just east of Lopez Canyon. The Crafton well was drilled some years ago and encountered small quantities of heavy oil. The San Fernando Oil Company well is at present testing the region and has to date encountered only small showings of heavy tar. At the mouth of the Tujunga Valley there are outcrops of Vaqueros sandstone, Monterey shale and Fernando, which lie on the crystalline rocks of the Verdugo Mountains to the south, and the main San Gabriel Range to the north. In the region consisting of the Verdugo Mountains, La Cañada, La Crescenta, Verdugo Canyon, the San Rafael Hills and Eagle Rock Valley, the possibilities of obtaining oil are extremely slight. The greater portion of the region is covered with crystalline rock and only small patches of sedimentary rocks are present. Any drilling here would be a waste of money.

The Coastal Plane Area of Los Angeles and Orange Counties.

Roughly, this region may be defined as lying between Santa Monica and Newport and south of the Santa Monica Mountains and the San Gabriel Valley. Within it are located the chief proven fields of southern California and it also offers the most favorable opportunities for future development.

The proven fields lie roughly along three parallel lines of structure which have a general northwest–southeast trend. These lines of structure consist of a series of domes, anticlines and faults along which the oil has accumulated. These are not in any sense absolutely continuous, but are apparently arranged along these three general parallel lines.

The first and most northerly of these begins at the Salt Lake field, near Hollywood, and runs east to the Los Angeles City field and thence southeast through the Montebello, Whittier Hills, Brea Canyon and Olinda fields. The second line of structure lies about three miles south and parallel to the first and is separated from it by a narrow syncline. Beginning at the southeast this general structure starts in the Richfield district and runs northwest to the Coyote Hills field and thence to the Santa Fe Spring area, beyond which it has not, to date, been identified.

The third and last line is apparently the longest in extent, and is separated from the second by a broad, flat area of about twelve miles in width which is apparently a syncline but which might contain buried folds. Beginning at the southeast, this general line of structure starts in the semi-proven area at Newport and runs thence northwest to the Huntington Beach field and thence to the Signal Hill dome. At this point the strike changes more to the north and the general line of uplift continues through Dominguez, Athens on the Hill, Inglewood, Culver City (Ivy) and finally ends in the proven area around the Wolfskill lease of the West Coast Oil Company about one mile southwest of Beverly. Sec. A. B., Fig. 9, shows the general relationship of these three lines of structure.

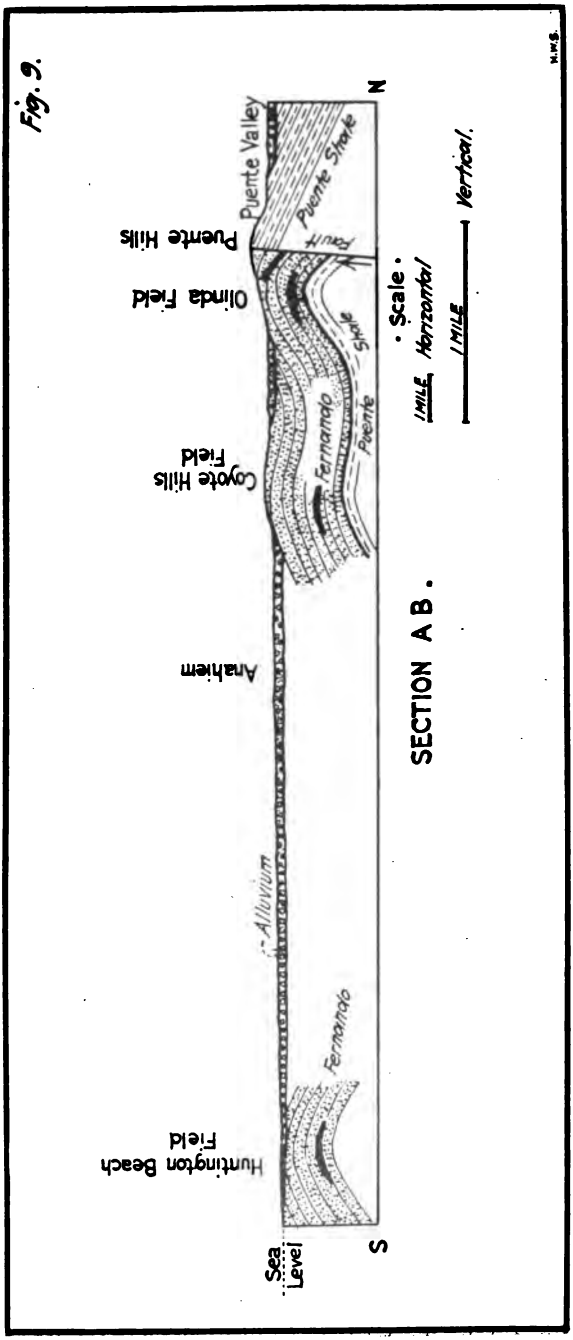

FIG. 9. Section A-B—Generalized section across the Coastal plain area of Orange County, showing the three general lines of structure along which the oil has accumulated.

Following is a brief description of the fields that lie along the first and most northerly line of structure:

Salt Lake Field.

The Salt Lake field lies at the western end and comprises the proven area south of Sherman and Hollywood. The oil is found in sandstone beds of the Puente formations and varies from 11° to 18° Baumé in gravity. As there are no surface outcrops, the exact structure is somewhat obscure. It is probable, however, that the accumulation is due to a major anticline which runs east to west just south of Colegrove and Sherman. This structure, however, has been faulted on both flanks and contains minor folds within it. Sec. 3, Fig. 3, shows a portion of the south faulted flank. The limits of the field are practically set. There is, however, a chance to encounter deeper sands, as shown by recent work on property of the Salt Lake Oil Company. The total proven area in March, 1921, was 904 acres. The total average daily production in December, 1920, was 2240 barrels of oil. The average number of producing wells was 250, with a daily average production, per well, of 9 barrels of oil and 10 of water.

Los Angeles City Field.

The Los Angeles City fields lie in the region between West Lake Park and Elysian Park. Drilling was first started here in 1892 by E. L. Doheny, and the area was the scene of extensive drilling operations up to about 1907. Since then, however, there has been practically no development work. This is due mainly to the exhaustion of the oil sands, and the restriction placed upon the drilling of new wells within the city limits. At the present time about 400 of the old wells are still pumping, and the total daily production averages about 1000 barrels. The structure consists of a series of small folds and faults in the Puente formation. The majority of the wells start down in the Fernando, but draw their production from the sandstone beds of the Puente. The oil varies from 11° to 18° Baumé in gravity. The field has at all times been characterized by shallow wells and small production, and it is probable that the next few years will see the abandonment of the remaining producing wells.

The Montebello Field.

The next field that lies along this line of structure is the Montebello field which is located in the La Merced Hills about six miles east of Los Angeles. The structure consists of a well developed dome in the Fernando formation, and the oil is found in the basal sands of this formation, and possibly in the uppermost sands of the Puente. The limits of the field have practically been defined by drilling, and no extension is looked for. There is, however, still considerable room within the proven limits to drill up. This field has been one of the most prolific in Southern California, but it can be considered as having passed the day of flush production. The total proven area in March, 1921, was 819 acres. The total daily average production in December, 1920, was 30,000 barrels of oil. The total number of wells producing was 133, with a daily average yield, per well, of 240 barrels of oil and 19 of water. For a detailed description of the field, the reader is referred to a report by Augur.[1]

In the region lying between Montebello, East Los Angeles and South [illegible] there is a series of low rolling hills in which there are folds much beyond well No. 1 of the Standard Oil Company. Drilling to date indicates that the eastward portion of the structure is the most favorable.

[illegible]

ground. Outside of these hills there is no surface evidence of the underground structure. At the date of this report only one producing well has been obtained in the Santa Fe Springs field—the 'Meyer' well of the Union Oil Company. This well has been producing for two years light-gravity oil at approximately a hundred-barrel rate from below a depth of 4000 feet. There is no evidence available as to what the structure consists of. It is probable, however, that it is an anticlinal fold, with a northwest-southeast trend, and probably passes just north of Santa Fe Springs. The extent and productiveness of this field can only be determined by actual drilling.

Newport District.

The fields along the third and most southerly structure are as follows: At the extreme southwestern end is found the semi-proven area of the Newport district. To date no wells of commercial value have been obtained here, and it is doubtful whether any better results will be obtained in the future. The structure consists in general of a monocline dipping to the northwest. The formations exposed consist of diatomaceous shale and sandstone of the Monterey Series, which rest on sandstone beds probably of Eocene age in the San Joaquin Hills, and are, in turn, overlayed by Pliocene beds in the area west of Newport Bay. The Monterey shale is apparently the source of the oil which has collected in sandstone beds of this formation. There are several outcrops of tar sand along the road on the east side of Newport Bay. Approximately 10 wells have been drilled in this area, nearly all of which have encountered heavy tar, but have been unable to produce on a commercial scale. This is probably due to the unfavorable monocline structure. However, in one portion of the field there is a rather poorly developed anticline, this being due to a slight doming of the Monterey shale beds. The axis of this fold runs approximately east and west, and lies half-way between the Liberty Petroleum Company's well No. 1 and the Interstate Oil Company's well 'Irvine' No. 1. If any further development work is undertaken, a location on the axis of this structure would be the most favorable position for a well to test out the district.

Huntington Beach Field.

Seven miles northwest of Newport lies the newly discovered Huntington Beach field. This field centers around the town of Huntington Beach, and a group of low hills just northeast of the town, known as Las Bolsas. The only surface evidence of an oil field consists of these low hills, which serve as a topographic expression of the underground structure and gas found in shallow wells on the property of the Bolsa Chica Gun Club. The limits and structure of this field can only be determined by drilling. From such data as is available to date it is probable that the structure consists of an anticlinal dome, with a northwest–southeast trend. Drilling has been almost entirely confined to the northeast flank of this supposed anticline, so that the location of the axis is still undetermined. However, it is probable that it runs in a northwest–southeast direction a few hundred yards west of 'Bolsa Chica' well No. 1 and 'Huntington' No. 2-A of the Standard Oil Company. From the vicinity of Huntington 2-A it curves towards the

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beach in a southeast direction, so that it passes through well No. 1 of the Huntington Central Oil Company and well No. 1 of the Hurst Oil Company, and slightly east of well No. 1 of the Pantages Oil Company. From this point southeast its location is not known. Northwest of Bolsa Chica No. 1 the structure apparently plunges sharply to the northwest. 'Torrance' No. 1 of the Standard Oil Company, located approximately 2 miles northwest of 'Bolsa Chica' No. 1, and apparently along the continuation of the line of structure, has been drilled to a depth of 4000 feet without any indications of petroleum.[1] Drilling along the northeast flank of the supposed fold indicates that production may be obtained as far as a distance of three-fourths of a mile east of the axis as located above, but not at a distance of a mile. Roughly, then, the area in which production may be expected (based on the data available to date) consists of a strip lying approximately three-fourths of a mile on either side of a line drawn between 'Bolsa Chica' No. 1 and Pantages Oil Company well No. 1. The formations encountered on wells drilled close to the axis are as follows: From 0 to 500 feet, soft, loose sands and gravels, probably belonging to the San Pedro formation (Quaternary); from 500 to 700 feet, conglomerate and boulders are found—this marks the top of the Fernando. Then follows about 1600 feet of shales and sands of the Fernando, in which there are several tar sands. At about 2250 feet the first productive oil sands are encountered. Wells drilled down the dip encounter the first oil at depths from 2600 to 3400 feet. To date the oil sands have been penetrated to depths varying from 300 to 600 feet. Wells drilled on the northeastern flank have all claimed to have encountered the same productive sand, namely, the so-called 'Bolsa sand.' Whether this is so remains to be proved. However, the general uniformity of dip obtained by correlating the first productive sand encountered in these wells would lead to the belief that the same sands have been encountered in these various wells. In the vicinity of the Huntington Central and Pantages wells, which are located approximately on the axis, it is probable that an upper productive sand has been found which does not exist down the dip.

At the date of this report twelve wells are producing and the total daily production is 8000 barrels, or a daily yield of 666 barrels per well.

Signal Hill District.

As stated above, the anticlinal structure of the Huntington Beach field plunges sharply to the northwest, beyond 'Bolsa Chica' well No. 1. The general line of uplift, however, may be followed to the northwest, it being marked by the low hills just east of Seal Beach, known as Landing Hill, and by other low rolling hills on the north side of Alamitos Bay. From this point the structure apparently begins to emerge again till at Signal Hill, northeast of Long Beach, a well defined dome is apparent on the surface. The center of the dome is marked by the circular hill known as Los Cerritos, or Signal Hill. The formations exposed are gravels, sands and clays of the upper

[1]Since the date of this report a fair showing of oil has been encountered in this well below 4000 feet.

Fernando. The dip on the flanks vary from 10° to 25°, while the plunge to the northwest and southeast is about 15°. The general geological conditions here are extremely favorable for a highly productive field. At the date of this report three wells are drilling here. The Shell Company's well cemented off water at 2745 feet, and on drilling out the cement encountered fair showing of oil. On account of the sharp dips the productive area will probably be limited to a circle of about a half mile in diameter around the center of the hill.

Region from Signal Hill North to the Inglewood Hills.

Northwest from Signal Hill the structure again plunges sharply to the northwest, and the Fernando beds are overlaid by Quaternary sands. The general line of uplift, however, may be followed from Signal Hill northwest to Dominguez Hill, thence to Rosecrans, and thence through Athens on the Hill, and from there it continues northwest, passing about a mile east of Inglewood and running along the highest ridge of the Inglewood Hills. Along this entire distance it is marked by low rolling hills, and the position of the axis may be barely determined by low dips of 2° and 3°. In the Inglewood Hills, however, the position of the axis is well marked and dips of 5° to 10° may be obtained. The formations exposed are loose sands and clays of Quaternary age. This region has been tested by approximately nine wells: The Union Oil Company, the Standard Oil Company, and the Highland Development Company, each drilling a well at Dominguez. At Rosecrans, the Eddystone Oil Corporation drilled the two MacKey wells. At Athens on the Hill, the Union Oil Company drilled the 'Anderson well,' and in the Inglewood Hills the Standard Oil Company drilled two wells, and the Bartolo Oil Company drilled one well. These were all deep holes, those of the Standard Oil Company being over 5000 feet, and in none of them were any favorable indications found. It is probable that the plunge of the structure has buried the possible oil sands which should occur at the base of the Fernando formation beneath an excessive thickness of upper Fernando and Quaternary sands and clays, so that they are beyond the reach of the drill in this area.

Region from the Inglewood Hills to Beverly.

From the Inglewood Hills the general line of uplift continues northwest, passing just east of Culver City. From this point on the structure gradually emerges so that at a point about a mile west of Beverly the oil sands are again near enough the surface to be within reach of the drill. This area is known as the Beverly Hills field. The wells are grouped about the axis of the anticline which has a northwest–southeast trend, and run approximately along the west line of the Amalgamated Oil Company's 'Rodeo' lease. The total proven area of this field is 110 acres. The total average daily production in December, 1920, was 450 barrels of oil. The average number of wells producing was 15, with an average daily yield, per well, of 30 barrels of oil and 25 of water.

Region of the San Pedro Hills.

This region consists of the hills that lie west and northwest of San Pedro. The formations exposed here consist of diatomaceous shale and sandstone beds of the Puente formation (Monterey Series). Along the eastern and northern edges the Puente is overlaid by a small area of loose sands and gravels belonging to the San Pedro formation (Quaternary). The structure consists of a main anticlinal fold, with a northwest-southeast trend, the axis of which runs just east of the high center ridge of the hills and finally plunges to the south out to the sea at Point Fermin. Along this axis are several seeps of heavy tar, and at Point Fermin, where the plunge of the fold has caused the lower Puente shale to be overlayed by the upper sandstone beds, seepages of heavy oil are found at the contact. Shallow wells drilled here have encountered small showings of tar. On both sides of the main anticline there are several minor folds. One of these strikes out into the valley in a northeast direction, halfway between San Pedro and Redondo. Two wells have been drilled on this fold, located on the Weston Ranch. One, the Harbor Crude Oil Company's well, was drilled to about 1200 feet and encountered small showings. The second well, drilled by the Traders Oil Company, reached a depth of nearly 4000 feet. To a depth of 1800 feet, loose sands and gravels of the San Pedro formations were encountered, and small showings of heavy tar were found. Below 1800 feet the well has been drilled in 'brown shale' (Puente diatomaceous shale) and occasional small showings of oil have been noted. These two wells were favorably located, and their failure to obtain anything more than a showing would indicate that this region is not favorable for the accumulation of any appreciable amounts of petroleum. This is probably due to the lack of reservoir beds above the Puente shale.

Region Lying Between San Pedro and Santa Monica.

This territory consists of flat lowlands with some low sand hills along the coast from Playa del Rey to Redondo. There are no surface indications which give any hint as to the underlying formations or structure. This region, however, in common with the other flat areas of the coastal plain, has the possibility of containing buried productive anticlines. It has been thought that the low sand hills may possibly be a topographic expression of such a structure, and at the date of this report approximately 7 wells are drilling in the region east of El Segundo to test this theory out. Two of these wells, the Milwaukee Fountain Trust Company's well No. 1 and the Standard Oil Company's well No. 1 on Sec. 8, T. 3 S., R. 14 W., encountered considerable gas at about 1600 feet. There is no evidence to date to show whether or not this gas is connected with any petroleum deposit. No showings of oil have been found. The only manner in which the possibilities of this area can be told is by actual drilling. This entire region is worthy of being examined carefully for evidences of buried structure.

In the preceding paragraph all the areas in the coastal plain district in which there is the slightest indication of oil, or favorable structure, have been described. There yet remains to classify the areas in this district in which there is no direct geological evidence available to indicate whether or not they contain possible productive fields. These areas consist of the flat regions lying between the three general lines of structure above described. In general, they consist of the territory south and west from Los Angeles to Long Beach and Santa Monica, and southeast from Los Angeles to Anaheim and Santa Ana. The oil possibilities of these areas may be summed up by stating that they may contain buried anticlinal folds which may be productive. There is no direct evidence as to where, or whether, these folds actually exist but these areas are worthy of being carefully examined for such a possibility and have consequently been colored in blue on Plate I.

San Gabriel Valley.

This region may be considered as the territory lying north of the La Merced and Puente hills and south of the San Gabriel Mountains. The Puente sandstone and shale, and the Fernando sands and shales, which outcrop along the north flank of the Puente and La Merced hills, dip to the north and probably underlay the greater portion of the San Gabriel Valley, resting on the granite rocks of the San Gabriel Range, along the northern edge of the valley. The Fernando is principally confined to the northern slopes of the Puente and La Merced hills, and is found only in patches in the valley proper. In the San Jose Hills, which lie between Puente and Pomona, the diatomaceous shale of the Puente formations is domed up in an anticline, and along the northern edge the Puente is overlaid by a small area of Fernando. At the western end, just west of Pomona, outcrops of crystalline rocks are found, and similar outcrops are found in the north end of the Puente Hills, just south of Pomona. On the axis of the anticline, in the San Jose Hills, two wells have been drilled, one by the Santa Fe, and one by the Shell Company, both wells being drilled to a depth of over 3000 feet in the Puente and failing to find any favorable indications. Along the eastern slope of the Puente Hills in the vicinity of Chino it is possible that small showings of oil will be encountered by wells drilled here (see Chapter XII, San Bernardino County, for a further description of this region), and similar results can probably be obtained by wells drilled along the north flank of the Puente Hills north of the Whittier, Brea Canyon and Olinda fields, but it is extremely doubtful whether commercially productive wells ever will be encountered in the San Gabriel Valley, or along the northern and eastern flanks of the Puente Hills. This is due to the unfavorable structure and the lack of reservoir beds above the Puente shale.

Eastern Portion of Orange County.

This region will be considered in this report as that portion of the county lying east of the Santa Ana River and Newport Bay. The oil possibilities may be summed up by stating that the region is not a favorable one for the accumulation of petroleum. The geology of the region is as follows: The main portion of the Santa Ana Mountains is composed of ancient crystalline rocks, mostly slates of Jurassic age; along the western and southern flanks, rocks of Chico age are exposed, which, in turn, are overlaid by small patches of Eocene. This condition exists in the vicinity of the Orange County Park, where two wells are drilling, in beds of Eocene age.

Along the east bank of the Santa Ana River, from Olive to Corona, the Monterey Series and the Fernando formation, are exposed. These are folded in an anticline which runs parallel to the river from 'Horseshoe Bend' to Olive. This fold has been tested by approximately nine wells, and only small showings of oil have been encountered, so that it may be considered as unproductive.

In the Laguna Hills the formations exposed are mainly coarse sandstone of Eocene age. These are overlaid along the edges of the hills by beds of sandstone and shale of the Monterey Series. There are several minor anticlines in these hills, one of which is located at the edge of the hills south of Irvine and west of the Laguna road. The H. K. and T. Company has drilled a well on this fold to a depth of nearly 3000 feet without any encouraging results.

In the flat area running from Tustin to El Toro the diatomaceous shale of the Monterey is present, occupying a synclinal trough between the Santa Ana Mountains and the Laguna Hills. This condition continues southeast through the Capistrano district to the San Diego County line. Section AB, Fig. 10, shows this general structure, and the formations exposed. Following is a brief description of these formations: The Cretaceous consists of about 3500 feet of conglomerate sandstone and shale. The Eocene consists of the following beds: At the base about 1000 feet of shale characterized by dark red and purple clay beds, comprised of fine fragments derived from serpentine rocks, and similar to the 'Red Beds' of the Coalinga field. Above this is found about 2000 feet of coarse white sandstone, and finally at the top of these is another series of shales about 1000 feet in thickness. The base of the Miocene is characterized by an extremely coarse conglomerate, made up of fragments of schist, and of a thickness of over 200 feet. Above this conglomerate is found about 500 feet of Vaqueros sandstone and 1100 feet of Monterey shale, which occupy the trough of this syncline. Just north of Capistrano there is a minor fold in the Monterey on which the Union Oil Company has drilled a well to a depth of 4000 feet without any indications of petroleum.

The statement made at the beginning of this section that the region is not favorable for the accumulation of oil is based on the following facts: The greater portion of this area is covered by rocks that are older than the oil-bearing formations of Southern California, and which show no oil nor contain any beds that are capable of forming oil. The Monterey, which contains oil in other regions in Southern California, is found in this region only in a small thickness, and in an unfavorable structure, without reservoir beds for the oil to collect in. Lastly, to the best of the writer's knowledge, there are no surface indications of petroleum, such as seepages or gas blows, in the region lying east of Tustin.

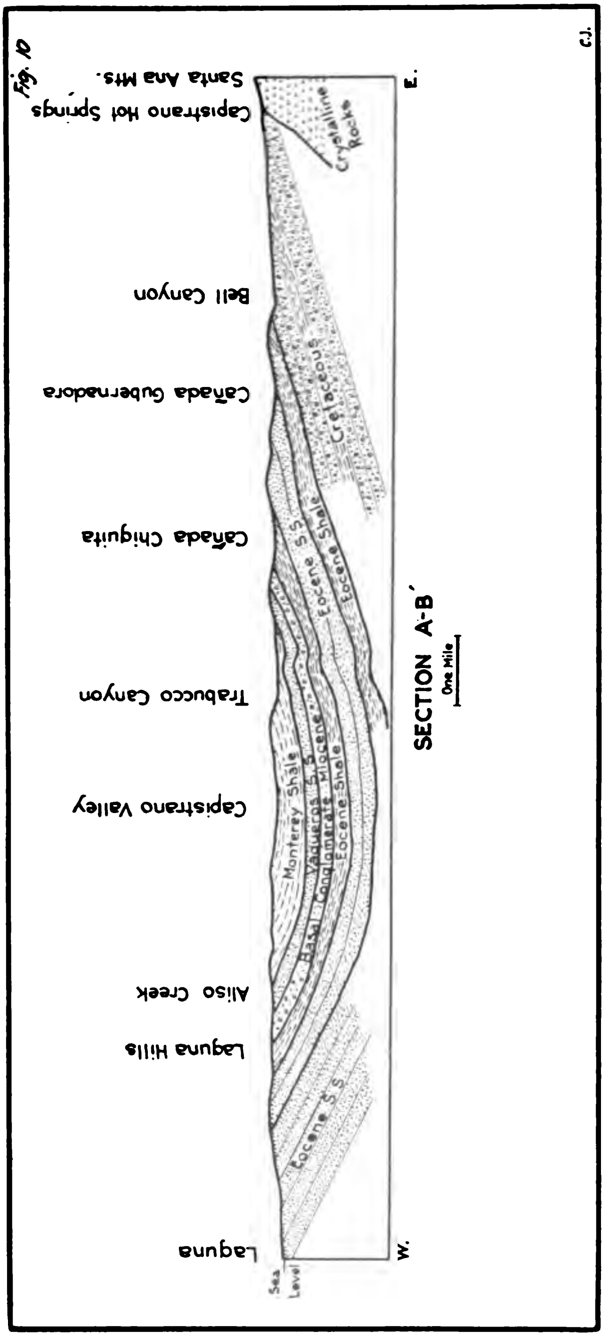

FIG. 10. Section A-B—From Laguna to the Santa Ana Mountains, across the Laguna Hills and the Capistrano Valley, Orange County.

CHAPTER XI.

San Diego and Imperial Counties.

San Diego County.

Topographically and geologically, San Diego may be divided into two areas, one a mountain highland area covering approximately eleven-thirteenths of the county and the other a narrow belt of about fifteen miles in width along the coast, characterized by broad, flat-topped sea terraces.

The highland area is a part of a great fault block, which is characterized by a steep descent to the Imperial County side and a gradual slope on the west to the terraces of the coastal plain. The formations of the highland region consist, for the most part, of granitic rocks, together with smaller areas of lavas and ancient crystalline schists and limestones. As none of these are capable of containing oil, no further discussion will be given of the highland area.[1]

The coastal strip is made up of sedimentary rocks, ranging in age from the Chico (upper Cretaceous) to the recent beach terraces. This area may best be discussed by dividing it into two parts, consisting of the region north of Del Mar and the region between Del Mar and the Mexican boundary.

In the region north of Del Mar, the sedimentaries are lying against the crystalline rocks, in a gentle monocline dipping about 10° to the west. The following formations are exposed: Eocene, lower Miocene and recent terrace deposits. The Eocene is best exposed along Santa Margarita Creek, between Ysidora and the Home Ranch. It consists of about 2500 feet of medium coarse white sandstone and above the sand is about 2000 feet of fine, tan-colored, muddy shales. North of Santa Margarita Creek the base of the Eocene is characterized by red and purple clay beds, known as the Red Beds and referred to in the description of the Eocene in the vicinity of Capistrano (Orange County). On account of the strike of the beds, which is approximately north and south, the upper shales disappear and run out to sea just south of Oceanside and from this point on south only the lower white sandstone beds are exposed, at times covered along the terraces by recent deposits. The entire Eocene Series is continuous north into Orange County and connected with formations of the same character and age, described in the vicinity of Capistrano. In the region at the head of San Mateo Creek, it is possible that the Eocene is underlaid by shales and conglomerates of Chico age, which in turn rest on the granite. The lower Miocene consists first of about 500 feet of coarse conglomerate made up of flat fragments of crystalline schist, probably derived from rocks of the Franciscan formation. This conglomerate is a continuation of the conglomerate beds referred to in the descriptions of the eastern portion of Orange County. It is most prominent in the vicinity of San Onofre Mountain, and disappears in its southward extension by striking out to sea at Oceanside.

[1]Certain areas of Tertiary sedimentary rocks found along the eastern border of the county, near Carrizo Creek and San Felipe Creek, will be discussed in connection with Imperial County.

The Vaqueros sandstone and semi-diatomaceous shale of the Monterey which overlies the conglomerate farther north in Orange County do not outcrop in San Diego County, but they are probably present beneath the sea terraces from the county line as far south as Santa Margarita Creek. In Fig. 11, Sec. AB shows the general structure and character of the formations north of Santa Margarita Creek. Between Oceanside and Del Mar, the only sedimentary formation present is the white sandstone member of the Eocene, dipping at a low angle to the west. There is no evidence of petroleum anywhere in the area between the Orange County line and Del Mar. The following wells have been drilled here:

Clark Oil Company well east of La Costa, NW. ¼ of Sec. 26, T. 12 S., R. 4 W., depth 2665, now being redrilled by the La Costa Oil Company. Pacific-Laguna Company well east of La Costa, SW. ¼ of Sec. 26, T. 12 S., R. 4 W., depth 1400 feet. Both wells failed to show oil. At the present time the Oceanside Oil and Gas Company is drilling a well in the Eocene shales about a mile and a half northeast of the town of Oceanside, and has reached a depth of about 1600 feet.

The La Costa Oil Company has taken over the old Clark well, which was abandoned some years ago, and redrilled to a depth of 2700 feet. Showings of oil and gas have been reported.

In the area between Del Mar and the Mexican boundary the general structure partakes of the nature of a very flat syncline, the axis of which parallels the coast about five miles inland. Beds of the following ages are found outcropping: Cretaceous, Eocene and Pliocene.

The Cretaceous is represented by the Chico and consists of beds of medium grained sandstone, blue-gray in color and interbedded by thin layers of dark colored shales. It outcrops on the surface only at the southern end of Point Loma and in the sea cliff at La Jolla. It probably underlies the entire area. The total thickness is not known, but well logs indicate that it is over 3000 feet.

The Eocene is probably represented by beds of Meganos age, and consists of clay shales and white sandstone, with a total thickness of about 1000 feet. The outcrops are limited to Point Loma, the sea cliffs from La Jolla to Del Mar, the vicinity of Soledad Mountain and at low levels in Soledad and Rose canyons. The Pliocene, known locally as the San Diego formation, overlies almost the entire area. It consists of beds of sandstone conglomerate and clay shales, with a total thickness of about 500 feet.

In Fig. 11, Sec. CD shows the probable structure in the vicinity of La Jolla and San Diego. The following wells have been drilled in this area:[1]

La Tengo Oil Company. Well one mile north of Tia Juana, in SW. ¼ Sec. 31, T. 18 S., R. 1 W., depth 3290 feet, reported oil and gas; drilled in 1911.

Tia Juana Valley Oil Company. Well about two and one-half miles south of Nestor and a few hundred yards north of the Mexican border, Sec. 9, T. 19 S., R. 2 W., known as the Scott well. Depth 1474 feet; drilled in 1910. The Community Oil Company has recently made an attempt to clean this well out.

[1]See Fourteenth Report of the State Mineralogist, pp. 708–712.

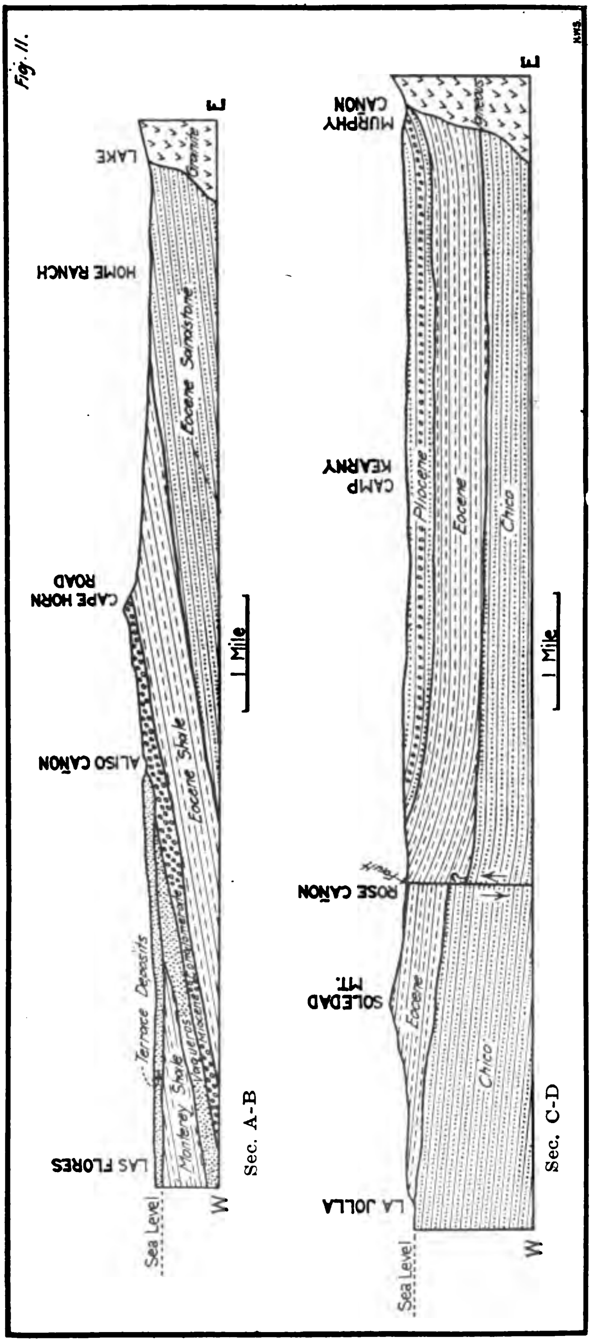

FIG. 11. Section A-B—East-west section along the north side of the Santa Margarita Valley, San Diego County. Section C-D—East-west section through La Jolla, San Diego County.

Otay Oil Company. Southeast of Otay, NE. ¼ of Sec. 30, T. 18 S., R. 1 W. Depth 2185 feet; drilled in 1910. Reported showing of oil and gas.

Balboa Oil Company. Well in the Mission Valley, Pueblo Lot 1105. Depth 5675 feet; drilled 1911.

San Elijo Oil Company. Two wells just west of Sorrento Station; Pueblo Lot 27. Depths 1599 feet and 1303 feet.

The Puterbaugh well at Moreno, about one and one-half miles north of Mission Valley. Depth 1200 feet.

The Chula Vista well, drilled near the town of Chula Vista, reached a depth of 1812 feet.

At the present time the following wells are drilling:

Linda Vista Petroleum, Sec. 23, T. 15 S., R. 3 W.

Community Oil Company has started the following wells: Well No. 1 (old Scott well), Sec. 9, T. 19 S., R. 2 W. The company is endeavoring to clean this well out. Well No. 2, Sec. 4, T. 19 S., R. 2 W. Well No. 3, T. 17 S., R. 2 W., Lot 17. Well No. 5, one mile east of Moreno, T 15 S., R. 3 W.

The Tecalote Dome Oil Company, T. 16 S., R. 3 W., Pueblo Lot 1272. Depth, 2650 feet.

Mission Valley Company, Sec. 24, T. 16 S., R. 3 W., Pueblo Lot 1108.

While most of the wells which have been drilled or are drilling at the present time report showings of oil or gas, the significant fact is that no actual production of oil has ever been obtained.

The possibilities of obtaining oil in this area are not very favorable. There is apparently a total lack of any actual evidence of petroleum, such as seepages or gas blows. The formations exposed show neither favorable structure nor contain sufficient organic material to form any noticeable quantities of petroleum. Unless evidence is found to disprove these facts, further drilling in this area is a waste of money.

Following is a portion of a report on the oil possibilities of San Diego County, from a press bulletin of the United States Geological Survey, March, 1920, based on an examination made by Mr. W. S. W. Kew:

"The region was recently examined by William S. W. Kew, of the United States Geological Survey, Department of the Interior, who is of opinion that San Diego County is not a favorable place in which to drill test wells for oil. The reasons for this opinion can be summarized as follows: (1) The principal formations that furnish oil elsewhere in California are not found in San Diego County. (2) The Upper Cretaceous strata, which probably constitute a large part of the sedimentary beds at San Diego, are not commercially productive in other parts of California, and there is nothing to indicate that they will be productive in the southern part of the state. (3) The Eocene strata, though of the same age as the oil-bearing strata in other parts of California, do not appear to contain oil here. As far as known, no structural features that are favorable to the aucumulation of oil, such as anticlines, have been discovered in San Diego County. As the strata dip very gently and at many places lie nearly flat, careful geologic work would be necessary to locate these structural features. If drilling is continued near San Diego, the structure should be carefully studied in order to determine the most advantageous places for sinking wells to test the oil sands that are reported to have been penetrated in previous tests.."

Imperial County.

Imperial County occupies the desert region in the extreme southeastern portion of the state. Its length east and west is approximately 100 miles and its width north and south is about 55 miles. About one-half the county is a great flat plain, known as the Imperial Valley, the major portion of which is below sea level. This great, flat valley represents the old sea bed of the most northerly extension of the Gulf of California, and has been separated from the present gulf by a barrier of sediments built up by the Colorado River. The waters of the gulf in this isolated portion gradually evaporated, leaving the basin of Salton Sink. In 1904, the Colorado River broke through its western bank and partly refilled Salton Sea. A little water is still running into it by way of the New River. At the present time the total area occupied by the sea is about 270 square miles, of which 230 square miles lie within the county, occupying the northeast corner. The surface of the water is about 250 feet below sea level and the depth is about 37 feet.

On two sides the Imperial Valley is surrounded by mountain ranges. On the west the highland area of western San Diego County (Peninsula Range) rises abruptly from the valley floor along a line marked approximately by the boundary between the two counties. Superstition Mountain is a detached range lying out in the valley northwest of the town of Imperial.

On the east, forming the northeastern one-half of the county, are several mountain ranges, chief of which are the Chocolate Mountains. This portion of the county may be considered as having no oil possibilities. The formations which are exposed consist mainly of ancient metamorphic rocks, probably of pre-Cambrian age. In various localities these metamorphics are covered by lava flows of a much younger period. Along the west slope of the Chocolate Mountains are outcrops of vivid colored sands, clays and gravels, probably of Pliocene age. The character of the formations and the total lack of any evidence of petroleum make this region unfavorable.

That portion of the county which is underlaid mainly by Tertiary sedimentary rocks, and contains the only areas worth investigating, lies west of the main line of the Southern Pacific Railroad, and consists of approximately a little more than one-half the county (Plate No. VI shows this area). With the exception of a strip about ten miles wide along the western border, and the areas around Superstition Mountain and Yuha Buttes, this district is covered entirely by recent deposits of fine silt and sand. The geology of it will therefore have to be determined by studying the formations exposed in the localities mentioned above. The strip along the western border, which contains the exposures of the underlying formations, is formed by spurs of the Peninsula Range jutting out into the valley. The principal spurs are Coyote Mountain and Fish Creek Mountain. North of San Felipe Creek there is a series of low, rolling hills, which may be considered as the southeastward extension of the Santa Rosa Mountain, and which contain excellent exposures of the sedimentary formations. Superstition Mountain, lying mainly in Townships 13 and 14 S. and Range 11 E., has a core of crystalline rocks and the Tertiary sedimentaries are exposed in the low, rolling hills to the northeast. Yuha Buttes consists of a few low mounds in Secs. 28 and 33, T. 16 S., R. 11 E., which are formed by an uplift in sedimentary strata.

The oldest rocks in this district consist mainly of marbles and schists, into which have been intruded masses of granitic rocks and pegmatite dikes. The age of this complex crystalline series is not definitely known, but Fairbanks[1] believes it to be of Carboniferous age. It is a part of

[1]Eleventh Annual Report of the State Mineralogist, H. W. Fairbanks, p. 90, 1893.

the crystalline series that form the highland area of San Diego County, and is commonly referred to as the basement complex. Within this area it is found outcropping along the north slope of Fish Creek Mountain, along the central core of Coyote and Superstition mountains, and finally in the group of mountains between Coyote Wells and the Mexican border.

The next oldest formation is a highly colored Andesitic lava flow, approximately 200 feet in thickness. It lies unconformable upon the eroded surface of the basal complex and is best exposed running east and west along the central ridge of Fish Creek Mountain and in small patches on the eastern slope of Coyote Mountain. The age is probably middle Tertiary.

Lying with marked unconformity upon the lava and basement complex is a series of sedimentary rocks, first described by Kew[1] and called by him the Carrizo formation. The basal beds of this formation consist of medium-coarse gray sandstone, together with beds of coarse conglomerate. The sandstone is characterized by numerous fossils and coral reefs. Above this sandstone member are found beds of fine sandy shales, silts and clay shales. The fine clay shales are usually of a chocolate color and bear at first sight a resemblance to certain varieties of diatomaceous shale. However, an examination under the microscope shows no diatoms and the beds apparently are lacking in any appreciable amount of organic matter. The upper shale beds are characterized by fossil reefs made up of the remains of oysters and pectens. The age of the Carrizo formation is probably upper Miocene to lower Pliocene, and the thickness between 3000 and 4000 feet.

The formation is exposed in the following places: at Yuha Buttes, at Coyote Mountain, along the south slope of Fish Creek Mountain, in the low hills north and east of Superstition Mountain, in the low hills north of San Felipe Creek, and continuing north to the Riverside boundary. This latter area also continues westward into San Diego County as far as Clark Lake.

Considerable movement has taken place in the valley, and the Carrizo beds have been sharply folded into numerous structures. The principal areas are as follows: Yuha Buttes is a domed anticline. A plunging anticline apparently strikes out of the east slope of Coyote Mountain. There are numerous folds to the east and north of Superstition Mountain. Carrizo Creek marks the axis of a syncline running east and west. In the area north of San Felipe Creek, the major fold runs southeast along the south line of T. 11 S., Rs. 9 and 10 E., and at least two minor folds diverge from this structure and strike to the northeast.

Seepages of oil and the presence of asphaltum have been frequently reported as being found in the Imperial Valley, and the majority of wells now drilling in the valley have reported showings of oil and gas. However, none of these reputed seepages or showings of oil have ever been verified by any representatives of the State Mining Bureau.

The possibilities of finding oil in the valley may be summed up as follows: while the structure of the Carrizo beds is extremely favorable for its accumulation, there is apparently no formation present that

[1]University of California. Bull. 5, Vol. 8, 1914. Tertiary Echinoids of the Carrizo Creek Region in the Colorado Desert. By W. S. W. Kew.

could form petroleum. From the above description of the rocks exposed, it is evident that the only beds that could possibly contain oil are those of the Carrizo formation and it is equally evident that this formation does not contain sufficient organic matter to form any noticeable amount of petroleum. It should also be noted that the Carrizo beds are sharply folded and tilted, and if any oil were present it would show as seepages along the outcrops. The only possibility of finding oil lies in the bare chance that somewhere in the valley there are beds of organic shale, the outcrops of which are hidden by the overlapping of the Carrizo beds against the crystalline rocks. If such beds existed, and there is no direct evidence that they do, oil would tend to collect in the anticlinal structure of the Carrizo formation.

The wells now drilling, a list of which is given below, are nearly all favorably located and should conclusively prove or disprove the presence of oil in the county. Recent reports have been made on the county by Mr. W. S. W. Kew[1] and Mr. Irving Augur.[2]

Following is a portion of Kew's report:

"The Carrizo Creek beds have been folded into numerous arches (anticlines) and troughs (synclines). One of the larger anticlines that seems favorable to the accumulation of oil lies north of San Felipe Creek. Others are on the north, east and south sides of Superstition Mountain, the core of which is granite. The southeastern extension of this mountain is an anticline, which extends from the granite in the southeast corner of T. 14 S., R. 11 E., across the southwest corner of T. 14 S., R. 12 E., into T. 15 S., R. 12 E. The beds along the anticline in this area dip rather steeply away from its axis, which plunges gently to the southeast. Anticlines also occur north and northeast of the granite center of Superstition Mountain.

"The strata in the hills between San Felipe Creek and the Salton Sea have beeen considerably folded, though southeast of Seventeen Palms there appears to be only one major anticline or dome upon which subsidiary folds are superposed. This main anticline trends southeastward across the southeastern part of T. 11 S., R. 9 E., and the southwestern part of T. 11 S., R. 10 E., and extends into T. 12 S., R. 10 E. The highest point on this anticline—the apex from which it plunges to the northwest and southeast—is near the line between Secs. 25 and 36, T. 11 S., R. 9 E., and the angle of plunge is about 10° to 20°, becoming less steep with increase of distance from the apex. The beds dip from the axis of the anticline at an average general rate of 15° to 30°, but those that form the subsidiary folds attain at some places a dip as high as 55°.

"In general, the top of the anticline is fairly flat, though it is broken into minor folds. The well of the Imperial Valley Oil and Development Association is on the east side of the highest point or apex and the Diamond Bar well is on the west side; both wells are only a short distance north of the axis of the anticline. This anticline is probably one of the most promising in Imperial Valley, and the test wells are properly located to prove the presence or absence of oil there.

"Seepages and oil sands in Imperial Valley have frequently been reported, but none of these reports have been authenticated, and samples of so-called oil sands have always proved to be sands blackened by manganese oxide, but it is reliably reported that asphalt occurs on the southeast edge of a dry lake west of Signal Mountain, about 3 miles south of the Mexican border. Several wells drilled for oil in the valley have not yielded favorable results. In 1902 two wells were sunk at Yuha Buttes, in Sec. 32, T. 16 S., R. 11 E., on a domelike uplift in the Carrizo Creek beds. One of these wells was sunk 1300 feet without getting any indication of oil except a little gas. The Harper well, also known as the Mesquite drill hole, in the northeast corner of Sec. 34, T. 12 S., R. 10 E., is reported to have gone 700 feet and to have struck a little gas. It now yields water. The Hanna well, on the north side of Fish Creek Mountain, is said to be 800 feet deep. The Hudson well, in the southwestern part of T. 14 S., R. 11 E., is about 500 feet deep. The result of what is known as the Barrett drill hole, sunk near the mouth of Carrizo Canyon, is not known.

"The geology structure in Imperial Valley is exceptionally favorable to the accumulation of oil, and if any of the beds of the Carrizo Creek formation contain oil it should be found in some of the anticlines that are now being tested. These beds show no surface indications of oil, but in some of the wells they have yielded a little gas. As these beds crop out in great thickness, and they are faulted at many places, they should show seepages, or oil-impregnated sands, if they contain oil. The

[1] U. S. Geological Survey. Press Bull., June, 1920. Oil Prospects of the Imperial Valley. By Mr. W. S. W. Kew.

[2] California State Mining Bureau. Summary of Oil Field Operations for April, 1920. Resume of all Well Operations in the Imperial Valley. By Irving Augur.

absence of such seepages is the strongest evidence against the presence of oil in the Imperial Valley, but it is not conclusive. In Mr. Kew's opinion, Imperial Valley should be tested for oil, but the tests should be made only by persons or companies who can afford to invest large sums of money with poor chances of success."

Following is a list of the wells now drilling (see Plate VI):

In Sec. 9, T. 16 S., R. 10 E., the San Diego and Imperial Valley Oil Company has a well down to a depth of about 1100 feet. The hole known as the 'James well' is located on the south side of a plunging anticline in the Carrizo formation.

In Sec. 6, T. 16 S., R. 11 E., the Southwestern Pipe Line and Petroleum Company has a well down to a depth of about 700 feet. This well is located in the flat lands of the valley and apparently no structure is present. In the area just north of the well the writer noted several outcrops of coarse sandstone dipping about 40° to the east. This exposure, however, was too meager to determine whether any structure was actually present. The log of the well indicates that the beds penetrated belong to the upper portion of the Carrizo formation.

In Sec. 11, T. 16 S., R. 14 E., near Holtville, the 104 Oil and Drilling Company has a well drilling.

In Sec. 32, T. 11 S., R. 10 E., the Imperial Valley Oil and Development Company has a well known as the Brawley well, which is located on a dome in the Carrizo formation. A depth of 2570 feet has been reached.

In Sec. 25, T. 11 S., R. 9 E., L. Lechtenberger is drilling a well known as the Diamond Bar well, which is located on a dome in the Carrizo formation. A depth of 3083 feet has been reached.

CHAPTER XII.

The Desert Region.

(Includes the counties of Riverside, San Bernardino, Northeastern Los Angeles, Eastern Kern and Inyo and Mono.)

This region, for the purpose of this report, will be regarded as lying east of the Sierra Nevada, Tehachapi Mountains, Sierra Liebre Range, San Gabriel Range, and east of and including the San Bernardino Mountains and Peninsula Range. This group of mountains, running approximately north and south, with a slight westward bend in the Antelope Valley region of Los Angeles County, effectually shuts off the desert area from the southern coastal plain and the central valley of California.

As the area will be discussed by counties, the fertile western portions of Riverside and San Bernardino counties, lying west of the mountain and properly belonging to the coastal area, are discussed partly here and partly in Chapter X.

Imperial County, which is a portion of this area, has, on account of slightly different geological formations and recent attempts at development, been included in a separate chapter (XI) with San Diego County.

While this region is commonly known as the desert area, it is far from being a land of broad desert plains, as possibly one-half of the territory is occupied by high mountain chains, which rise with striking abruptness from the desert floor.

In Mono and Inyo counties these mountain chains form a series of parallel ranges, with a north and south trend.

The central region is occupied by what is known as the Mojave Desert, the western part of which is known as the Antelope Valley. The southeastern portion is known as the Colorado Desert and the southwestern quarter is occupied by the San Bernardino and Peninsula ranges.

The general geology and oil possibilities of this region may be summed up as follows (excluding the small portion of Riverside and San Bernardino counties which lies west of the mountains and belongs to the coastal area):

The greater part of the flat desert floor is covered by recent sand deposits. Along the lower foothills of the mountain ranges, particularly in the western and northern portions, there are small areas of Tertiary sedimentary rocks, interbedded with lava flows. These sediments, for the most part, represent either lake or land deposits. The higher ranges of the southern region are composed of crystalline rocks, either granites or pre-Cambrian metamorphics. The high ranges of the northern region are also crystalline in character, being either composed of granites or highly metamorphosed sediments of Paleozoic and Mesozoic age. With two exceptions which will be noted below, there are no known deposits of sedimentary rocks which may correspond to the oil-bearing formations of California. It is evident from a study of this region that it had a totally different geological history from the oil fields. The various Tertiary seas in which the oil-bearing formations were deposited apparently did not cover any appreciable portion of this area. The two exceptions mentioned above consist of beds of Eocene age, and the only thing they have in common with the oil-field formations is that they were laid down in the same sea and consequently are of the same age as certain Eocene beds which are oil bearing in other portions of the state. One area of Eocene is found along the western border of the Mojave Desert, near Rock Creek, Los Angeles County, and consists, according to Dickerson,[1] of about 5000 feet of coarse sandstone and shale, belonging to the Martinez formation. This area probably represents the eastward line of the Martinez Sea. The second area of Eocene is found in the Elsinore Valley and consists of small thicknesses of highly colored shales and sands of Tejon age. Neither of these deposits show the slightest indication of petroleum. The rocks that are present, consisting mainly of granites, highly metamorphosed Paleozoic and Mesozoic sediments, Tertiary sediments of land or lake origin, together with lava flows, are all unsuitable for the formation of any appreciable amount of petroleum.

To the best of the writer's knowledge there are no known authentic seepages of oil in this area. Two rather doubtful cases may be cited, however. On an island in Mono Lake there is a hot mineral spring from which it is reported that oil seeps, and the writer has been furnished with a bottle of the oil. The formation in the vicinity of the lake and on the island is composed in part of fresh-water diatomaceous shale, about 100 feet in thickness. This shale has been intruded by an igneous dike and it is conceivable that this intrusion may have caused destructive distillation of the fresh-water shale, with the result that an insignificant amount of oil was formed. The second case consists of a sample which was brought to the Bureau by a prospector from 'somewhere near the Inyo-Mono county line.' This sample turned out to be a piece of Gilsonite, or mineral tar. Deposits of this tar have been reported as occurring in Nevada. Innumerable seepages and indications of oil have been reported from this area and a certain well in the Mojave Desert has been reporting oil for the last eighteen years, but it may be noted here that in no case have these reports been verified.

From the above brief description of the geology it is evident that the possibility of obtaining oil in the desert region is extremely small.

Following is a brief description of the particular geology and attempts at development in each county:

Mono County.

Mono County lies at the extreme northern end of this area. The formations exposed are mainly granitic rocks and lava flows. In the mountains west of Mono Lake and in the southeastern portion of the county, reddish gray limestones and beds of sandy shale of Cambrian age have been reported. In the vicinity of Coleville, Bridgeport and on the east side of Mono Lake, there are fresh-water sedimentary deposits, probably representing old lake beds. At Mono Lake they contain a bed of fresh-water diatomaceous shale, from which seepages of oil have been reported, a possible explanation of which has been given in the preceding paragraphs. Following is a portion of McLaughlin and Waring's report on this area:[2]

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[1]University of California. Bull. Department of Geology, Vol. 8, No. 14. The Martinez, Eocene and Associated Formations at Rock Creek. By R. E. Dickerson, 1914.

[2]California State Mining Bureau. Bull. 69. Petroleum Industry of California. By R. P. McLaughlin and C. A. Waring, 1914.

"Mono County

"Attempts have been made to develop oil near Mono Lake and a brief statement, based upon examinations by the author, of the very scant possibilities, may be useful. Surrounding the lake are sedimentary deposits containing marl, clay and diatoms, volcanic ash and gravel. Israel C. Russell reports[1] a measured thickness of 200 feet, and states that the total must be very much greater. This deposit was laid down during Quaternary time when the lake was much larger than at present. There are no other unaltered sediments known. The lake deposits rest upon granite, metamorphics and glacial drift and are intruded or overflowed by recent basic igneous rocks.

"The only reported indications of oil is a spring near the eastern shore of Paoha Island. Russell mentions this spring and the fact that it had an odor of petroleum. However, he gives the temperature of the water and its analysis, but makes no further mention of the presence of oil. Several experienced oil men have stated that they collected oil on the surface of the water.

"During 1908 there were two wells drilled. One, near Dechambau's Ranch on the northern shore of the lake, is about 900 feet deep, and hot water flows over the casing. The other well, near the southwestern shore of Paoha Island, was drilled to 2010 feet, all in blue shale except between 1700 and 1800 feet, where pink sand gave a strong flow of hot water which rose over the casing.

"There is no reason to suppose that other drilling would be successful."

A detailed geological description of the county can be found in the Eighth Annual Report of the United States Geological Survey, Part I, pp. 261–394, by Israel C. Russell.

Inyo County.

The formations of Inyo County may be divided roughly into three classes. The first consists of beds of highly altered sediments, mainly limestones and slates, varying in age from the Cambrian to the Triassic. They are found in the mountain ranges east of the Owens River Valley. The second consists of great masses of granite, which have been intruded into the altered sediments.

The third consists of Tertiary lava flows, lying unconformably upon the first two. All have been highly crushed and folded. The only area of unaltered sediments is a small thickness of Tertiary beds along the west flank of the Funeral Mountains, near Furnace Creek. These beds, with a maximum thickness of about 500 feet, consist of tuffaceous sandstone, conglomerates and clays. Ball[2] has correlated them with the Siebert lake beds of Miocene age. No evidence of petroleum has been reported from this formation. A detailed geological map and report of the county has been made by Waring and Huguenin.[3]

Eastern Kern County.

This includes the desert region of Kern County, which lies east of the Tehachapi Mountains and forms the northwestern portion of the Mojave Desert and the Antelope Valley.

The formations exposed consist mainly of much altered schist, gneisses, marbles and slates, probably of Paleozoic age, together with smaller areas of granite. Overlying these ancient rocks is a series of beds of Tertiary age, to which the general name of the Rosamond Series has been applied by Hershey.[4]

These beds are found at wide intervals over practically all the Mojave Desert region. They consist of beds of sandstone derived from granitic

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[1]U. S. Geol. Survey. Eighth Annual Report. Part I, pp. 261–394.

[2]U. S. Geological Survey. Bull. 308. Geologic Reconnaissance in Southwestern Nevada and Eastern California. By Sidney H. Ball, 1907.

[3]California State Mining Bureau. Geological Map of Inyo County. By C. A. Waring, 1917. Mines and Mineral Resources of Inyo County, 1915–1916. By C. A. Waring and E. Huguenin. Also in Report XV, pp. 29–134.

[4]Hershey, O. H. Some Tertiary Formations of Southern California. Am. Geologist. Vol. 29, pp. 365–370, 1902.

debris, together with beds of rhyolitic tuff, coarse breccias of lava and granite and some muddy clay shales. Their maximum thickness is about 3000 feet and the age is upper Miocene. They contain no evidence of petroleum. Within the area under discussion they are found, just north of Rosamond Station, and in the El Paso Range, near Ricardo post office. It is also possible that they outcrop in the hills north of Neenach, in the Antelope Valley.

In Sec. 27, T. 9 N., R. 17 W., S. B. B. and M., about six miles northwest of the ridge route of the state highway, there is a well being drilled by Robert Watchorn. A depth of 4100 feet has been reached, at which point a large flow of hot mineral water was encountered. The well is located just south of an area of crystalline rocks and the material around the rig consists of granitic debris. It is possible that the well was drilled for a portion of the way in the Rosamond Series.

Northeastern Los Angeles County.

This comprises that portion of Los Angeles County lying north of and including the north flank of the Sierra Liebre and San Gabriel ranges. The level portion of this area is known as the Antelope Valley and is covered by recent desert deposits. Along the eastern line of the county there are outcrops of crystalline rocks. The north flank of the San Gabriel and Sierra Liebre ranges are composed mainly of granite, with smaller areas of metamorphic rocks. At various places along the southern edge of the Antelope Valley there are small patches of unaltered Tertiary deposits. These consist of coarse sandstone conglomerates and clays, partly old lake beds and partly landlaid deposits. The age is mainly Miocene. The only marine deposit recognized consists of the area of Martinez Eocene, reported by Dickerson at Rock Creek and referred to at the beginning of the chapter.

It is possible that beneath the recent desert sands there are present beds of the Rosamond Series. Nowhere in the district is there any evidence of petroleum.

San Bernardino County.

Practically nine-tenths of the county lies north of the San Bernardino Mountains and forms the greater portion of what is known as the Mojave Desert region. The flat desert spaces of this region are covered with recent desert deposits. The mountain ranges are composed of crystalline and highly altered metamorphic rocks. These consist of granitic rocks, areas of metamorphosed sediments of pre-Cambrian and Paleozoic age, together with lava flows, mainly of Tertiary age. There are also in various basins, beds of coarse sand, conglomerates and clays, representing lake and landlaid deposits of Tertiary and Quaternary age.

In the region around Barstow and Daggett, extensive areas of the Rosamond Series (upper Miocene) have been recognized. The Rosamond beds are here composed of lava flows, fine-grained tuff, volcanic ash, beds of green clay, conglomerate, impure limestone, and coarse sandstone, none of which are capable of forming any amount of petroleum. Nevertheless, a superficial resemblance of certain of the clay beds to some of the oil field formations has caused periodic 'oil booms' in this region for the last eighteen years. Seepages and oil showing in wells drilled here have been reported but never verified. The area has been examined by the United States Geological Survey[1] for oil and has been condemned.

Following is Pack's conclusion of the region:

"CONCLUSIONS AS TO THE PRESENCE OF PETROLEUM.

"The writer believes that the northern part of the Mojave Desert between Barstow and the town of Mojave offers practically no promise of becoming a productive oil field, and that further drilling will prove but a waste of money. The principal reasons for believing that this land will not prove productive are (1) the lack of strata from which it would seem reasonable to believe that oil might have been formed, especially the lack of thick masses of organic material (diatomaceous and foraminiferal shale), such as those which occur in or near all the oil fields in the southern half of California, and in which the oil is believed to have originated; (2) the lack of structural features favorable for the correction of petroleum, even if it existed, disseminated through the strata.

"The pre-Tertiary rocks can not reasonably be regarded as a source of petroleum. Only a small portion of these rocks are of sedimentary origin, and they are so metamorphosed that even had oil once existed in them it is hardly conceivable that they should still contain it. The granitic rocks in the complex are, if possible, an even less likely source of petroleum, as their texture is so dense that they would offer practically no reservoir in which oil might collect if it existed in the near-by rocks. Oil has been found in rocks lithologically similar to some of the pre-Tertiary rocks of the Mojave Desert at only a single locality in California. This occurrence, at Placerita Canyon, about 20 miles north of Los Angeles, has been described by Eldridge[2]. The oil, at this place, occurs in fractured schists which rest upon the granite of the San Gabriel Mountains. The most logical explanation for the presence of the oil here is that it has migrated from early Tertiary organic shales which may have at one time rested upon the metamorphic rocks, and which may now occur in the vicinity beneath the unconformably overlying late Tertiary beds. In the Santa Clara River Valley, a few miles west of Placerita Canyon, the early Tertiary strata and the beds in contact with them are filled with oil. As organic materials similar to those in the Santa Clara Valley are unknown in the Barstow-Kramer region, it can not be expected that a similar accumulation of oil will be found in the metamorphic rocks in this region.

"The recent coarse gravel, sand and clay which form the filling in the topographic basins and which, in places, extend as a veneer over the lower hills, are equally as unlikely a source of petroleum as the pre-Tertiary complex. They are composed almost or quite complete of fragments derived from the older rocks in this or in adjacent regions, and it is not reasonable to believe that these masses of rock fragments would be more likely to produce petroleum than the same rocks in place. The Tertiary volcanic rocks are likewise not to be considered as a source of petroleum for much the same reasons as apply to the granitic rocks in the pre-Tertiary complex.

"It remains then but to consider the Tertiary sedimentary rocks. The coarse-grained Tertiary beds are formed of fragments of various types of granitic, volcanic, and metamorphic rocks and are evidently no more probable a source of petroleum than are the recent beds of sand and gravel. On the other hand, to casual observation, the fine-grained Tertiary rocks of the Barstow-Kramer region appear to be similar to the Tertiary rocks in many of the oil fields of this state, and it is not so very surprising that in this region they have been regarded as a possible source of oil. A careful examination of them shows, however, that they are really very different from the Tertiary shales in the productive oil fields, and in place of being composed very largely of the remains of organisms they are formed almost wholly either of fine volcanic ash or of detrital material derived from rocks of various types. They thus resemble the coarse-grained beds in the same region, differing from those beds mainly in the size of the particles they contain, and are not to be compared with the masses of organic material in the large productive oil fields of California. The only indications of organic matter seen in these beds were small particles of carbonized terrestrial vegetation scattered through some of the clayey and finer sandy beds, but the total amount of organic matter is entirely too small to be considered as a possible source of more than the merest traces of oil.

"It is, of course, possible that in the broad, level desert areas, rocks of different types from any exposed in the hills may lie buried beneath the desert gravel. It is also possible that such rocks, if they occur, are like those in the Tertiary formations in the San Joaquin Valley on the opposite side of the Tehachapi Mountains. There is, however, nothing in the geology of this region, or, so far as known, in that of the desert as a whole, to support such a hypothesis.

"No surface indication of petroleum was seen anywhere in the region. It is commonly rumored that a seep occurs in the Tertiary rocks northwest of Black Mountain, but a careful search failed to reveal it nor did persistent questioning discover anyone who could describe its location. The structure of the Tertiary rocks

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[1]U. S. Geol. Survey. Bull. 541. Reconnaissance of the Barstow-Kramer Region. By R. W. Pack, 1914.

[2]Eldridge, G. H., and Arnold, Ralph. The Santa Clara Valley, Puente Hills and Los Angeles Oil Districts, Southern California. U. S. Geol. Survey. Bull. 309. Pp. 100–101, 1907.

is complex. In many places they are tilted to high angles and intricately faulted, and if oil occurs in them it is surprising that it does not, at some place, show at the surface.

"Even if oil was originally distributed in minute quantities through the rocks, the structure is not such that it would have tended to collect or trap the oil. Irregular and faulted folds occur in at least three places northwest of Barstow—the Barstow syncline in T. 11 N., R. 2 W., a small anticline just north of the Giroux well in T. 32 S., R. 44 E., and an irregular fold or folds in T. 31 S., R. 44 E. It is generally reported that a well-marked anticline passes through the hills north of Barstow. Indeed, it is believed by some that such a fold extends along the north side of the desert from Tehachapi Pass nearly to Barstow. This idea is erroneous, for the only folds here are small, discontinuous and much faulted. Faults, not folds, dominate the structure. Thus the structure is much more favorable for the escape of any oil that might possibly have been found here than it is for its concentration in appreciable quantities."

Four wells have been drilled here. The Kramer Consolidated Oil Company's well in the NW¼ of Sec. 11, T. 10 N., R. 5 W., is located about three miles north of Hawes Station, on the Santa Fe Railroad. This well has been drilling for the last 18 years, and a depth of 3000 feet has been reached. The Chicago Oil Company's well in the SW¼ of Sec. 35, T. 11 N., R. 1 W., is located on the west side of the Calico Mountains, and a depth of over 2000 feet is reported.

The Giroux well in the SE¼ of Sec. 17, T. 32 S., R. 4 E., is located a mile west of Black Canyon. A depth of 440 feet is reported.

The Mojave Oil Company's well in the SE¼ of Sec. 14, T. 11 N., R. 12 W., is located about 2½ miles southeast of Mojave. A depth of 1100 feet is reported.

In Cajon Pass, and in the region north and west of the Paso, there is an area of highly-tilted deposits consisting of fanglomerates, coarse conglomeratic sandstone, clays and shales. Dickerson[1] believes these to be of upper Miocene age, and to represent lake and land-laid deposits.

The San Bernardino Mountains consist mainly of granitic rocks, together with smaller areas of highly altered crystalline sediments of Paleozoic age.

District Lying West of the San Bernardino Mountains.

This district comprises the fertile valley land lying in the vicinity of Redlands, San Bernardino and Chino. On the north and northeast it is bounded by crystalline rocks of the San Gabriel and San Bernardino ranges; on the east and southeast it extends into Riverside County for a few miles, where it is terminated by crystalline rocks of the Peninsula Range. At the extreme southwest corner lie the Chino Hills, composed of sedimentary rocks of Tertiary age. The greater portion of this area is covered by recent soil and valley alluvium, but it is probable that the crystalline rocks which bound it on three sides are present at no great depth beneath this surface soil. There are two areas of unaltered sedimentary rocks within this district. One lies south of Redlands, and is composed of light-colored clays and shale, together with beds of gravel. These beds are continuous with similar beds in the vicinity of Beaumont and San Gorgonio Pass, and will be discussed more fully under the article on Riverside County. It can be noted here, however, that they contain no indication of petroleum. The second area of sedimentary rocks lies in the Chino Hills. This is the

[1]University of California. Department of Geology. Bull. 14, Vol. 8. The Martinez, Eocene and Associated Formations at Rock Creek on the Western Border of the Mojave Desert. By Roy E. Dickerson, 1914.

only portion of San Bernardino County, or of the entire region under discussion in this chapter, that offers the slightest possibility of containing oil. These hills, which lie to the south and west of Chino, are the northeast portion of the Puente Hills of Los Angeles County, but are known locally as the Chino Hills. The formations exposed consist mainly of sandstone and diatomaceous shale belonging to the lower portion of the Monterey Series, which is known in this locality as the Puente formation. At the extreme south end of this area, along the Santa Ana River, the lower Puente is overlaid by a small area of Fernando. The diatomaceous shale of the Puente is the source of the oil in the proven fields of Los Angeles and Orange counties, and within the area under discussion it contains indications of oil. These consist of numerous outcrops of oil sand and bituminous shale. The general structure consists of a monocline dipping to the northeast in which there are minor anticlinal folds.

The region can not be considered as favorable for the accumulation of oil in commercial quantities. This is due to the lack of reservoir beds overlying the Puente, and to the general unfavorable structure.

There have been a number of wells drilled in this region, the majority of which encountered small showings of heavy tar in the sandstone beds of the Puente, but failed to produce on a commercial scale. There is no reason to believe that wells drilled here in the future would have any better results.

Following is a list of the abandoned wells:

The Chino Land and Water Company's wells were located on Sec. 32, T. 2 S., R. 8 W., and encountered heavy oil between 900 and 1000 feet. The Chino Valley Beet Sugar Company's wells were located on Sec. 30, T. 2 S., R. 8 W., and encountered heavy tar between 450 and 465 feet.

At the present time the following wells are drilling in this area:

The International Petroleum Company's well is located on Sec. 17, T. 2 S., R. 8 W.; The Pomona Petroleum Company's well is located in Sec. 28, T. 2 S., R. 8 W.; The Chino-Corona United Company's well is in Sec. 1, T. 3 S., R. 8 W. The Mahala Oil and Gas Company's well is in Sec. 13, T. 3 S., R. 8 W. All of these wells have reported showings of heavy oil.

Riverside County.

The eastern half of the county, lying east of the Salton Sink area, is a mountainous and desert region, commonly known as the Colorado Desert. The chief mountain ranges are the San Bernardino Range and the Hathaway and Chuckawalla mountains. The level desert areas are covered by recent sand, while the mountain ranges are composed of crystalline rock, chiefly granites and ancient metamorphic sediments. On the west slope of the Hathaway Mountains, bordering the Salton Sea, Pliocene beds of red and white clay and gravel are reported. They apparently contain no evidence of petroleum and are probably not of marine origin.

Along San Gorgonio Pass, from Whitewater to Redlands, there are outcrops of gritty clay shales and gravels, probably of Pliocene age.

The total areal extent of these beds is about 36 miles in length from east to west, and about 12 miles in width from north to south. Small patches of the same formation are found in the hills east of Hemet and along the north side of Temecula Creek in the vicinity of Murrietta and Temecula. In all of these localities they lie on the eroded surface of the underlying crystalline rocks.

These beds can not be considered as oil bearing. This statement is based on the following facts: They contain absolutely no indication of oil, such as seeps, or gas blows; they contain no diatomaceous shale, or other organic material that is capable of forming oil; their total areal extent and thickness is such that even if they did contain organic material, the amount of oil capable of being formed would be negligible. Lastly, it is doubtful that they are of marine origin, it being probable that they represent land-laid desert deposits. Nevertheless, the following wells are being drilled in this region: Riverside County Oil Company well No. 1 in Sec. 12, T. 2 S., R. 1 W.; Painted Hills Oil Syndicate well No. 1, Sec. 25, T. 2 S., R. 3 E.; Beaumont Crude Oil Company well No 1 in Sec. 15, T. 3 S., R. 1 W.; Moreno Oil Company well No. 1, Sec. 15, T. 3 S., R. 2 W.; Neuvo Oil Company well No 1, Sec. 26, T. 3 S., R. 7 W.

That portion of the county lying south from San Gorgonio Pass to the San Diego and Orange county lines, is a mountainous region of the Peninsula Range. It contains two rather flat areas, one known as the San Jacinto Basin, and the other as the Temecula Basin. The mountains in the northern portion are known as the San Jacinto Mountains, while those south of Temecula Creek are known as the Santa Ana Mountains. The major portion of this region is covered with crystalline rocks, consisting of granites, lava flows and ancient slates and schists, probably of Triassic age. None of these rocks, of course, are capable of containing oil. Around Hemet, Temecula and Murritta are the deposits of shales and gravels of Pliocene age referred to in the preceding paragraphs. Along Temecula Wash, between Elsinore and Corona, there are approximately five small patches of rocks of Eocene age, which are lying on the eroded surface of the underlying crystalline rocks. These consist of red, yellow and white clays, containing beds of lignite and probably belonging to the Tejon formation. They seldom cover a square mile in extent, and the maximum thickness is about 600 feet. They show no evidence of petroleum. A well drilled for oil in 1915, located about a mile east of Lucerne, encountered the following formations: 0 to 250′, gravel and conglomerate, probably Pliocene; 250′ to 927′, clays and shales, probably of Tejon age; at 927′ crystalline rocks were encountered.

In the valley area between Corona and Riverside, forming the extreme southwestern end of the county, the surface is covered mainly with recent valley alluvium. But it is probable that this is underlaid at no great depth by crystalline rocks, especially that portion of the area lying east of the Santa Ana River. In several places the granite actually outcrops in low rounded buttes. Along both banks of the Santa Ana River, in the vicinity of Rincon and where the river crosses the boundary line into Orange County, there are outcrops of Monterey shale (Puente) and Fernando sandstone. These formations are continuations of similar beds in the Chino Hills region and described in the article on San Bernardino County.

The total areal extent that these beds cover in Riverside County is not over four square miles. While they belong to the oil-bearing series, there is no evidence that they would produce any appreciable amount of oil in this region. It is barely possible that they might contain some dry tar sands. Two wells are being drilled in this general region, the N. B. Tannehill well in Sec. 35, T. 2 S., R. 7 W., and the Corona Oil Company's well in Sec. 2, T. 3 S., R. 7 W. These wells are located about four miles north of Corona and about three miles from the granite buttes.

CHAPTER XIII.

REGION OF THE SAN JOAQUIN VALLEY.

(Includes the following counties: San Joaquin, Stanislaus, Merced, the western one-third of Madera, the western two-thirds of Fresno, Kings, the western half of Tulare and Kern.)

The region of the San Joaquin Valley contains the chief producing fields of California. These are found along the west side of the valley from Coalinga to Sunset, and on the east side in the region immediately about Bakersfield.

In addition to containing the chief proven areas of the state, the valley may be regarded as offering the best opportunities for future development. These include not only the development and extension in the already proven areas, but also include the possibility of discovering new fields buried beneath the surface soil of the valley floor.

GENERAL GEOLOGY OF THE VALLEY.

The principal formations which are exposed consist of approximately 20,000 feet of unaltered sediments of Tertiary age, ranging from the Eocene to the late Pliocene. These are overlaid by small thicknesses of recent Quaternary deposits. On the east and south sides of the valley these sediments rest against the crystalline rocks of the Sierra Nevada, Tehachapi, and San Emigdio mountains. On the west they rest on the eroded surface of the older Cretaceous and Franciscan rocks of the Coast ranges. It is very probable that during the greater portion of the Tertiary period the valley was a great inland sea, the eastern and southern edges being marked approximately by what is now the Sierra Nevada, Tehachapi, and San Emigdio mountains, while the present Coast ranges were a series of islands. Twice during this period were great thicknesses of organic sediments deposited and these beds may be considered as the ultimate source of the greater portion of the oil now being produced in the valley.

The oldest of these formations is of Oligocene age and is known as the Kreyenhagen shale. It consists of approximately 1500 feet of pink diatomaceous and foraminiferal shale. The area occupied by this formation may be considered as lying along the western side of the valley from approximately the vicinity of Tulare Lake north to the vicinity of the northwestern boundary of Stanislaus County. This shale is the source of the greater portion of the oil produced in the Coalinga field.

The second deposit of organic shale of the Tertiary period is of Miocene age and consists of nearly 5000 feet of diatomaceous shale belonging to the Monterey and Santa Margarita series. The area occupied by it may be regarded as covering the entire southern end of the valley south of Tulare Lake. This Miocene shale is the source of the oil in the Sunset, Midway, Elk Hills, McKittrick, Belridge, Lost Hills and Kern River fields. From the above it is evident that the productive areas of the San Joaquin will be in the districts occupied by these two deposits of organic shale.

In addition, during the Cretaceous period, there was an older body of organic shale deposited belonging to the Chico formation and known as the Moreno shale. This consists of about 2000 feet of diatomaceous and foraminiferal shale and occupies an area along the foothills of the Coast ranges from Coalinga north to Livermore Pass. It is the source of the small amount of light-green Cretaceous oil produced in the old Oil City field at Coalinga. It is important only in the Coalinga district and even then it fails to produce an appreciable percentage of the output.

The reservoir formations in which the Tertiary oil has collected consist mainly of porous sandstone beds which overlie the two shale deposits. In the case of the Kreyenhagen shale the so-called Vaqueros sandstone at Coalinga acts as the reservoir from which the oil is produced. The oil from the Monterey and Santa Margarita shales has collected mainly in the porous sandstone beds of the McKittrick group. Some of the oil, however, is found in sandy beds within the organic shale deposits, this being the case at the Lost Hills and Belridge fields in the deep, light gravity oil zone.

STRUCTURE.

The general structure of the San Joaquin Valley is that of a great syncline, lying between the Sierra Nevada fault block in the east and the anticlinorium of the Coast ranges on the west. Within this great syncline, however, there are series of anticlinal folds which are marked on the surface in *most cases* by low rolling hills. These are found mainly along the western side of the valley and for the most part project obliquely out into the valley from the main body of the Coast ranges. In some cases, however, these structures lie out in the valley floor and run parallel to the Coast ranges, such as the folds of the Lost Hills and Elk Hills fields. In some cases, also, there is no evidence of these structures on the surface as is exemplified by the buried anticline of the Belridge field.

It is on these folds that the oil has been trapped and collected and the proven fields are located. All of these structures that are at all evident have, with one exception, been drilled upon and found productive. It is, therefore, necessary if new fields are to be found, that other structures which are not at present known, be discovered. Such structures in all probability exist, buried beneath the floor of the valley with the greater portion of the surface evidence of their existence removed by erosion. This possibility will be discussed in the following paragraphs under "Buried Structures."

The one exception referred to above consists of the great Kettlemen Hills anticline. This fold, to date, remains to be proved as containing oil in commercial quantities.

BURIED STRUCTURES.

As stated above, the chief hope of finding new fields in the San Joaquin Valley lies in the possibility of locating structures which are buried beneath the surface soil of the valley. One such fold was discovered when the Belridge field was found productive. At the present an area around Buttonwillow, which apparently shows some evidence of containing a buried anticline, is being tested and with encouraging results to date, such as quantities of gas and small showings of oil. As stated above, there is little or no evidence of these buried structures on the surface, in the form of outcrops of rocks or low hills, such as mark the already proven areas. The chief surface evidence that might be present would be slight elevations and ridges that rise above the dead level of the valley floor. Also some evidence might be furnished by water wells and prospect holes.

It is evident that these folds will be found only by a close study of the topography and logs of water wells within the region in which they are likely to occur.

The general area in which the writer believes these structures are likely to be found in the San Joaquin Valley is in the districts referred to above as being underlaid by the organic shale beds of the Kreyenhagen, Monterey and Santa Margarita formations, namely an area along the west side of the valley, running from the vicinity of the northwestern boundary of Stanislaus County southward to Tulare Lake, and a second area comprising the entire floor of the valley lying south of Tulare Lake. In the first area the oil would be formed from the Kreyenhagen shale and collect in the Vaqueros sandstone. In the second area the oil would form in the Miocene shales and collect in the McKittrick beds. Fig 12 shows two hypothetical sections across the valley. Section AB in the region north of Coalinga and Section CD in the area south of Tulare Lake. These two sections show the possible source and reservoir beds in each district, as well as two kinds of possible accumulation—a possible anticlinal fold, shown in the left half of the sections, and in the right half a possible monoclinal structure along the old shore line of the sea in which the diatomaceous shales were deposited, and where the oil might accumulate by reason of a possible overlap of the reservoir bed on the upturned edges of the shale.

These two areas have been shown on Plate I, colored in blue, as possible oil land. This does not mean that oil fields are going to be found over this entire region, or for that matter, that any will be found. It simply indicates that within this region there is a fairly good chance that buried productive structures may be found.

REGION OF THE PROVEN FIELDS.

The proven fields of the San Joaquin may be divided into three general groups. One, those fields lying along the west side of the valley from Sunset to Lost Hills and commonly known as the "West Side Fields"; second, the Coalinga field; and third, the Kern River field, commonly known as the "East Side Field."

THE WEST SIDE FIELDS.

These begin at Sunset and stretch north in an almost unbroken line of derricks to Lost Hills, a distance of nearly fifty miles. In these fields the oil has had its source in the diatomaceous shale of the Monterey and Santa Margarita formations, and has accumulated mainly in the overlying sandstone beds of the McKittrick group. Exceptions to this are found in the Lost Hills and Belridge fields and in the Twenty-five Hill

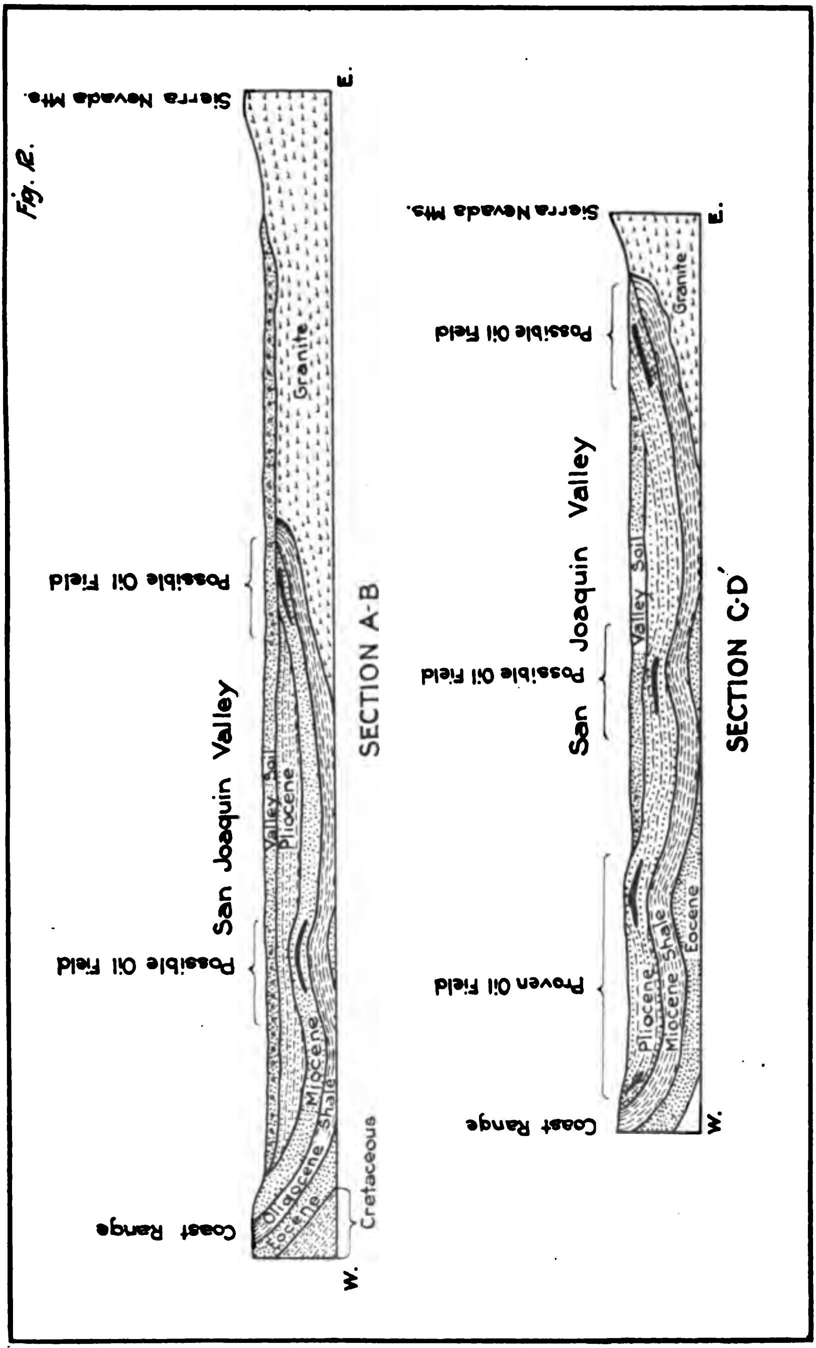

FIG. 12. Hypothetical sections across the San Joaquin Valley. Section A-B—Shows possible accumulation in the region north of Coalinga. Section C-D—Shows proven fields and possible accumulation in the region of Tulare Lake (see pages 174 and 177).

area at Taft, where some of the oil has collected in the sandy beds of the Miocene diatomaceous shale and has given rise to the so-called "shale oil." Also at Sunset, on the Pioneer anticline, some oil has collected in the Vaqueros sandstone.

MIDWAY-SUNSET.

The Midway-Sunset area is generally considered as one field, which stretches in an unbroken line of production from Sunset to a point three miles north of Shale, a total distance of nearly twenty miles. The southern portion is known as the Sunset district and the northern portion as the Midway district.

The Sunset district lies at the extreme southern end of the valley and may be considered as embracing the region around Sunset, Maricopa and the Maricopa flats. Its northern limits are placed at the furthest township north of the San Bernardino Meridian (T. 12 N.), at which point the Midway district is considered as beginning. The oil has collected along a monocline that runs from Sunset to Maricopa, and in a plunging syncline which lies just north of Maricopa, and finally in the great "Thirty-five" or "Maricopa" anticline, which runs out of the hills into Maricopa flats at the northern end of the field. This last structure has been one of the most prolific folds discovered in California. On its northern flank is located well No. 1 of the old Lake View Oil Company. This well was probably the largest ever 'brought in' in California. It flowed wild for approximately eighteen months, with a reported production of over 8,000,000 barrels and a maximum daily production of about 65,000 barrels. At the present time it is producing about 30 barrels per day. The Sunset field may be considered as about three-fourths drilled up. The most favorable area for extension lies eastward from Hazelton and Pentland towards the San Emigdio District, especially along the Pioneer anticline and the Western Minerals area. In March, 1921, the total proven area in this field was 5868 acres.

The Midway district may be considered as comprising the region around Taft, Fellows, Shale and the Buena Vista Hills. The oil has collected along three general lines of structure. The first of these may be considered as an eastward-dipping monocline, containing minor anticlinal folds, some of which are quite extensive, such as the "Twenty-five Hill anticline." This structure exists along the foothills of the Temblor Range, west of the Midway Valley, and in general takes in the region back of Taft and Fellows. The wells on this structure average around 2000 feet in depth and are fair and constant producers. East of this area lies the Midway Valley, which, structurally, is a plunging syncline. While oil has collected along this structure, the wells are not very prolific and this, together with the depth to the oil (average about 3000 feet) and serious water conditions, has not made drilling very profitable in this area. The last structure consists of the dome of the Buena Vista Hills, which lies just east of the Midway Valley. In general these hills may be regarded as an elongated dome, along the crest of which there are minor anticlinal folds. This region is the district of the largest producers and the heavy gas pressure. It is probable that the McNee lease of the Standard Oil Company, on Sec. 36, T. 31 S., R. 23 E., when in its prime about eight years ago, was the most prolific square mile of oil territory in the world. The average depths of wells in the area is about 3000 feet. While big gushers are no longer found here, the region still produces fair sized wells.

In general, the Midway district may be considered as two-thirds drilled up. The most favorable areas for extension lie at the east and west ends of the Buena Vista Hills. In addition the region north from Fellows to McKittrick, lying east of the highway, offers opportunity for small-well development.

In March, 1921, the total proven area was 39,447 acres. The total daily average production in the Midway-Sunset area in December, 1920, was 84,580 barrels of oil. The average number of wells producing was 2429, with an average daily production per well of 35 barrels of oil and 18 of water. The gravity ranges from about 11° Baumé to 31° Baumé, the heavy oil being found along the outcrops in the Sunset district, while the lighter oil is encountered in the sealed anticlines of the Maricopa Flat and the Buena Vista Hills. Figure 2, section 1, page 17, shows the general structure across the Midway field in the vicinity of Taft.

McKITTRICK FIELD.

The McKittrick field lies about three miles north of the present northern limits of the Midway field. It is probable, however, that future drilling in the low hills east of the highway will connect the two fields. These low hills contain several well developed anticlines in the McKittrick formation which are capable of producing small wells of heavy oil at depths of from 1000 to 1500 feet.

The structure of the McKittrick field as mapped by Arnold & Johnson[1] is extremely complicated, consisting of a double anticline, overturned. However, recent work on the underground structure indicates that this is not the condition. A peg model, based on the well logs and constructed by the Department of Petroleum and Gas of the State Mining Bureau at Taft, indicated that the structure really consists of a great over-thrust fault, the older Monterey shale being thrust over the younger McKittrick beds. This structural condition exists in the McKittrick field proper, which lies between McKittrick and Reward, and west of the McKittrick Valley. The wells start down in the diatomaceous shale of the Monterey and encounter showings in these beds, but the productive sands are not reached until the McKittrick sands are entered below the fault zone. While the wells are not large producers, they are steady and long-lived, and show a remarkably slow rate of decline. This probably is due to the fact that the oil is heavy and continues to hold the gas in solution over a long period of time, thus forcing it to do its full share of work in expelling it from the sands. This process is explained more fully in Chapter I, under "Saturation and Recovery."

The low hills east of the McKittrick field proper, and separated from it by the McKittrick Valley, which structurally is a syncline, are known as the McKittrick Front field. The structure here consists of three small, parallel anticlines. Periodically this area has been the scene of drilling operations, which after a few years have ceased and the wells

[1]U. S. Geol. Survey. Bull. 406. Preliminary Report on the McKittrick-Sunset Oil Region. By Ralph Arnold and Harry Johnson, 1909.

[redacted]

average production in December, 1920, was 11,500 barrels. The average number of wells producing was 571, with a daily average yield per well of 21 barrels of oil and 21.5 of water.

a [illegible] The structure consists o[illegible] a great flat-topped dome on which the dips range from 2° to 10°. On the flanks of this general structure, however, there are a number of sharp minor anticlines, which apparently do not influence underground conditions. The actual underground structure probably conforms in a large measure to the surface topography. To date the proven area consists of two districts, one in the vicinity of Sec. 36, T. 30, R. 23 E., known as the Hay area, and the other in the vicinity of Sec. 36, T. 30, R. 24 E., known as the Tupman area. Drilling to date indicates that the proven area can be carried to a distance of about one mile north or south of the center of the dome. The total proven area in March, 1921, was 1451 acres. Following is a brief description of the field, written for this report by C. C. Thoms:[1]

"The Elk Hills cover, roughly speaking, an elliptical area about sixteen miles long and seven miles wide, with the major axis running in a northwesterly and southeasterly direction. These hills reach a maximum elevation of about 1540 feet in Sec. 28, T. 30 S., R. 23 E., M. D. B. and M., and topographically represent the anticlinal structure of the area.

"The structure probably represents a single major anticline with minor folds on either flank which probably do not extend deep enough to affect the oil bearing formation, or if they do reach that depth are mere slight undulations. The surface drainage indicates that the present crest of the hills corresponds quite closely with the axis of the fold. This broadly-arching anticline has low angles of dip and probably extends from about McKittrick to the north end of Buena Vista, where it plunges beneath the San Joaquin Valley. The axis of the fold probably passes south of the northeast corner of Sec. 8, T. 31 S., R. 25 E. Sufficient drilling has not yet been done to definitely locate the sub-surface structure. However, present indications are that the probable axis runs from a point near the northeast corner of Sec. 8, T. 31 S., R. 25 E., about through the center of Sec. 6, T. 31 S., R. 23 E., the northwest corner of Sec. 1, T. 31 S., R. 24 E., then nearly in a straight line, slightly convex to the north, to about the northeast corner of Sec. 36, T. 30 S., R. 23 E.

"The approximate dips as shown by the correlations of the oil-bearing formations are as follows:

"Dip along the east line of the Standard Oil Company Tupman wells, on Sec. 36, T. 30 S., R. 24 E., about 400′ in a mile to the north.

"Dip along the south line of the Standard Oil Company Tupman wells is about 500′ in a mile to the east. The dip to the southwest from the northeast corner of Sec. 36, T. 30 S., R. 23 E., is about 230′ to the mile.

"The logs of the wells on Sec. 36, T. 30 S., R. 24 E., and Sec. 31, T. 30 S., R. 26 E., show about 700′ of sandy formation (sandy shale or sand), then about 2000′ of shale or sandy shale. At this point the top of the oil zone is encountered, which in the deepest well stratigraphically in this area has been drilled only about 340′ below the top of the oil-bearing formation. These oil-bearing formations are mainly sand.

"The logs of the wells of the Standard Oil Company wells on the Hay and Carman leases on Sec. 36, T. 30 S., R. 23 E., show about 1200′ of sandy shale and sand above the gas zone, then about 1200′ of rotten shale comprising the gas zone. From this depth to the greatest depth drilled in this area lies the oil zone, which is practically all sandy shale. The deepest well, stratigraphically, in this westerly portion of the proven

[1]Deputy State Oil and Gas Supervisor, Taft, California.

field is Standard Oil Company well No. 15, which has been drilled about 1400′ below the top of the oil zone.

"There is not sufficient geological information available to correlate stratigraphically the formation in the easterly and westerly portions of the proven Elk Hills field, and, therefore, it cannot be said definitely whether or not the oil-bearing zones in the two fields are at the same stratigraphic horizon. The upper or sandy formations, however, are probably Tulare or Paso Robles. The formations below this depth are probably all Etchegoin, since it is the generally accepted belief that none of the wells in this field have yet been drilled deep enough to reach the Monterey. The oil-bearing formations in the easterly portion of the field, it will be noted, are mainly sand, while those of the westerly portion are shale or sandy shale.

"No prominent markers have yet been noted in this field above the oil zone. Occasionally some two or three wells seem to show a possible marker above the oil zone, but adjacent wells lack such markers. The main oil sand, however, does seem to be a consistent marker in the eastern portion of the field.

"No prominent water zones have been noted and no water has been found below the top of the oil zone in the easterly portion of the field or below the top of the gas zone in the westerly portion of the field. The lowest top water has been quite definitely located as being about 200 feet above the top oil sand.

"As has been noted above, in the westerly portion of the field there is a 1200′ gas zone, while in the easterly portion no gas zone has been noted. Sec. 36, T. 30 S., R. 24 E., M. D. B. and M. Only one oil zone has apparently been penetrated and the depth and thickness of this zone has not been determined, since the deepest wells drilled are apparently still within the zone."

For a complete description of the West Side fields the reader is referred to the publications of the United States Geological Survey[1] and the California State Mining Bureau.[2]

A full description of the surface geology and underground conditions will be found in these reports. In addition, peg models of the various fields are open to inspection at the office of the Department of Petroleum and Gas, California State Mining Bureau, Taft, California.

COALINGA FIELD.

This is the most northerly field in California from which any appreciable amount of production is being obtained. Three types of structure are present. The great, plunging Coalinga anticline, which runs out into the valley in a southeast direction, forms what is known as the 'East Side field,' and furnishes the greater portion of the production. Lying west of this anticline is the plunging Coalinga syncline, which runs down the Pleasant Valley. An area around the head of this syncline is productive. On the west side of the Pleasant Valley, and forming the

[1] U. S. Geol. Survey. Bull. 406. Preliminary Report on the McKittrick-Sunset Oil Region. By Ralph Arnold and Harry Johnson, 1909. U. S. Geol. Survey. Professional Paper 116. The Sunset-Midway Oil Field. By R. W. Pack, 1920.

[2] California State Mining Bureau. Bull. 69 and Map folio. Petroleum Industry of California. By R. P. McLaughlin and C. A. Waring, 1914. First, Second, Third, Fourth and Fifth Annual Reports of the State Oil and Gas Supervisor, California State Mining Bureau.

west limb of the Coalinga syncline, is the 'West Side' field. This structure is a monocline.

The formations exposed along this monocline and on the Coalinga anticline consist of the Cretaceous, the Tejon, the Kreyenhagen shales, the Vaqueros sandstone, the Santa Margarita and the Etchegoin and Jacalitos formations. These last three formations are not oil-bearing in this region, and only act as an overburden above the oil measure.

The greater portion of the oil was formed by the Kreyenhagen shales and has collected in the sandstone beds of the Vaqueros formation. This oil is black and of an asphaltic base. The gravity ranges from about 11° to 38° Baumé.

A little oil was also formed by the Moreno shale, which is the uppermost member of the Chico. This oil is found in the old Oil City field, at the head of the Coalinga anticline. This is the only region in California where the Cretaceous is commercially productive. Here, under the most favorable conditions, the total daily production is 135 barrels. This comes from twelve producing wells. The oil is light green in color and ranges above 50° in gravity.

The wells in the West Side field range from 500 to 2500 feet in depth. Those at the head of the syncline and along the Coalinga anticline in the East Side field range from 800 to 4000 feet in depth. In March, 1921, the total proven area was 14,272 acres. The total daily average production in December, 1920, was 40,500 barrels of oil. The average number of wells producing was 1288, with an average daily yield per well of 35 barrels of oil and 10 of water.

The limits of the field are practically fixed, with the possible exception that the proven region may be extended south of Waltham Canyon along the Jacalitos anticline Old wells drilled in this region have reported small showings, and it is worthy of being examined carefully as a possible productive area. The region west of the proven area and up Waltham Canyon, west of Alcade, is not favorable for drilling operations.

For a detailed description of the geology and underground conditions, the reader is referred to the publications of the United States Geological Survey[1] and the State Mining Bureau.[2]

KERN RIVER FIELD.

This field lies along the Kern River, just north of the town of Bakersfield. The structure consists of a low monocline, dipping to the southwest, the dips varying from 5° to 7°. The reason for the oil collecting in a structure such as this is somewhat obscure. Following are two theories which may possibly account for the accumulation: the first is that the oil has been trapped in the monocline by a buried anticlinal fold which lies out in the valley west of Bakersfield. The second is that the oil has accumulated by reason of the unconformity of the McKittrick beds on the upturned edges of the Monterey shale. The oil is found

[1]U. S. Geol. Survey. Bull. 398. The Geology and Oil Resources of the Coalinga District. By Ralph Arnold and Robert Anderson, 1910. U. S. Geol. Survey. Bull. 581-D. Geology and Oil Prospects of the Waltham, Priest, Bitterwater and Peachtree Valleys. By R. W. Pack and Walter English, 1914.

[2]California State Mining Bureau. Bull. 69. Petroleum Industry of California. By R. P. McLaughlin and C. A. Waring. The First, Second, Third, Fourth and Fifth Annual Reports of the State Oil and Gas Supervisor, California State Mining Bureau.

in the loose, incoherent sands of the upper portion of the McKittrick formation, and probably had its origin in the diatomaceous shale of the Monterey Along the northeast edge of the field the bituminized beds at the base of the McKittrick may be seen. However, no Monterey shale is exposed, the McKittrick beds aparently overlapping directly on the Vaqueros formation which in turn rests on the granite. At Poso Creek, however, the Monterey shale is exposed beneath the McKittrick and it is probably present beneath these latter beds over a considerable portion of the Kern River field.

This field is a consistent, steady producer of long-lived wells of from 40 to 100 barrels daily. The oil averages in gravity about 15° Baumé and the wells range in depth from 200 to 1500 feet. The total proven area in March, 1921, was 7152 acres. The total daily average production in December, 1920, was 20,067 barrels of oil. The average number of producing wells was 2067 and the daily average yield per well was 10 barrels of oil and 40 of water.

Recent exploration work has extended the field north to Poso Creek. The wells in this new district are small producers, coming in with an initial yield of about 40 barrels at depths of about 2000 feet. From this it is apparent that the Poso Creek district is not going to be as prolific a producer as the old field. To date, no commercial production has been obtained north of Poso Creek, but several wells drilling just north of the creek have reported showings, and it is probable that the Poso Creek district can be extended to the north for several miles yet. The structure and geological conditions are somewhat obscure, as there is a lack of good surface outcrops. It is probable, however, that the same conditions are present here as in the main Kern River field.

In the region east of Bakersfield, and south of the Kern River, no production has been obtained except for a few small wells along the south bank of the river. From the meager surface indications that are available, it is probable that the formations which are present in the Kern River field continue south across the river and underlie the plateau region east of Bakersfield. This region is, therefore, worthy of being examined carefully as a possible, productive area.

UNPROVEN AREAS.

SOUTH END OF THE VALLEY.

This region includes the flat portion of the valley lying south of Tulare Lake, together with the foothills of the San Emigdio and Tejon regions.

This foothill area at the south end of the valley has been mapped and reported on by the U. S. Geological Survey.[1]

The formations exposed along the San Emigdio and Tejon hills are similar to those found in the Midway-Sunset district. At Muddy Creek and along Wheeler Ridge there are seepages of oil in the McKittrick formation. The general structure of this foothill area, however, is unfavorable for the accumulation of petroleum, with two exceptions: these consist of the Wheeler Ridge anticline and the Tejon

[1]U. S. Geol. Survey. Bull. 741. Preliminary Report on the Geology and Possible Oil Resources of the South End of the San Joaquin Valley. By Robert Anderson, 1910. U. S. Geol. Survey. Professional Paper 116. The Sunset-Midway Oil Field. By R. W. Pack, 1920.

Hills anticline. Both of the structures are worthy of being tested, and the Wheeler Ridge fold is now being drilled on by the Standard Oil Company.

In the flat valley area lying out in front of these hills and extending north to Tulare Lake, there are no surface indications of petroleum. However, the outcrops in the foothills that surround this portion of the valley on three sides indicate that it is underlaid by the Miocene diatomaceous shale, and the reservoir beds of the McKittrick formation and, as stated in the article on "Buried Structures," it may possibly contain anticlines which may prove productive. Section C-D, (page 165) is a hypothetical section across this portion of the valley, and shows how possible oil-bearing structures may exist.

REGION OF THE FOOTHILLS OF THE TEMBLOR RANGE.

This area lies west of the Sunset-Midway, McKittrick and Lost Hills fields. In general this region is not favorable for the accumulation of any appreciable amount of petroleum. The formations are older than those of the producing field, and the structure is highly tilted and folded. On Sec. 36, T. 29 S., R. 20 E., there is a production of about 20 barrels per day of 15° Baumé gravity oil, from about fifteen shallow wells. This is known as the Temblor field. The oil has accumulated in the Vaqueros sandstone at a point where it is faulted against the Monterey shale. The accumulation is only local and of no great commercial value. In the Gould Hills there are some tar sands at the contact of the Santa Margarita and McKittrick formations. Wells drilled here have encountered small showings of heavy oil, and there is no reason to believe that future drilling would meet with any better success. In the flat area lying between the northern end of the Temblor Range and the Lost Hills-Belridge area, there is a possibility that buried anticlinal folds exist which may be productive later. This region is known as the Antelope Hills and Antelope Plain district.

KETTLEMAN HILLS.

The district consists of the range of hills running from Coalinga south to Lost Hills, and lying just west of Tulare Lake. They are separated from the Diablo Range by the Kettleman plain. The structure of these hills consists of a great anticline, the axis of which runs along the highest ridge in the center of hills, with a general northwest and southeast trend. The dips on the flank vary from 10° to 35°. This structure may be considered as a continuation of the Coalinga anticline and it, in turn, continues into the Lost Hills region. The formations exposed along the axis of this fold are soft, loose sands and clays of the Etchegoin formation. As to what is present beneath these beds there is no direct evidence. It can be assumed, however, that in the northern portion, formations similar to those found in the Coalinga field should be present; while on the southern end, rocks similar to those found in the Lost Hills and Devils Den district should be present. This assumption is based not only on the fact that the Kettleman Hills is a portion of the general structure that runs from Coalinga to Lost Hills, and should, therefore, contain rocks similar to those regions, but it is also based on a study of the formations exposed in the hills west of the Kettleman plain and which runs from Waltham Canyon to Devils Den.

The oil possibilities may be summed up as follows: The structure is extremely favorable for the accumulation of petroleum. At the northern end of the hills it is possible that the oil-bearing formations similar to those found in the Coalinga field may be present, while in the southern end a similar condition may exist in regard to the oil-bearing formations of the Lost Hills region. Whether or not these formations, if present, would contain oil in commercial quantities, or be within reach of the drill, can only be told by actual drilling. Wells drilled to date indicate that there is no commercial production above approximately 4000 feet. There are, however, sufficient favorable conditions present to make this region worthy of being tested by at least several deep wells located on the axis of the fold.

In the northern end about nine wells have been drilled, only two of which were located sufficiently close to the axis of the fold to afford a fair test. These two wells were the Coalinga-Kettleman, located in Sec. 4, T. 22 S., R. 17 E, and drilled to a depth of 4810 feet, and the Medallion Oil Company well, located in Sec. 20, T. 22 S., R. 18 E., drilled to a depth of 3848 feet. Neither of these wells revealed any showings of oil, and it is probable that they did not penetrate deep enough to encounter the Vaqueros sandstone which is believed to contain the oil in this portion of the hills.

At the south end of the hills two wells have been drilled in recent years, one of which, the Crescent Petroleum Company's well, has been abandoned, and second, the Standard Oil Company's 'Kettleman well,' is still drilling. The Crescent well was located in Sec. 2, T. 25 S., R. 19 E., and was drilled to a depth of about 2700 feet. Between 1600 and 1700 feet several small showings of black oil were encountered. When tested, these showings yielded about 3 bailers full of oil. It is reported that the Standard Oil Company, in their well on Sec. 34, T. 24 S., R. 19 E., encountered similar showings at about the same depth. The formations penetrated by the Crescent well were soft sands and clays of the McKittrick series.

A description of the geology of the Kettleman Hills, as well as the region to the west, can be found in Arnold and Anderson's Coalinga report.[1]

KREYENHAGEN HILLS REGION.

This district may be considered as comprising the foothills of the Diablo Range, between Waltham Creek and Devils Den. The northern and central portions are known as the Kreyenhagen Hills and the southern end in the vicinity of the McClure Valley is known as the Pyramid Hills. The general structure of the region is that of a steep monocline dipping about 40° to the east. The formations exposed are the Cretaceous, the Eocene, the Kreyenhagen shales, the Vaqueros, the Santa Margarita, and the Etchegoin and Jacalitos formations. At the northern end, in the vicinity of Waltham and

[1]U. S. Geol. Survey. Bull. 398. Geology and Oil Resources of the Coalinga District. By Ralph Arnold and Robert Anderson, 1910.

Jacalitos creeks, the hills widen out and there is a well-developed anticline lying in the hills east of the general monoclinal structure. This fold is known as the Jacalitos anticline, and was referred to in the article on the Coalinga field as a possible productive area. The axis of this fold is plunging sharply to the south, so that in the vicinity of Jacalitos Creek the oil-bearing formations (Vaqueros) are more than likely below a depth of 4500 feet. The Azores well, located on the axis of the fold, in Sec. 26, T. 21 S., R. 15 E., reached a depth of 4420 feet and found only slight showings, these being reported at about 3500 feet. At the northern end of this fold, however, in the vicinity of Waltham Canyon, the oil-bearing formations should be shallower, and it is possible that the proven area of the Coalinga field may be extended into the region. Along the general monoclinal structure of the central and southern portions of this region, there is little possibility of obtaining oil in any appreciable quantities. This is due to the unfavorable structure. In Canoas, Big Tar and Little Tar canyons, there are prominent seepages of oil in the basal sands of the Vaqueros, and wells drilled here have encountered small quantities of oil. The territory in the region of these canyons is known as the Kreyenhagen field. Two general groups of wells have been drilled here; namely, those that are drilled in the Kreyenhagen shales and draw their oil from sandy beds in that formation, and those that start down in the Santa Margarita and probably draw their oil from the Vaqueros. The first group is credited with eight wells, all of which encountered showings and one of which, Kreyenhagen No. 1, located in the SE¼ of Sec. 32, T. 22 S., R. 16 E., is reported to have yielded at the rate of about 15 barrels per day at the start, but soon fell to 5 or 6 barrels. The depth of the well was 650 feet. The oil is said to have been light green, and of 37° Baumé gravity. The second group includes four wells, all of which encountered showings of heavy, black oil. Well No. 1, of the Black Mountain Oil Company, located in the NW¼ of Sec. 33, T. 22 S., R. 16 E., is said to have produced 5 or 6 barrels of 18° Baumé gravity oil at a depth of 720 feet. None of the wells in either group were of commercial value.

This region is chiefly of interest because the oil-bearing formations are dipping to the east, and may possibly continue across the Kettleman plain, and come up again in the Kettleman Hills. Here, on account of the anticlinal structure, the conditions for the accumulation of oil in appreciable quantities would be quite favorable. In the region between the Kettleman Hills and the Kreyenhagen Hills there is little possibility of finding oil, as the structure is that of a great syncline in which the oil-bearing formations are beyond the reach of the drill, and also very likely barren of oil. The geology and oil possibility of the Kreyenhagen Hills is covered in Arnold and Anderson's Coalinga Report.[1]

THE REGION NORTH OF COALINGA.

This district includes the foothills and the western side of the valley from Coalinga to Livermore Pass. The general structure of the foothill area is that of a great monocline dipping to the east. In

[1] U. S. Geol. Survey. Bull. 398. The Geology and Oil Resources of the Coalinga District. By Ralph Arnold and Robert Anderson, 1910.

the hills just north of Salado Creek, and at the mouth of Panoche Creek, there is evidence of anticlinal folds, and further work in this region may disclose other folds. The formations that outcrop along the monocline consist of the Cretaceous, the Eocene, the Kreyenhagen diatomaceous shales, sandstone and shale beds of the Monterey series, the Santa Margarita formation, and finally loose sands, clays and shales of Pliocene age, belonging to the Etchegoin, Jacalitos and Tulare formations. Of these, the Kreyenhagen shales and the sandstone beds of the Monterey series, are of chief interest, as the former is a probable source of petroleum, and the latter would act as the reservoir formation for such oil.

The popular belief that there are no evidences of petroleum in this region is contrary to facts. Numerous seepages have been reported to the writer as occurring along Monocline ridge. In the SW ¼ of Sec. 9, T. 16 S., R. 13 E., about one-fourth of a mile southwest of the Union Oil Company's well, there is a good outcrop of dry oil sand which, when tested by the writer with ether, gave an excellent test for petroleum. This sand occurs about the middle of the Monterey series, and would indicate that this formation is a possible reservoir for oil in this region.

The possibilities may be summed up as follows: Along the foothills the chances are not good on account of the steep monoclinal structure. The fact, however, that the Kreyenhagen shales outcrop here, and are a possible source of oil, and that the lower Miocene sands above them show petroleum, would lead to the belief that, if favorable structure could be found in this region, in which the lower Miocene sands were folded, they would contain petroleum in commercial quantities. The most likely place for such structures would be out in the flat valley area lying from 2 to 10 miles east of the foothills. In this region it is possible that buried anticlinal folds may exist similar to the Lost Hills and Belridge areas, and along the axis of which the lower Miocene sands would be present. Consideration, however, must be taken of the fact that a great overburden of Pliocene and upper Miocene beds are also present, and in case any buried fold was located, these beds would have to be penetrated before the possible oil sands of the lower Miocene would be encountered. However, the entire region of the west side of the valley may be considered as worthy of being carefully examined for the possibility of containing buried structure which might be indicated on the surface by low mounds or ridges. Section A-B, Fig. 12 (page 165), is a hypothetical section across this portion of the valley, showing how possible oil-bearing structures may exist. This matter is also taken up at the beginning of this chapter under "Buried Structures."

REGION AROUND TULARE LAKE.

In the low marshy area around Tulare Lake gas has been obtained for a number of years from shallow water wells, and recently some deep wells have been drilled which showed large quantities of gas at depths below 2000 feet. In no case, however, has the State Mining Bureau been able to verify any of the reported oil showings. The gas encountered resembles strongly the 'marsh gas' obtained in the wells around Stockton and Sacramento. It is perfectly odorless and burns with an uncolored flame. As yet there is no evidence that this gas is connected with any petroleum deposit. The surface in this region is flat and covered with valley alluvium and soil which gives no evidence as to what is beneath it. This portion of the valley, however, falls within the area that may possibly contain buried anticlinal folds, and it is possible that the gas found here has accumulated by reason of such a fold. Whether or not it would contain petroleum, or actually exists, can only be told by drilling.

BUTTON WILLOW DISTRICT.

This district lies about 8 miles northeast from, and parallel to, the Elk Hills field. Running in a northwest direction across the center of T. 29 S., R. 24 E., is a low ridge which continues to the northwest in the direction of Lost Hills. It is believed that this ridge may mark the axis of a buried anticline which, on account of its relationship to the Elk Hills and Lost Hills area, should be highly productive. Outside of the low ridge there is no other surface evidence that would indicate a fold. Attention was first called to this area by Mr. R. N. Ferguson, of Bakersfield, who gave the name of Button Willow anticline to this low ridge. At the present time four wells are drilling here and encouraging results have been obtained to date. The Petroleum Midway wells, located in Sec. 12, T. 29 S., R. 23 E., and Sec. 6, T. 29 S., R. 24 E., have both encountered large quantities of gas which is in apparently sufficient amount to be of commercial value. In the National Exploration well, on Sec. 27, T. 28 S., R. 23 E., samples tested by the State Mining Bureau, from a vicinity of 3000 feet, gave good indications of petroleum. The region may, therefore, be considered as worthy of being thoroughly tested. It may also be noted here that the results obtained at Button Willow will, in a large measure, prove or disprove of the theory that the San Joaquin Valley contains buried productive structures other than those already known.

EAST SIDE OF THE VALLEY.

This region as described here includes the eastern portion of the valley lying north from the vicinity of Tulare Lake to Stockton. The eastern side of the valley lying south of Tulare Lake has been included in the article on the "South End of the Valley."

At Terra Bella the Pliocene beds which continue on north to this point from the Kern River area, disappear, and from this point north to the region east of Madera, the valley soil rests directly against the crystalline rocks of the Sierra Nevada. Evidence of the presence of sedimentary rocks is lacking, and it is probable that the granite is present at shallow depths beneath the surface sand over a great portion of this region.

From the vicinity of Madera northward to Stockton, the foothills of the Sierra Nevada are composed of highly-altered slates and intrusive rocks belonging to the Mariposa formation (Jurassic). Resting against these older rocks along the foothills is a body of sedimentary rocks of Eocene age. These beds consist of a coarse sandstone at the bottom which, in some places, is of a dark red color, due to stains from various iron compounds. Above the sandstone are found beds of clay, volcanic tuff, and conglomerate. It is probable that these beds represent the most southerly extension of the Ione formation and Dickerson[1] has found good Tejon fossils in the sandstone member in the vicinity of Merced Falls.

These beds do not contain any indication of petroleum, and they lie in a gentle monocline, dipping about 4° to the east. It is probable that they underlie the greater part of the northeast portion of the San Joaquin Valley.

The geological conditions of this region are distinctly unfavorable for the production of petroleum. This is based on the following facts: There are no surface indications of oil; the oil-bearing formations, which are present in the proven areas of the valley, are lacking here; such sediments as are present are not of a character to form oil; there is no structure evident that is favorable for the accumulation of petroleum.

From the above it is evident that the region is not a desirable one in which to prospect for oil.

Near Knights Ferry, in Sec. 18, T. 1 S., R. 12 E., W. H. Clary is drilling a well. At Oakdale, in Sec. 1, T. 2 S., R. 10 E., the Southern Oil and Gas Company's well has reached a depth of nearly 4000 feet. Showings have been reported from this well, but have never been verified by any representative of this Bureau.

[1]University of California. Department of Geology. Bull. 17, Vol. 9. Stratigraphy and Fauna of the Tejon Eocene of California. By Roy E. Dickerson, 1916.

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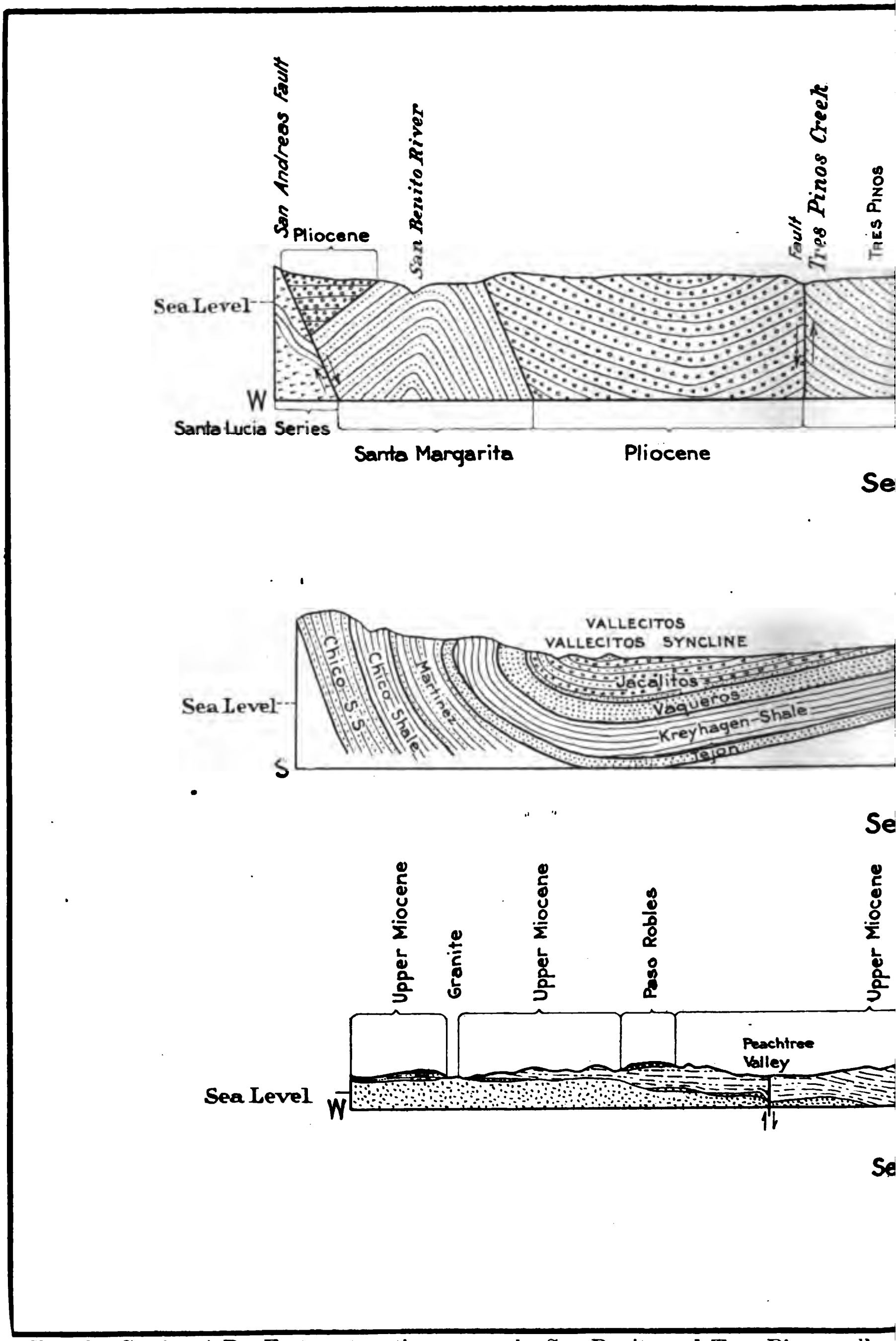

FIG. 6. Section A-B—East-west section across the San Benito and Tres Pinos valleys
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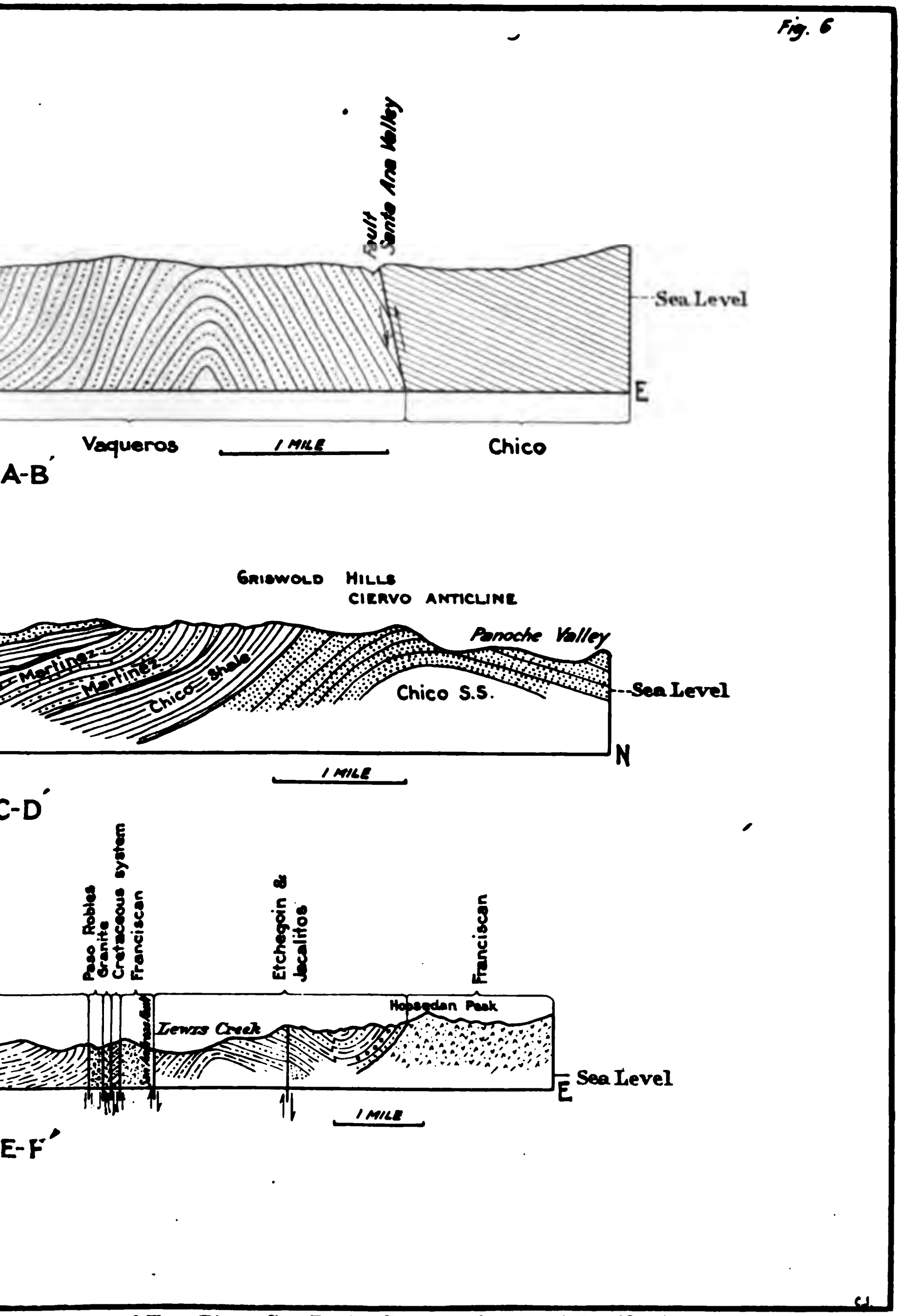
Monterey County (adapted from the U. S. G. S. Bull. 581-D).



h the town of Tres Pinos, San Benito County. Section C-D—North-south section across the
East-west section across Lewis Creek and the Peachtree Valley in the vicinity of Lonoak,

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