CALIFORNIA STATE MINING BUREAU.

A. S. COOPER, State Mineralogist.

BULLETIN No. 19. San Francisco, November, 1900.

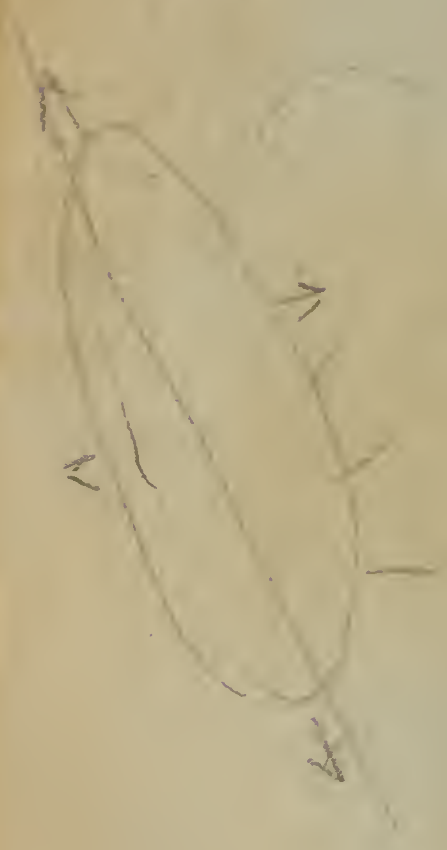
OIL AND GAS YIELDING FORMATIONS

OF CALIFORNIA.

By W. L. WATTS, E.M.

Published under the Direction of HENRY T. GAGE, Governor of the State of California.

SACRAMENTO:
A. J. JOHNSTON, : : : : : : SUPERINTENDENT STATE PRINTING.
1900.



CALIFORNIA STATE MINING BUREAU

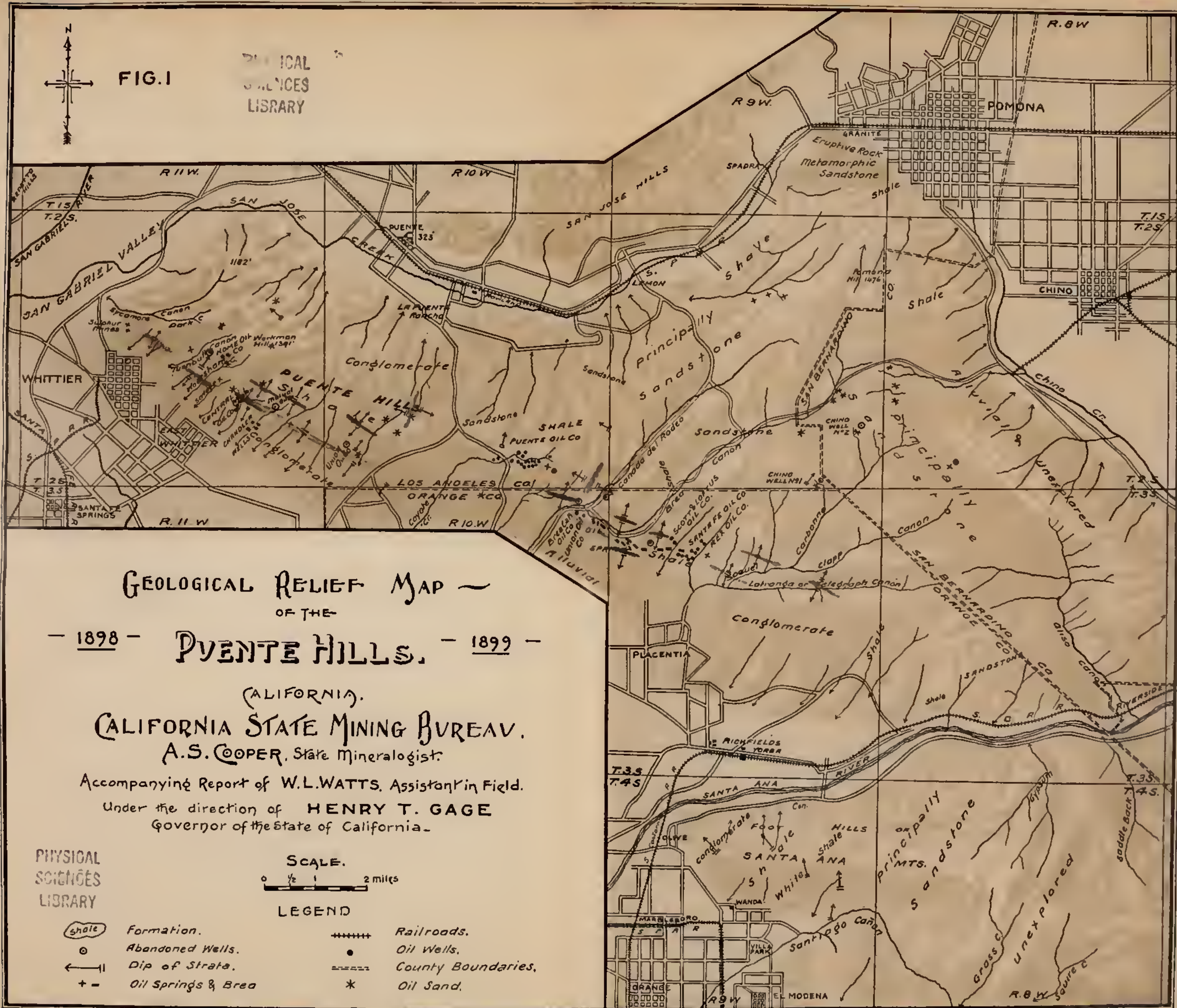


FIG. 1
N
GEOLOGICAL RELIEF MAP
OF THE
- 1898 - PUENTE HILLS. - 1899 -
CALIFORNIA.
CALIFORNIA STATE MINING BUREAU.
A.S. COOPER, State Mineralogist.
Accompanying Report of W.L.WATTS, Assistant in Field.
Under the direction of HENRY T. GAGE
Governor of the State of California.
SCALE.
0 ½ 1 2 miles
LEGEND
Shale Formation.
Abandoned Wells.
Dip of Strata.
Oil Springs & Brea
Railroads.
Oil Wells.
County Boundaries.
Oil Sand.
POMONA
CHINO
WHITTIER
EAST WHITTIER
PLACENTIA
RICHFIELDS
YORBA
OLIVE
ORANGE
EL MODENA
VILLA PARK
WANDA
MARBLEBORO
PUENTE 325
LA PUENTE Rancho
LEMON
SPADRA
SANTA FE SPRINGS
SAN GABRIEL VALLEY
SAN GABRIEL RIVER
SAN JOSE HILLS
SAN JOSE CREEK
PUENTE HILLS
SANTA ANA RIVER
SANTA ANA MTS.
Chino Cr.
Canada del Rodeo
Brea Canon
Carbonne Canon
Lohronda or Telegraph Canon
Aliso Canon
Santiago Canon
Coyote Cr.
Sycamore Canon
Turnbull Canon
Workman Hill 1391'
1182'
Pomona Hill 1476
Eruptive Rock
GRANITE
Metamorphic Sandstone
Shale
Principally Sandstone
Conglomerate
Sandstone
SHALE
Alluvial
Alluvial & Unexplored
Unexplored
Foot Hills
PUENTE OIL CO
HOME OIL CO
CENTRAL OIL CO
SCOTT & LOFTUS OIL CO.
SANTA FE OIL CO
REX OIL CO.
UNION OIL CO
CHINO WELL No 1
CHINO WELL No 2
LOS ANGELES CO
ORANGE CO
SAN BERNARDINO CO
R.11 W.
R.10 W.
R.9 W.
R.8 W.
T.1 S.
T.2 S.
T.3 S.
T.4 S.

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LETTER OF TRANSMITTAL.

California State Mining Bureau,
October 31, 1900.

To His Excellency Henry T. Gage, *Governor of the State of California;* The Honorable the Board of Trustees of the State Mining Bureau; *and* Hon. A. S. Cooper, *State Mineralogist:*

Gentlemen: I have the honor to submit to you Bulletin No. 19, entitled "The Oil and Gas Yielding Formations of California."

The matters treated in this Bulletin are descriptions: (1) of certain territory extending westward from the Santa Ana Mountains in Orange County, to the City of Los Angeles, including the Puente Hills and the oil-fields situated therein; (2) of the Los Angeles oil-fields; (3) of certain territory extending westward along the coast-line between San Diego County and Newport in Orange County, and northward, inland, for a distance of about ten miles; (4) of the peninsula of San Pedro; and (5) of certain territory in Ventura County extending eastward from the Sespe Creek to the Piru Creek in the mountains north of the valley of the Santa Clara River.

A brief description is given of recent developments at Summerland in Santa Barbara County, and of the oil-fields in the foothills of the Central Valley of California, which have attracted so much attention. A chapter by Mr. F. M. Anderson on the oil-fields of Humboldt County, and remarks by H. S. Fairbanks, Ph.D., on the oil-yielding formations of San Luis Obispo and Monterey counties, are also included.

The geological facts which I mention, concerning the Kern River, the Sunset, and the Coalinga districts, are largely quotations from Bulletin No. 3, now out of print, for which there is a great demand. In addition to the above, I have written chapters on the structural conditions pertaining to the occurrence of petroleum, and the geographical and geological distribution of this mineral in California. I have also added a summary of available data concerning the character and fuel value of California petroleum, also a chapter on the descriptive geology pertaining to the occurrence of petroleum in the territory I have investigated. Under the head of productive wells, I have mentioned only such wells as were productive when the locality in which they are situated was visited.

The records given of fractional distillation of California petroleum are from experiments made by the late Dr. W. D. Johnston, formerly chemist to the California State Mining Bureau, and by myself.

The palæontological determinations shown in the tables at the end of this volume were made by Dr. J. C. Merriam of the State University of California; and the palæontological matter quoted from Bulletin No. 3 is based on determinations made by Dr. J. G. Cooper of Haywards.

Since the beginning of 1897, I have been stationed principally in Southern California. A large portion of my time has been devoted to answering questions and attending to correspondence concerning not only petroleum, but also other minerals. This class of work has been especially onerous during the petroleum excitement of the past two years. I have also collected and compiled the annual statistics of petroleum and of several other mineral products in the southern part of the State.

Since my appointment, in 1899, as State Expert in California Mining, I have had charge of all the field-work of the State Mining Bureau prescribed under Chapter XCV, Statutes of California, 1899. Furthermore, in order that there might be no delay in placing before the public the information obtained, I delivered lectures and compiled maps, giving such facts concerning the oil-yielding districts as my investigations warranted. By these means, many of the facts set forth in this Bulletin found their way into the public press. Although the greater portion of this report might have been printed somewhat earlier, I considered it advisable to complete the work already in hand, and bring the statistical portion as nearly as possible up to date before offering my report for publication.

Allow me to take this opportunity of returning thanks to the numerous gentlemen who have aided me in my work; also to the Academy of Sciences of San Francisco, California, and the Los Angeles Chamber of Commerce, for courteous assistance in the matter of office room. Permit me also to thank the Puente Oil Company, the Union Oil Company, and D. C. Cook, Esq., of Piru, Ventura County, for the handsome gift of text-books which they presented to the Library of the California State Mining Bureau as a token of their appreciation of the researches made by our Department concerning the oil-yielding formations of California.

Most respectfully,

W. L. WATTS.

OIL AND GAS YIELDING FORMATIONS OF CALIFORNIA.

PART 1. CHAPTER 1.

INTRODUCTORY.

1.1.1.* California's mineral wealth consists not only in those minerals from which metals are obtained, but also in numerous other mineral substances, which become in greater demand as our manufacturing interests expand and as our civilization advances.

The most important of the latter class of minerals, which, in a commercial sense, may be regarded as non-metallic, are the hydrocarbons; and of these, petroleum, in the form of asphaltum, oil, and natural gas, is of the greatest value. This Bulletin is confined to the last two of these items.

It is only of late years that the importance of the petroleum interests of California has been recognized. The value of our petroleum industry is far-reaching. Exclusive of asphaltum and gas, it is represented by the amount of foreign capital expended in the work of extracting and handling the oil, by the price obtained for that portion of our petroleum which is exported by California residents, and by the value of that portion which is consumed in California. The part consumed in this State constitutes the bulk of our petroleum output, and is used chiefly as fuel, thus becoming one of the leading factors in our commercial economy.

In California the question of petroleum as fuel assumes a special importance, owing to the fact that the deposits of coal thus far discovered in our State are inadequate to the steadily increasing demand for fuel.

1.1.2. Since the publication of our last Bulletin on this subject, the opening of new oil-fields has widened the horizon of research; and it is very encouraging to note that the new developments have been made along lines indicated in the reports of the Mining Bureau.

1.1.3. Investigations in which information is gathered by interviewing parties interested, and obtaining from them data which are the result of their researches, or by the compilation of records, can be made

*The numbers at the beginning of the paragraphs are so arranged that the figure on the left hand denotes the Part, the next the Chapter, and the figure or figures on the right hand the Paragraph. Thus, 1.2.15 means Part 1, Chapter 2, Paragraph 15.

with rapidity; but investigations which require that information be gathered by the personal research of the investigator demand a much longer time. In many instances the latter class of investigations involves a concentration of energy within a comparatively small area. Thus, in Los Angeles, Orange, and Ventura counties it was apparent that the relation of the oil-yielding rocks to the rocks which inclose them should be demonstrated; but this was not the work of a day or a week or a month.

1.1.4. There are few things which facilitate education as much as the object method of imparting ideas; hence, the stress laid on maps and illustrations.

1.1.5. There has been some discussion as to the value of fossils in connection with researches among the petroleum-yielding rocks of California.

In order to make a competent record as to the occurrence of petroleum in this State, it is necessary to define the rocks in which petroleum is found, and to show their horizontal and vertical range; or, in other words, to show the area over which they extend, and the way in which they lie one on another. Furthermore, such a record requires that the petroleum-yielding rocks in the different oil-fields should be correlated with the geological formations of the State at large. The physical character of sedimentary rocks is an insufficient index by which to classify them. The rock-forming sediments in every age consist of mud, calcareous matter, sand, and fragments of rock, which have formed respectively shale, limestone, sandstone, and conglomerate.

The accepted method of distinguishing such rocks or groups of rocks belonging to one age, from similar rocks or groups of rocks belonging to another age, is by means of the fossils they contain, which show the form of life existing at the time the sediment forming the rocks was deposited.

This report describes a series of sandstones, shales, and conglomerates in which petroleum is found. It is essential, therefore, to mention such evidence as may define the position of these sandstones, shales, and conglomerates in point of vertical as well as of horizontal range, and to show their relation to the other sedimentary rocks found throughout California. Much more might be said as to the value of fossils in geological investigations.

1.1.6. In order to systematize the work, it has been found necessary to confine investigations to definite lines of research. The direction of these lines has been determined by the probabilities of finding the requisite geological data, by the amount of development done or about to be done in different areas, by the amount of interest taken in the work of investigation by citizens connected with the petroleum industry in the various oil-yielding districts, and by the demands for information concerning districts which were supposed to have value as oil-lands.

PART 2.

TERRITORY BETWEEN THE SANTA ANA MOUNTAINS IN ORANGE COUNTY AND THE SAN GABRIEL RIVER IN LOS ANGELES COUNTY.

CHAPTER 1.

GEOLOGY OF THE PUENTE HILLS.

2.1.1. In Los Angeles County there are three distinct formations which comprise the oil-yielding rocks and the rocks which inclose them, and it became apparent that the relation of these formations one to another should be demonstrated. Since the most urgent requests for information came from parties operating or about to operate oil-territory in the Puente Hills, in Los Angeles and Orange counties, those hills were selected as an area within which to work out the problem.

2.1.2. Reference to Figs. 1 and A shows that the Puente Hills consist of a low range cut off from the Santa Ana Mountains by the Santa Ana River. On the north they are separated from the San José Hills by the south fork of the San Gabriel Valley (see Photo No. 9); on the west they are separated from the Rapetto Hills by the San Gabriel River; on the south they slope down to the valley of the Santa Ana River and the level country which stretches southward toward the Pacific Ocean, about 20 miles away. The highest elevation in the Puente Hills is about 1650′. The elevation of the valley of the Santa Ana River ranges from about 200′ near the village of Olive to 450′ at the narrows, where the Santa Ana River divides the Puente Hills from the Santa Ana Mountains. The elevation of the south arm of the San Gabriel Valley varies from about 350′ near the west extremity of the Puente Hills, to about 700′ near the village of Spadra.

2.1.3. The Puente Hills are traversed by numerous cañons. Their trend appears somewhat erratic, but Fig. 1 shows that in a general way the cañons are of two orders: (1) Numerous small cañons, which run nearly at right angles to the crest of the hills; (2) Larger cañons, which either cut through the crest of the hills or run parallel to their course. The cañons of the first order have been formed principally by erosion. The course of the cañons of the second order has probably been determined by the geological structure. The trend of the cañons which cut through the crest of the hills is east of north, as is seen by looking at the Sycamore and Turnbull cañons, the Cañada del Rodeo, and the upper portions of the Soquel and Brea cañons. The trend of the cañons which run nearly parallel to the crest of the hills is east of south, and can be observed best by noting a depression which, as depicted in Fig. 1, extends through the Puente Hills and forms portions of cañons at the Central, the Puente, and the Santa Fé oil-wells, and in the lower portions of Brea, Soquel, and Telegraph cañons. The course of the cañons of the second series appears to follow the course of folds or faults in the rocky strata. Thus, Rodeo Cañon and portions of Brea, Soquel, and Telegraph cañons are evidently worn along the axes of folds; for on one side of these cañons the strata dip in one direction, and on the other side in the opposite direction.

2.1.4. All the rocks seen by the writer in the Puente Hills are of sedimentary origin, except in the low foothills immediately south of Pomona, where granite and eruptive rocks are exposed. The sedimentary rocks show little or no signs of alteration, except in the spur of hills which culminates in Pomona Hill, and at the Sulphur mines which are about 1 mile northwest of Whittier, where the rocks have been subjected to chemical change by the action of sulphureted vapor.

2.1.5. At Pomona Hill there are sedimentary rocks consisting of hard brownish sandstones and a few strata of crystalline limestone. At the Sulphur mines the sedimentary rocks are decomposed by chemical action.

2.1.6. The unaltered sedimentary rocks of the Puente Hills may be classed in three groups. Mentioned in the order of their upward vertical range they are as follows:

2.1.7. *First*—A group consisting of sandstone varying in color from white to light brown or yellow. The sandstone is interbedded with some shale and a little conglomerate. The uppermost beds of this series consist of a very silicious shale. These sandstones correspond to certain sandstones in the Santiago Cañon, which contain fossils, the age of which probably corresponds to that of the Lower Neocene formations in the Central Valley of California. (See table of fossils.) As seen in Fig. A, a large portion of the Puente Hills lying to the north and east of the Puente oil-wells is formed of these sandstones. At several points these sandstones are, or have been, impregnated with bituminous matter and constitute "dry oil-sands." Only in two instances did the writer note a spring of liquid petroleum in this formation.

2.1.8. *Second*—A group consisting of shale with a few strata of sandstone, which become thicker and more numerous toward the bottom of the formation. The upper portion of the rocks of this group consists of thin-bedded clay-shales and sandy strata; lower, the shales become a putty-like clay; still lower, they are sandy and are interstratified with sandstone. In some places the lower portion of this shale is white or whitish. It appears either to have undergone some chemical change or to be made up largely of diatomaceous material, for in some places it resembles diatomaceous earth. The sandy strata interstratifying the lower portion of the shale formation constitute the principal oil-sands which have been penetrated by the productive oil-wells in the Puente Hills. These oil-sands, where they crop out at the surface of the ground, may or may not show traces of oil; in many places they show a brown pulverulent sandstone, but when the surface is removed the sandstone smells more or less of petroleum. At one point on the south side of Brea Cañon the shale contains nodules of limestone with fossils of Middle Neocene age. (See table of fossils No. III.)

2.1.9. *Third*—A group consisting of conglomerate, sandstone, and a little shale. In this group the conglomerate preponderates. The pebbles forming the conglomerate are, for the most part, granitic with black mica. In some places the conglomerate contains shells of Middle Neocene age. (See table of fossils No. III.) It appears, therefore, that these shales and conglomerate correspond in point of age to what are hereinafter described as the Middle Neocene formations of the Central Valley of California.

At some points the rocks forming the conglomerate are more or less impregnated with petroleum; indeed, two of the wells of the Santa Fé Railroad Company yield oil from strata of conglomerate.

2.1.10. The complexity of the geological structure, the alluvium which covers the greater portion of the Puente Hills, and the scarcity of fossils made the differentiation of these formations slow work. Indeed, it was not until the country on the east side of the Santa Ana River was reached that the relative position of the conglomerate, shale, and sandstone was clearly made out.

2.1.11. An examination of Figs. 1 and A shows that the conglomerate forms a fringe around the base of the hills. At a higher elevation the conglomerate has been worn away, disclosing a formation of shale underlying it. At still higher elevations, the conglomerate and shale have both been worn away, disclosing the sandstone which forms the greater portion of the eastern half of the Puente Hills.

2.1.12. Crossing the Santa Ana River to the western end of the Santa Ana Mountains, we find the same sequence of formation. Thus, traveling east from the village of Olive, and ascending a ridge belonging to the foothills of the Santa Ana Mountains, we pass over, first the conglomerate, then the shales, then the sandstone. The sandstone rests on older rocks.

2.1.13. If we examine Fig. A, we see that at two points there are small patches of conglomerate surrounded by shale. The patches of conglomerate are "outliers" (i. e., patches remaining of the sheet of conglomerate which at one time covered the shale, but which has been partly removed by erosion). The question of the conformability or non-conformability of these formations will be discussed later.

2.1.14. In Fig. A only the leading structural features are shown, for in many places the strata are much disturbed and the stratigraphy is so complicated that it cannot be represented to advantage or any definite structure figured therefrom.

2.1.15. In the Puente Hills there are two predominant systems of folds or lines of geological disturbance. They are disjointed and rather hard to trace, and at many points they resemble faults rather than folds; but since for the most part they show an anticlinal structure and play an important part in the distribution of the oil-lines in the Puente Hills, they are herein spoken of as folds and cross-folds. The most important of these folds have a strike of east of north, and in the southern portion of the Puente Hills they mark the axis of a larger anticlinal fold of which they form a part. The cross-folds have a strike of east of north. The general effect of these folds and cross-folds has been to break up the formation into blocks, which fact adds greatly to the complexity of the geological structure.

The course of the first-mentioned series of folds is marked on Fig. A by lines AA, BB, XX, ZZ, DD. As stated, the second series are cross-folds to the folds of the first series. They can best be seen by examining the strata exposed in cañons, which, as hereinbefore mentioned, cut through the crest of the hills. The rock-exposures which indicate the cross-folds are seen to the best advantage on the slopes of the hills.

The complexity of the stratigraphy and the scarcity of rock-exposures in the Puente Hills render it hazardous to define the course of the axes of folds as precisely as is done by lines XX, ZZ, AA, BB, in Fig. A. These lines must be considered merely as pointers to direct the reader to the stations at which the exposed rocks give a clue to the course of the folds.

It may appear that, in some instances, the inclined strata, treated as indicating cross-folds, may really be the termination of short anticlines. Reference to Fig. A shows that at the points where the existence of cross-folds is inferred, the dip does not swing around the axes of the dominant folds, but frequently inclines toward it, and in some cases both limbs of the cross-folds can be observed. At a few places the exposed rocks suggest a local reversal, and at one point, as is shown in Photo No. 1, the reversal is evident. There is, however, no ground for believing that there is extensive overturning of the formations in the Puente Hills.

2.1.16. The southern portion of the Puente Hills constitutes an anticlinal ridge, which has a trend of S. 70° E., or thereabouts. Through that portion of the Puente Hills which lies between the Central oil-wells and Brea Cañon, two lines of geological disturbance can be traced, which

PHOTO 1. Overturned Fold in Puente Hills, Los Angeles County.

PHOTO 2. Crushed Sandstone in Puente Hills, Los Angeles County.

have a strike of west of north. The axes of these folds have an average trend of about S. 70° E., and they are marked on Fig. A by lines AA and BB, respectively. In the syncline between these subordinate folds there appears to be a fault-line, the downthrow being to the south.

2.1.17. The northernmost of these folds or lines of disturbance (see line AA, Fig. A) can be traced as follows: From Station 228, in the edge of the foothills, west of Turnbull Cañon, where the formation is sandy shale, to the abandoned oil-wells in Turnbull Cañon, and thence to Station 150 in Woersham Cañon, where the formation consists of oil-sand and thin-bedded sandstone, with conglomerate on the southern limb of the fold. From Station 150 it probably extends to Station 134 at the Central oil-wells, where the formation is oil-sand and crushed shale. Between Stations 33 and 34 the prevailing dip is to the north; the formation is clayey and sandy shale, apparently resting on conglomerate. Since the normal position of the conglomerate is on the top of the shales, the structure at this point indicates a fault or a reversal.

2.1.18. It is probable that this fold extends to Station 58, where the oil-sand is exposed near the axis of the fold. At Station 58 the southern limb is very short and crushed, and the oil-sand is overlain by sandy and clayey shale; on the northern limb the oil-sand is overlain by sandy and clayey strata and conglomerate. Fold AA probably extends to Station 70, where the formation is sandy shale; and on the northern limb of the fold the sandy shale is overlain by conglomerate. Near this point the shale on the southern limb of the fold is white, and appears to be diatomaceous. Farther to the southeast the structure is very irregular, and appears to be complicated by cross-folds which have a strike of about N. 40° E. The best evidence as to the course of these cross-folds is to be found at Stations 39, 35, and 36, on the north slope of the Puente Hills.

2.1.19. Farther eastward and immediately west of the Puente oil-wells, the shales have been worn away, exposing the underlying sandstone, which appears to be chiefly influenced by the folds having a northeastern strike.

2.1.20. At the Puente oil-wells the axis of a fold is exposed, on both sides of which are numerous remunerative wells belonging to the Puente Oil Company. (See wells of Puente Oil Company.) The rocks exposed in the Puente Cañon are principally shales, varying in color from dark brown to light brown or whitish, and in composition from sandy to clayey or calcareous. The strike of the exposed strata varies from S. 80° E. to N. 80° E. At the Puente oil-wells a cañon has been worn along the axis of a fold, showing a strike of south of east. There appears also to be a cross-fold having a strike of north of east. This is corroborated by the drilling record of the Puente Oil Company, which indicates that the strike of the oil-sand at the Puente oil-wells is a little north of east.

2.1.21. For nearly 2 miles east of Puente oil-wells the formation is much disturbed. The prevailing dip is northerly. The rocks are shales and sandstones. It is not until Brea Cañon is reached that the structure of the formation can be definitely figured out. The structure of the formation from Brea Cañon eastward will be discussed later.

2.1.22. The most southerly of the folds or lines of disturbance previously mentioned as having a southeast course and extending eastward from the Central oil-wells, is marked BB on Fig. A. It is situated at a lower elevation and is less easy to trace than is line AA; for along its course it is only here and there that the rocks are not covered with alluvium. In the conglomerate, which forms the lower portion of the Puente Hills immediately to the north of the town of Whittier, and west of the Central Oil Company's wells, there is no trace of this fold; but a somewhat extensive oil-spring near Station 11 in Savage Cañon lines up with the strike of the axis of the fold. The western extremity of this fold is noticeable at the Central oil-wells, the northern limb of the fold being soft sandstone, and the southern limb soft sandstone covered with conglomerate. The most remunerative wells of the Central Oil Company are on the south limb of this fold. (See Photo No. 3.) About 1 mile farther to the east, near the abandoned well of the Mutual Oil Company, the axis of this fold is again exposed. Its northern limb shows sandy shale and soft sandstone, and its southern limb soft sandstone covered with conglomerate. About a quarter of a mile south of the Mutual Oil Company's well, are the Chandler wells.

A short distance south of Station 34 the axis of fold BB is again seen, and there is an oil-spring. At this point the northern limb of the fold consists of comparatively soft sandstone and sandy shale overlain by conglomerate. For a short distance down the southern limb of the fold, the formation is conglomerate; but at Station 37 the clay-shale comes to the surface. The outcrop of clay-shale at this point is probably due to a fault, the trend of which is southeasterly. At Station 37 the clay-shale contains Middle Neocene fossils. (See table of fossils No. III.)

The next point where the axis of this fold can be observed is Station 55, the exposed rocks being, for the most part, grayish sandstone and sandy shale. Continuing in a southeasterly direction, which observation has shown to be the trend of the axis of the fold under consideration, more than half a mile of alluvium-covered territory is passed over, until, at Station 270, conglomerate and sandstone are seen dipping east of north. The hills between Station 270 and the La Habra Valley are composed of conglomerate and sandstone, dipping to the south. Still pursuing a southeasterly course to Station 230, soft sandstones are seen dipping to the north. Near Station 230 a well has been drilled by the Union Oil Company which has shown more or less oil from the surface down; and

PHOTO 3. Central Oil-Wells, Los Angeles County.

PHOTO 4. Oil-Wells in Brea Cañon, Orange County.

two pits have been sunk in oil-yielding rock. (See Union Oil Company's well at La Habra.) Farther to the southeast, the same course passes through Station 218, where the axis of an anticline can be observed.

2.1.23. The rocks dipping to the north are principally calcareous shale and soft sandstone; those dipping to the south are principally conglomerate and sandstone.

East of Station 218, there are some points where the exposed rocks show an anticlinal structure, which may possibly indicate an extension of the line of disturbance marked by line BB. Thus, a short distance south of the wells of the Puente Oil Company the structure is anticlinal, the formation being crushed shale impregnated with petroleum, and there is a small deposit of brea*. Farther to the east the formation is conglomerate and sandstone. In this portion of the Puente Hills the rocky formations are cut through by Brea Cañon, along the southern side of which the axis of a fold can be traced.

2.1.24. It will be observed that the axes of the folds AA and BB can not be followed in a straight line for any great distance. This may be accounted for by the block-tilting previously mentioned or by faults running in the direction of the dip; or it may result from variation of surface elevation, coupled with the fact that the axis of a fold may have different inclinations at different points.

2.1.25. From the foregoing it appears that the western portion of the Puente Hills consists of an anticlinal ridge, traversed by two systems of folds. The folds belonging to one of these systems are dominant folds. To this order of folds belongs the one indicated by line XX. It is interesting to note that if the axis of this fold were extended westward, it would enter the valley lands at or near the sulphur deposits about 1 mile northwest of the town of Whittier. The folds belonging to the other system have a course of east of north, and are cross-folds to the folds running west of north; it is doubtless a fold of this order which has given the strata exposed in Sycamore Cañon a strike of east of north. In Sycamore Cañon the dip is west of north; we look in vain, however, for the axis of a fold having a strike east of north, unless one is inferred from the fact that in Sycamore Cañon the exposed strata dip west of north, and that the conglomerate south of Turnbull Cañon dips east of south.

2.1.26. It is a reasonable deduction that, in a general way, the strike of the oil-lines follows the strike of the axes of the folds, or of the blocks of strata on which they are situated. It is evident that in rocky formations possessing as complex a structure as those of the Puente Hills the folds have been modified by fracture and faulting; but where the rocks are much covered by alluvium it is impossible to work out details of such displacement from surface observation.

* Asphaltum formed by the exudation of heavy oil.

2.1.27. The reader will be able to gather a further conception as to the geological structure of that portion of the Puente Hills which has been thus far described, by examining the cross-sections shown in Figs. 2, 3, 4, 5, paying attention to the arrows indicating the change in the dip of the different strata, and by noting also the position of the cross-sections in Fig. A.

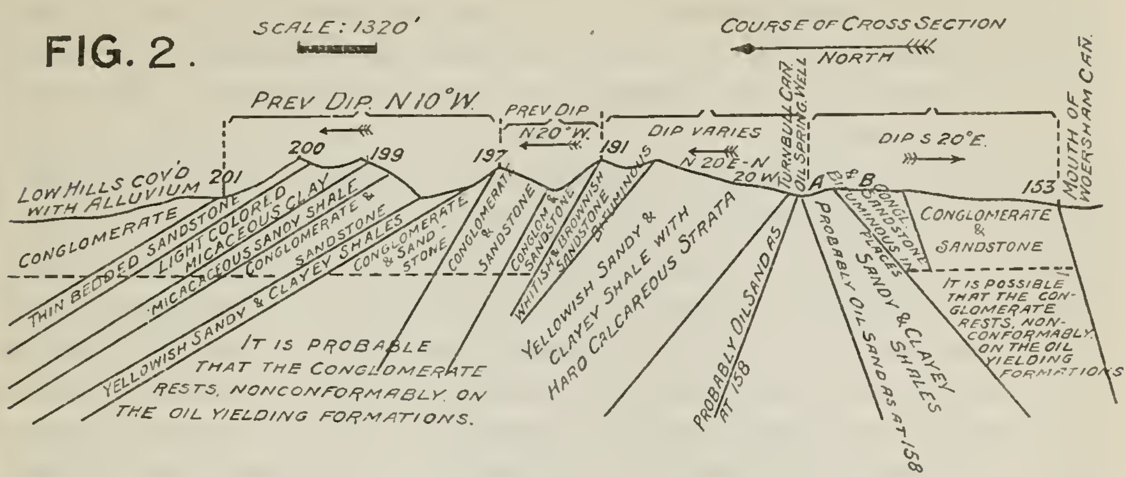
2.1.28. Fig. 2 represents a cross-section about 3 miles in length through the western end of the Puente Hills. It shows the general structure to be that of an anticlinal fold. If we infer the strike of the axis of this fold from the prevailing dip of the strata on the outermost slopes of the fold, we should conclude that it is N. 80° E., or thereabouts. As the axis of this fold is approached, there is a discrepancy between the strike of the clayey and sandy shales which have been found elsewhere resting on the oil-sand (as is shown in Fig. 2) and the conglomerate which overlies them. An analysis of Fig. 2 shows that the first outcropping rock observed on the northern side of the Puente Hills at this point is conglomerate, consisting of fine pebbles. (See Station 201, Fig. A.) The stations mentioned in paragraphs 28, 29, 30, 31 refer to those shown in the diagram of cross-sections, unless it is otherwise stated. Pursuing a southerly course, the following formations appear to rest with practical conformability one upon another: Thin-bedded sandstone, light-colored micaceous clays, micaceous sandy shale, conglomerate sandstone, and clay-shale; the latter being very similar in appearance to that before mentioned as overlying the oil-sand in other places.

Between Sycamore Cañon and Dark Cañon conglomerate is again the prevailing rock, the direction of the dip being practically the same as on the northern side of Sycamore Cañon, but the angle of the dip increases to 60° or more. This probably indicates a fault on the northern limb of the fold. At Station 191 the conglomerate is underlain by a brownish and whitish sandstone, some of which is pulverulent and indicates dry oil-sand. If this sandstone is followed along its line of strike to Station 216 (see Fig. A), a sandstone saturated with petroleum is found underlying the conglomerate. Beneath this sandstone is a yellowish shale, which varies from clayey to sandy and is interbedded with sandstone and hard calcareous strata. These shales constitute a very characteristic formation in the Puente Hills and appear to overlie a body of oil-sand, which, at Station 150 (see Fig. A), shows a thickness of about 50′. The dip of these shales varies from N. 20° W. to N. 20° E., and along the line indicated on Fig. 3 the angle of inclination does not exceed 50°; at many points it is less.

In Turnbull Cañon there is an oil-spring; and a few rock-exposures indicate that the formation corresponds to that exposed at Station 150. Several years ago two wells were drilled near the mouth of Turnbull

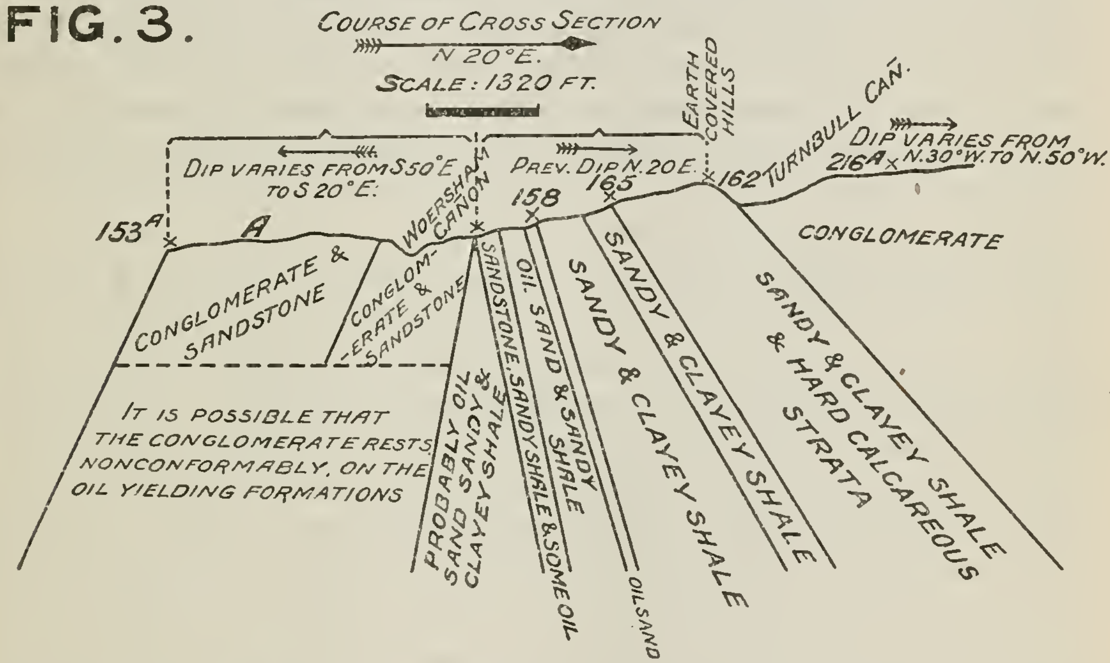
CROSS SECTION THROUGH W. END PUENTE HILLS FROM STA. 153 AT MOUTH OF WOERSHAM CAÑON TO STA. 201 N. OF SYCAMORE CAÑON

FIG. 2.



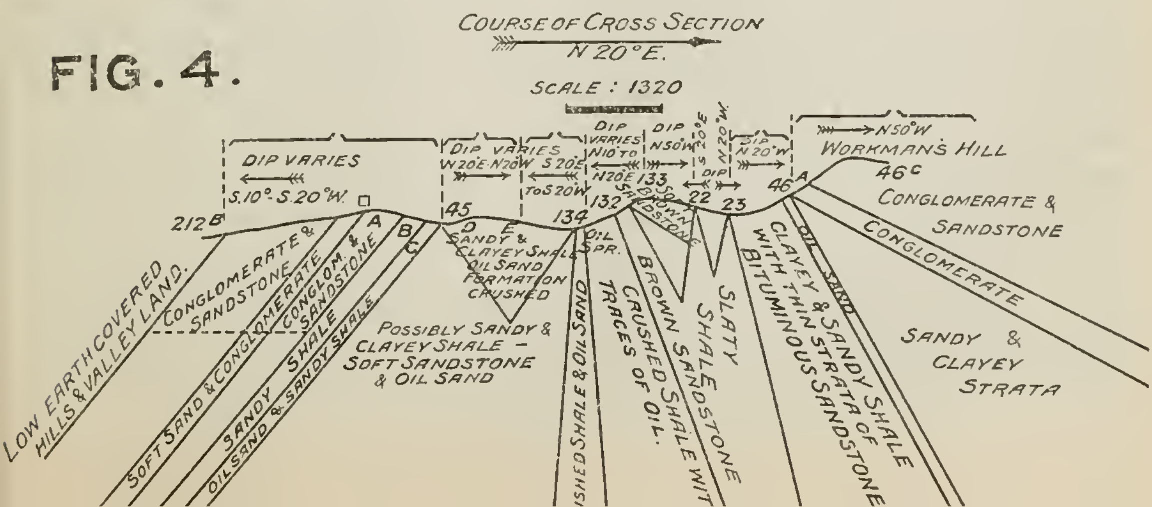
CROSS SECTION RUNNING N. 20° E FROM STA. 153^A NEAR THE MOUTH OF SAVAGE CANON TO STA. 216^A ON N. SIDE OF TURNBULL CAÑON.

FIG. 3.



CROSS SECTION RUNNING N 20° E. FROM STA. 212^B NEAR MURPHY WELL TO 46^C A SHORT DISTANCE N. OF U.S. SIGNAL STA. IN SEC. 14. T 2 S. R. 11 W.

FIG. 4.



Cañon; and it is said that one of them, a 400′ well shown in Fig. A, would have been remunerative had not an accident occurred in the drilling which choked the well. On the summit of the hill, immediately south of Turnbull Cañon, the exposed rocks consist mainly of conglomerate and sandstone. In some places this sandstone looks as though it had been impregnated with oil; but the oil has evaporated, leaving the sandstone colored with carbonaceous residuum. A short distance southeast of the abandoned well in Turnbull Cañon is the first well drilled by the Home Oil Company of Whittier.* At, and immediately around, this well, the exposed rocks are principally conglomerate; and the drilling records show that the strata to a depth of about 900′ resemble the sandy and clayey shale, which, as before mentioned, is found immediately overlying the oil-sand at Station 150. This well proved a "dry hole," and was abandoned. Subsequently the Home Oil Company drilled a well about a third of a mile southeast of their abandoned well and close to the axis of the fold; they were successful. (See Home Oil Company.) At the mouth of Savage Cañon are the wells of the Whittier Oil Company. Their records show that after drilling through conglomerate for a few hundred feet, a formation was penetrated resembling the clayey and sandy shale, which, as before mentioned, underlies the conglomerate.

2.1.29. Fig. 3 represents a cross-section running N. 20° E. from Station 153*a* near the mouth of Savage Cañon to Station 216*a* on the northern side of Turnbull Cañon, a distance of rather more than 1½ miles. Fig. 3, like Fig. 2, delineates an anticlinal fold, but the position of the oil-sand is more clearly shown than it is in Fig. 2. An analysis of this cross-section shows as follows: In the foothills near the mouth of Savage Cañon the exposed rock consists of conglomerates and sandstones, which have a dip ranging from S. 5° E. to S. 20° E. About a quarter of a mile east of point A, Fig. 3, there are oil-springs. The angle at which the conglomerate dips is about 65°. A short distance south of Station 150, Fig. A, the axis of the fold is exposed, and close by, on the south side of the fold, are the wells of the Home Oil Company. (See Home Oil Company's wells.) The rocks on the north side of the fold are thin-bedded sandstone, sandy shales, and oil-sand; and on the southern side conglomerate and sandy strata. At Station 150, strata of soft sandstone, aggregating about 50′ in thickness, are impregnated with oil, and the rocks between Station 150 and the axis of the fold show more or less indications of petroleum. The formation overlying the oil-sand is yellowish clayey and sandy shale interbedded with a few strata of sandstone and hard limestone. At this point the shale formation is at least 800′ thick, perhaps twice that thickness, but there is a

*Since the writing of this manuscript, several wells have been drilled between Turnbull Cañon and the Central oil-wells. (See wells in Whittier oil-field.)

fault at Station 165 which renders it impossible to make a more exact estimation. A few rock-exposures between Station 165 and Turnbull Cañon indicate a broken structure. The oil-sand and overlying shales show a prevailing dip of N. 20° E. On the northern side of Turnbull Cañon the formation is conglomerate, and the dip varies from N. 30° W. to N. 50° W.

2.1.30. Fig. 4 represents a cross-section running N. 20° E. from Station 212*b*, near the Murphy well, to a point north of the United States signal station in Sec. 14, T. 2 S., R. 11 W., S. B. M. Reference to the plan of the locality (see Figs. 1 and A) shows that the cross-section indicated runs through the territory in which the wells of the Central Oil Company are situated. Fig. 4 exhibits a much more complicated structure than is delineated in Figs. 2 and 3. An inspection of Fig. 2 shows that the conglomerate has been removed from a much larger area in the territory immediately under consideration than is the case to the west. It follows that the rocks underlying the conglomerate are brought to light, and they exhibit a fold which is not seen in the conglomerate farther westward. It is not impossible that this fold may be represented by fractures in the conglomerate which cannot be readily discerned by surface observation. Fold BB, Fig. A, is clearly seen at the Central oil-wells; farther westward, along what we may reasonably presume to be the strike of the axis of this fold, there is an oil-spring and an exposure of oil-sand; but the oil-sand and the adjacent conglomerate dip uniformly to the south.

An analysis of Fig. 4 shows as follows: From Station 212*b*, the rocks exposed on the highlands are conglomerate and sandstone, which at point B give place to soft sandstone and sandy shales. About 200 yards S. 80° E. (i. e., along the strike of the formation) from point A is well No. 3 of the Central Oil Company. The record of this well shows that after passing through the conglomerate, "clay and gravel," for 340′, sandy and clayey strata (probably sandy and clayey shales) were penetrated to a depth of 880′, at which depth the oil-sand was struck and a remunerative well obtained. About 400′ S. 80° E. (i. e., on the strike of the formation) from point B, is well No. 7 of the Central Oil Company. The formation penetrated resembles that observed in well No. 3, below a depth of 340′. Remunerative oil-sand was struck in this well at a depth of 620′. Near point C is well No. 5 of the Central Oil Company. The formation penetrated resembles that observed in wells Nos. 3 and 7, but the oil-sand was not struck until a depth of 635′ was reached. As this well is nearly on the axis of the fold, it is somewhat extraordinary that the oil-sand was not struck at a less depth.

In the vicinity of Station 134, the scanty rock-exposures show sandy and clayey shales, and the formation is much crushed. The latter feature is also evidenced by the character of the formation penetrated by wells Nos. 2 and 4 of the Central Oil Company.

About 500′ S. 80° E. of point D is well No. 2. The formation penetrated is sandy and clayey shale and oil-sand, which appeared to be broken and crushed. Considerable oil was found between the depths of 650′ and 1135′. About 450′ S. 80° E. from point E is well No. 4. The formation penetrated in this well resembles that observed in well No. 2. At Station 134 the axis of another fold is exposed. The formation is oil-sand and dark-colored shale; the rocks are much crushed and stand at an angle of 85°, the direction of the dip being S. 20° E. to S. 20° W., and N. 10° E. to N. 20° E. At this point there is an oil-spring. Between Stations 134 and 132 the formation is crushed shale, with traces of oil. Between Stations 132 and 133 the shale gives place to a rather thick-bedded brown sandstone, and the dip lessens to about 60°. Several springs of mineral water ooze from this sandstone.

At Station 133 a soft brown micaceous sandstone is exposed, which dips N. 50° W., at an angle of about 25°. Immediately north of Station 133 the hills are covered with alluvium; but in a ravine a slaty shale crops out, which is crumpled into two compressed folds at Stations 22 and 23 respectively. North of Station 23 the formation is sandy and clayey shale, with thin strata of bituminous limestone. This formation is overlain by an oil-sand, which crops out at Station 46*a*. Resting with apparent non-conformability on the oil-sand is a formation composed of clayey and sandy strata, which has a dip of N. 40° W.; and still farther to the north is a thick deposit of conglomerate, which has a prevailing dip of N. 40° W.

2.1.31. Fig. 5 shows a cross-section running N. 20° E. through the Puente Hills north of La Habra, namely, from Station 261*a* near the southwestern corner of Sec. 32 to Station 236 near the northeastern corner of Sec. 29, T. 2 S., R. 10 W., S. B. M. Between Stations 261*a* and 244, Fig. 5, the exposed rocks are conglomerate and sandstone, the prevailing dip being S. 10° E., at an angle of about 25°. At Station 244 the formation is sandy clay, which dips S. 20° W., at an angle of about 30°. Half a mile or more N. 80° W. from point A are the wells drilled by the Union Oil Company near La Habra; close to the Union Oil Company's wells are two pits which penetrate rocks saturated with petroleum. At Station 245, a gray sandstone, which is capped with a stratum of limestone, dips N. 20° E., at an angle of about 65°. The physical appearance of the sandstone corresponds to the sandstone near the Union Oil Company's wells. At Station 270, Fig. A, about a quarter of a mile northwest of this well, a similar sandstone is capped with conglomerate, which pitches to the north. To the north of the La Habra Creek, as shown between Stations 245 and 246, Fig. 5, the formation consists of sandy shales, soft sandstones, and oil-sand. As seen in a cañon running nearly at right angles to the strike of the formation, these rocks are much crushed, and, for the most part, stand at angles ranging from 50° to 90°.

At several places the sand is impregnated with petroleum, and at one point there is a spring of mineral water. The direction of the dip ranges from N. 20° to N. 70° W., and in a few places the strata are inclined to the south. Between Stations 246 and 342 the formation is sandy shale. Near Station 181 (see Fig. A) the axis of another fold is exposed, the formation being oil-sand and sandy shale, as shown at Station 342, Fig. 5. The dip of the oil-sand is N. 30° E., and that of the sandy shale varies from N. 30° E. to N. 50° W. The sandy shale is overlain by conglomerate, which shows a dip of from N. 30° W. to N. 70° W. at an angle of about 35°.

2.1.32. From the foregoing it appears that in the portion of the Puente Hills which extends between Whittier and the Santa Fé oil-wells, the geological structure is that of an anticlinal fold modified by certain subordinate folds in the rocky formations, which are indicated in Fig. A by lines XX, ZZ, AA, and BB. As previously noted, it is probable that, in a general way, the oil-lines follow the axes of the folds referred to.

2.1.33. Figs. 4 and 5 represent cross-sections bisecting portions of the Puente Hills which are a little more than 3 miles apart. In Fig. 5 two distinct folds are shown, and in Fig. 4 two distinct folds and two minor plications. There are also other minor plications in the territory represented, but it would complicate the figures too much to delineate them. It is apparent that the outer slopes of these folds are formed of conglomerate, and the inner slopes of the underlying shales and sandstones. There also is a very slight interplication of conglomerate, which is shown in Fig. A, i. e., in the plan of the territory referred to, but not in Figs. 4 and 5.

It is appropriate, therefore, to regard that portion of the Puente Hills through which cross-sections 2, 3, 4, and 5 are drawn as constituting an anticlinal fold, with secondary folds running parallel to its axis.

2.1.34. The arrows in Figs. 4 and 5 show that there is considerable irregularity in the dip and strike of the different formations. In a general way, the prevailing strike of the shales and sandstones is west of north, while that of the conglomerate is sometimes east of north. These features may be noted at several points in the Puente Hills, although both the east of north strike and west of north strike are more or less common to both the conglomerates and underlying formations. For the most part the conglomerate is much less disturbed than the underlying shales; to some extent this may be accounted for by the fact that the conglomerate is much the stronger formation.

2.1.35. The contour of the hills between the Puente wells and Brea Cañon suggests that fold XX is a continuation of fold AA, and fold ZZ of fold BB. A careful examination of the territory, however, shows that if line XX were extended westward it would coincide with BB

FIG. 5.

CROSS SECTION BETWEEN STATION 261A NEAR S.W. COR. OF SEC. 32 & STATION 236 NEAR N.E. COR. SEC. 29. T. 2 S. R 10 W. S. B. M.

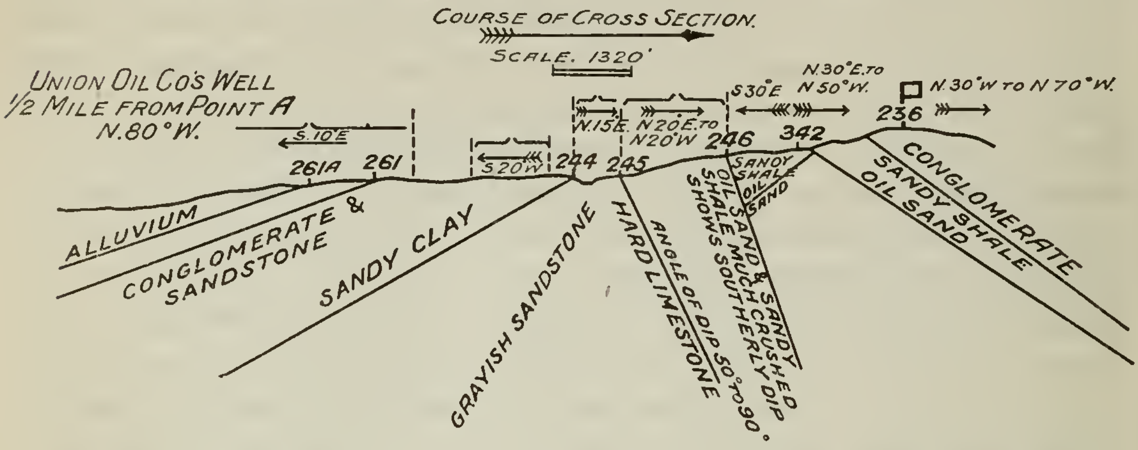


FIG. 6.

CROSS SECTION THROUGH FOLD "X.X."

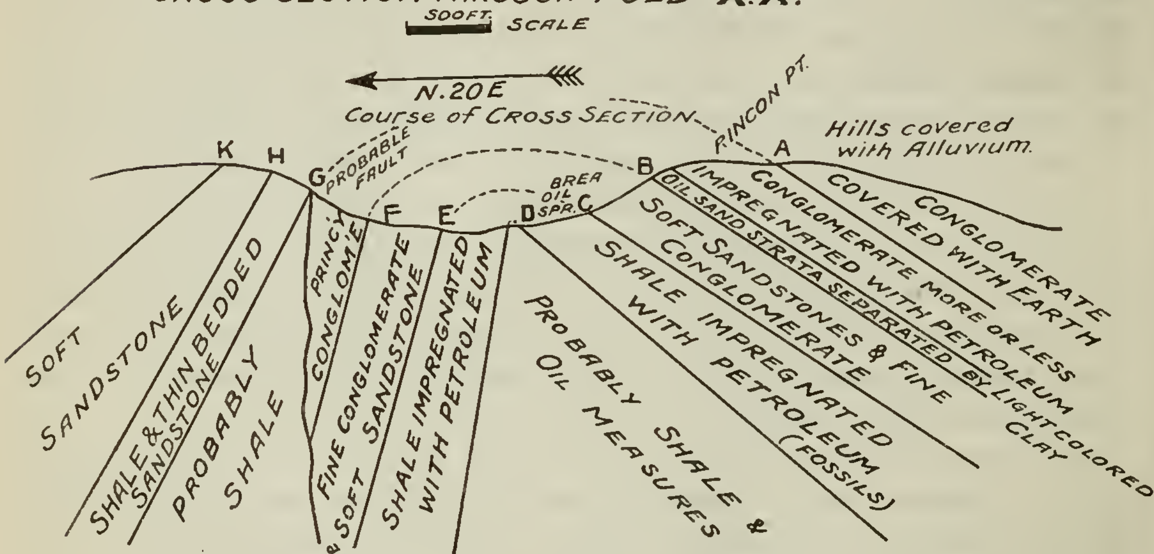


FIG. 7.

CROSS SECTION THROUGH FOOT HILLS, S. SIDE SANTA ANA RIVER, ORANGE CO.

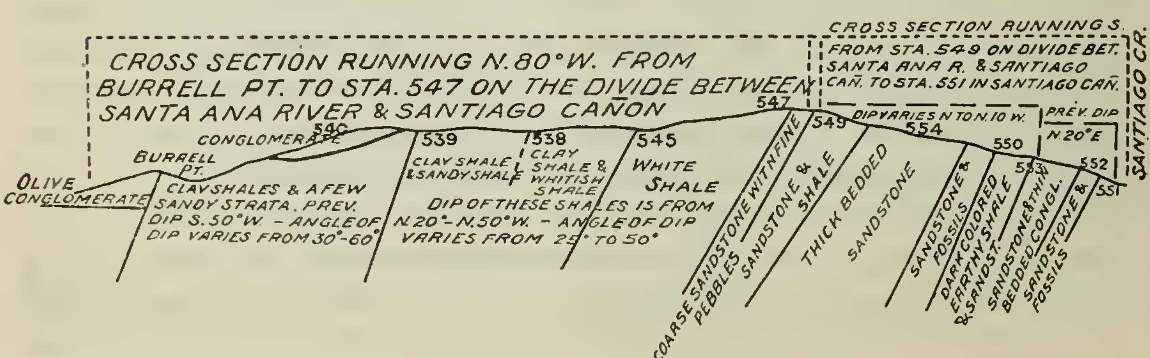


PHOTO 5. Santa Fé Oil-Wells, Fullerton Oil-Field, Orange County.
(Photo taken in 1898.)

PHOTO 6. View in Eastern Oil-Field, City of Los Angeles.

rather than with AA. This might be accounted for by the difference in elevation and the inclination of the axis of fold XX, but in view of the broken character of the structure between the Puente wells and Brea Cañon it would be a hazardous generalization.

At the south end of Brea Cañon there is a well-marked anticlinal fold, the axis of which has a strike of about S. 76° E. The probable strike of the axis of this fold is shown in Fig. 1 by divergent arrows and in Fig. A by line XX. A short distance west of the junction of Brea Cañon and the Spadra Road, fold XX is disturbed by a cross-fold, the axis of which has a strike of north of east, as is shown by rock-exposures along the Spadra Road.

Along the axis of fold XX there is a series of oil-springs. Investigation at the south end of Brea Cañon leads to the conclusion that the axis of this fold is inclined to the north at an angle of about 25° from the vertical; for on the north side of the fold the strata dip N. 20° E. at an angle of about 75°, and on the south side of the fold the dip is S. 10° E. at an angle of about 40°.

2.1.36. Fig. 6 represents a cross-section through fold XX. It is drawn from observation at the south end of Brea Cañon, which is locally known as Rincon de la Brea. As noted in Fig. 6, the delineation of the north limb of this fold must be accepted tentatively, for the scanty rock-exposures indicate a complex structure. Analysis of Fig. 6 shows as follows: Between points A and B the formation is conglomerate, the lower portion of which is more or less impregnated with petroleum. Near point B there are two strata of oil-sand, which are respectively 2′ and 1′ thick, and are separated by light-colored clay. The oil-sand is reddish in color, and contains granite and quartz pebbles. The oil-sand rests on soft sandstone and fine conglomerate, from which the writer obtained a small collection of fossils representing the Middle Neocene age. (See Bulletin No. 11, pages 79 and 80.) The soft sandstone rests on a grayish bituminous clay-shale, which is shown between points C and D, Fig. 6. The last-mentioned rock appears to be the source of the oil-springs previously mentioned as extending along the south side of Brea Cañon. Near the top of this deposit of shale at the Rincon de la Brea is a thin stratum of fossiliferous sandstone, from which the writer obtained several fossils which are referred by Dr. Merriam to the Middle Neocene age. (See table of fossils No. III.) In the center of that portion of Brea Cañon shown in Fig. 6 there are no rock-exposures. On the north side of the cañon, as indicated between points E, F, and G, there are strata of sandstone and conglomerate similar in appearance to the sandstones and conglomerate on the south side of Brea Cañon. Between points G and H the formation is shale and soft sandstone, which probably belong to the same geological horizon as do the shales exposed between points C and D on the south side of Brea Cañon. The upper portion of the shale between points G and H passes into thin-bedded, reddish sandstone, or sandy shale, intercalated with soft whitish material, which resembles diatomaceous earth. It will be observed that on the south side of Brea Cañon there is an orderly sequence of conglomerate and sandstone overlying shale, which, as before demonstrated, is normally the relative position of these formations in the Puente Hills. On the north side of the cañon the shale appears to overlie the conglomerate. It is not improbable that this apparent reversal is due to a fault such as that represented at point G, Fig. 6. The shales and thin-bedded sandstone between points G and H show no evidence of petroleum. As previously mentioned, the rocks exposed on the north side of the fold at the point under discussion indicate a complex structure; moreover, the rocks exposed on the north side of the fold do not correspond sufficiently to the strata exposed on the south side of the fold to warrant the divergent strata shown in Fig. 6 being connected by an air-saddle.

2.1.37. Southeast of Brea Cañon the fold marked by line ZZ (see Fig. A) traverses the mountain which lies to the north of the Santa Fé oil-wells. (See Photo No. 5.) Its course is somewhat obscure, but it appears to be in line with Station 40 in Clapp Cañon, where the axis of a fold can be observed. The formation immediately to the north of the Santa Fé oil-wells (see Fig. A) is principally sandstone, and the geological position of the exposed rocks is near the contact of the sandstone and shale formation. Since this locality was visited by the writer, wells have been drilled to the north of the wells of the Santa Fé Railroad Company.

South of fold XX and southeast of Brea Cañon, a series of oil-springs and beds of brea extend in a southeasterly direction toward the wells of the Santa Fé Railroad Company. These springs and brea beds mark the axis of a fold which is indicated by line ZZ. Along the fold the formation is shale and soft sandstone overlain by conglomerate, and most of the strata show a dip of from 60° to 80°. The wells of the Santa Fé Railroad Company are situated on this fold. (See wells of the Santa Fé Railroad Company.) In Telegraph Cañon the angle at which the strata dip gradually lessens to about 50°. East of Telegraph Cañon fold ZZ is very difficult to trace, and as the Santa Ana River is approached the geological structure becomes very complex.

2.1.38. The hills immediately west of the Santa Ana River are composed principally of whitish sandstone, corresponding to the whitish sandstone previously described. The writer did not find any springs of petroleum or brea beds east of Telegraph Cañon. South of Telegraph Cañon a series of hills, composed principally of conglomerate, slope down to the valley lands.

2.1.39. North of Telegraph Cañon the Puente Hills extend for a distance of about 7 miles toward the Chino Valley. For the most part they consist of sandstone, and constitute rough grazing land, and a large area is comprised by the Chino ranch.

2.1.40. Carbonne and Clapp cañons cut through hills nearly at right angles to the prevailing strike of the formation. The exposed rocks are principally sandstones. Between Stations 31 and 30 in Carbonne Cañon the formation consists principally of slaty shale similar in appearance to that seen between Stations 22 and 23, north of the wells of the Central Oil Company. (See Fig. 4.) This shale varies from clayey to sandy; in some places it is very silicious, and some samples show a calcareous reaction with acid; it is usually fissile, frequently presenting a slaty cleavage; more rarely it is thick-bedded; and, in some instances, it loses its shaly structure. Exposures of similar shale may be seen at some places on the Chino ranch. Farther to the north-east up Carbonne Cañon, between Station 30 and the Hiltscher ranch, the formation is principally sandstone. This sandstone varies in color from white to yellowish or light brown, and some of it is composed of mealy-looking grains which are very characteristic. In most places where it has been exposed to the weather it is soft and friable; but beneath the surface of the ground it is moderately hard; it resembles the Miocene (Lower Neocene) sandstone observed in Santiago Cañon, as hereinafter noted. North of the Hiltscher ranch, most of the exposed rocks are sandstone. There are, also, a few places where sandy and clayey shales are seen, resting on bituminous sandstone.

2.1.41. Bituminous sandstone is exposed at several points on the Chino ranch. In most places the outcropping bituminous rocks have no odor of petroleum; but the fresh-broken rock shows the brown pulverulent surface characteristic of oil-sand, and by a little digging rock smelling of petroleum can be found. On the Chino ranch bituminous sandstone may be observed at the following places: In a ravine about a quarter of a mile west of the well drilled by the Chino Valley Beet Sugar Company (see Chino Well No. 1, Fig. A) there are ledges of bituminous sandstone about 10′ or more in thickness, which at one time must have been saturated with oil. (See record of Chino Well No. 1.) After breaking away the weathered surface, specimens can be obtained which smell slightly of petroleum. At Station 200, near Chino Well No. 2, there is another outcrop of bituminous sandstone, and a seepage of heavy petroleum. The exposed sandstone is about 20′ thick, and the dip is N. 50° E., at an angle of about 25°. At this point there is an upper deposit of bituminous sandstone of less thickness than the main body, and separated from the latter by a stratum of barren sandstone. At Station 40 a ledge of bituminous sandstone is exposed, and there is a spring of heavy oil. A 1000′ well was drilled near this point. (See record of Gird well.)

2.1.42. At Gird's quarry, on the road to Brea Cañon, the bituminous sandstone shows a thickness of about 40′. In the lower portion of the quarry the sandstone is saturated with oil. In Rattlesnake Cañon, northwest of Chino Well No. 2, there are extensive ledges of bituminous sandstone, which aggregate a thickness of more than 30′. There are also several places in the vicinity of Gird's quarry where bituminous sandstone is exposed.

2.1.43. In the portion of the Puente Hills comprised within the Chino ranch, the prevailing strike of the formation is west of north. The lines of geological formation resemble faults running in the direction of the strike of the formation, and the block structure, although on rather a small scale, is apparent. Near Gird's quarry of bituminous sandstone the formation is traversed by short folds, along which the bituminous sandstone crops out. The dip of the formation is at a very low angle, in most places only 10° or 15°.

About a quarter of a mile south of Gird's quarry there is a line of disturbances of some importance; in places it exhibits more or less of an anticlinal structure; it is marked DD on Fig. A. Bituminous sandstone crops out at several places along this line. At one point near Station 200 a prospect well was drilled by the Chino Valley Beet Sugar Company, but without success. (See record of Chino Well No. 2.)

The lower foothills of the Puente range within the boundaries of the Chino ranch are covered with alluvium. The writer did not examine them east of the road leading from Gird's quarry to Chino.

2.1.44. The higher portions of the Puente Hills between Carbonne Cañon and the Cañada del Rodeo, which territory includes a portion of the Chino ranch, consist of rough mountainous grazing land. The most prevalent formation is thick-bedded sandstone, whitish or brownish in color, and resembling the Miocene (Lower Neocene) sandstone in Santiago Cañon. In a few places the formation is shale. At Station 201, near to where the Brea Cañon road crosses the San Bernardino county line, the sandstone is impregnated with brown pulverulent matter, and resembles dry oil-sand. The geological structure is quite complex. In some places the strike of the formation is east of north, and in others west of north. The crushing which the rocks of the Puente Hills have undergone is illustrated in many places where the surface of the strata is exposed, as is shown in Photo No. 2.

2.1.45. A reconnaissance along that portion of the north slope of the Puente Hills lying west of the town of Chino, showed that the foothills are composed principally of shale, which, south of Pomona, appears to rest on a gray or brown sandstone.

2.1.46. Pomona Hill is 1476′ in height; it is about 2 miles southwest of the town of Pomona. This hill and the ridge on which it is situated are formed of very hard sandstone, which, in one or two places, contains veins of calcite. There are also a few strata of crystalline limestone. The most northerly ridge in this portion of the Puente Hills is composed principally of eruptive rock (laminated rhyolite). (See Stations 271 and 272, Fig. A; also Fig. 1.)

On the boulevards in the southwest corner of the limits of Pomona, and at the foot of the ridge of rhyolite previously mentioned, the bedrock is granite. (See Fig. A.) South of Pomona there is a narrow valley occupied by marshy land, with numerous springs which are the source of Brea Cañon Creek. On the Wright & Lynch ranch, west of Pomona Hill, the foothills are composed of shale, resting on sandstone resembling that seen in the higher portions of the hills. There is also in this locality a somewhat extensive exposure of conglomerate, which probably belongs to the same geological horizon as the sandstones.

At Station 273, on the Lynch & Wright ranch, the shale is interbedded with oil-sand, and the sandstone immediately underlying the shale is more or less impregnated with bituminous matter. The prevailing strike of these rocks is west of north, and the angle of the dip is about 20° or less. No springs of liquid petroleum were observed in this locality. West of Station 273 the foothills are covered with alluvium. In a cañon running northwest of the water tunnel of the Puente Oil Company thick strata of sandstone are exposed, the dip being a little west of north at an angle of about 30°.

2.1.47. Immediately north of the Puente oil-wells the topography and the exposed rocks indicate considerable geological disturbance, probably in the nature of faults, running nearly in the direction of the strike of the formation (i. e., a little east of north). The formation is shale and sandstone.

In the creek which runs north from the Puente wells, ledges of thick-bedded sandstones crop out, and a similar sandstone is exposed on both sides of a trail which leads from the crest of the Puente Hills toward the Puente ranch-house. The sandstone is overlain by shale, in which are strata of oil-sand, as shown at Station 181, Fig. A. The shale is capped with conglomerate. (Figs. 1, A, and 5.) The prevailing dip of the formation in this portion of the Puente Hills is west of north. This is probably occasioned by a cross-fold which traverses the Puente Hills at this point, and complicates the geological structure. The conglomerate constitutes an elevated ridge, which rises to an altitude of more than 1300′. From this ridge a slope of grazing land descends toward the north; the underlying rocks being conglomerate, overlain in the lowest tier of hills by bluish micaceous clay. The conglomerate can be traced through the foothills of Station 36, where it is overlain by a grayish clayey sandstone containing much mica and some fossils.

Farther westward, erosion has worn down the hills, lessening their width and elevation and exposing the underlying shales and sandstones.

At Workman Hill, north of the Central oil-wells, the hills rise to an elevation of 1391′; and the north slope of the hills is formed of conglomerate underlain by shale. A stratum of oil-sand is exposed in the cañon at the south base of Workman Hill.

From Workman Hill to the west extremity of the Puente Hills, the north slope of the hills is principally conglomerate, with a few strata of sandstone. In some places the sandstone is impregnated with bituminous matter, and there are springs of sulphureted water which deposit a tufa containing bituminous matter.

As previously stated, the dip of the formation at the west end of the Puente Hills indicates a cross-fold or the nosing out of a fold of greater magnitude than those which have been individually described.

2.1.48. The west extremity of the Puente Hills descends somewhat abruptly to the San Gabriel River. The exposed rocks for the most part belong to those heretofore classed as the conglomerate series, but they are much obscured by alluvium. (See Fig. A.) In the lower portion of Sycamore Cañon, the clay-shale crops out in several places, and it is overlain by conglomerate.

About a mile north of the village of Whittier there are deposits of sulphur, which, in 1889, were mined by C. Prager of Los Angeles. These deposits present the usual characteristics of solfataric origin.* (See Solfataric Action, Bulletin No. 11.) It is probable that these sulphur deposits indicate a fault or fissure. It is noteworthy that if the line of disturbance marked AA on Fig. A were extended westward, it would strike the sulphur deposits. The sulphurous rocks consist of decomposed shale impregnated with sulphur and a little bituminous matter.

CHAPTER 2.

THE FOOTHILLS EAST OF THE SANTA ANA RIVER.

2.2.1. Although the line of research to which the writer was assigned did not extend to the Santa Ana River, he made a reconnaissance of a portion of the foothills of the Santa Ana Mountains, the reason being that the rocks are much better exposed in the Santa Ana Mountains than they are in the Puente Hills. As previously mentioned, the Santa Ana Mountains are separated from the Puente Hills by the Santa Ana River. These mountains at their northern end are formed of eruptive rock and sedimentary rock of Tertiary and Cretaceous age. (See Table III, at the end of this Bulletin.) The Cretaceous rocks con-

*The term "solfataric" as here used is not meant to imply volcanic action, but simply chemical phenomena similar to those incidental to volcanic solfataras.

tain coal veins, which have been mined for many years. The portion of the foothills of the Santa Ana Mountains which was specially examined by the writer, is between the Santa Ana River and Santiago Cañon, and extends from the village of Olive to the west line of the Rancho Santiago de Santa Ana. Throughout this area the formations correspond to those seen in the Puente Hills.

As this locality shows by far the best sequence of the conglomerate shale and sandstone formations which has come under the notice of the writer, it is in order to describe it in detail.

2.2.2. Fig. B represents the ground plan of certain portions of the hills constituting the divide between the Santiago and the Santa Ana rivers, and Fig. 7 represents two cross-sections through these hills. The section on the left hand is drawn from observation between Burruel Point and Station 547.

At Burruel Point the exposed rocks are conglomerate, resting on clay-shale interbedded with thin strata of sandstone. No actual contact between the conglomerate and the underlying shale is observed; but the following data suggest a non-conformability between the conglomerate and the shale: At Station 543 the dip of the conglomerate is N. 10° W., at an angle of 25°; in the cañon below (i. e., between Stations 540 and 541) the prevailing dip of the shale varies from N. 40° W. to S. 50° W., at angles varying from 30° to 60°. At Stations 543 and 340 patches of conglomerate constitute outliers on the shale. At Station 340 a few Middle Neocene fossils were obtained (No. 15, Table III). At Station 338 the shale becomes sandy and the direction of the dip changes. At Station 339 the formation is a tough blue clay-shale. Near Station 545 the blue clay becomes whitish, and at Station 545 passes into a white shale, which is exposed between Stations 545 and 547. The white shale rests upon a coarse sandstone. This portion of the diagram represents a cross-section between Burruel Point and Station 547. From investigation between these points it is obvious that the formations referred to rest one on another in the order named; but the shales have been so much disturbed that the locality is an unfavorable one in which to estimate their thickness, or to determine their conformability or non-conformability with the rocks inclosing them. In the opinion of the writer, the various kinds of shale mentioned rest conformably one on another, gradually passing from yellowish clay-shale to sandy shale, to tough blue shale, to whitish shale, and to white shale. Whether the whiteness of the shale is due to the character of the sediments from which it is formed, or whether it results from the alteration of the dark-colored shale, is a matter for further investigation. As set forth in Bulletin No. 11, Part 2, Chapter 1, Paragraph 38, and in Part 3, Chapter 1, Paragraph 3, a similar looking white shale is formed in Ventura and Santa Barbara counties by the alteration of dark-colored shale. No seepage of petroleum or oil-sand was observed, but these shales in every way resembled those which inclose the oil-sands in the Puente Hills. As is shown in Fig. B, the shales referred to rest on a deposit of sandstone. Fig. 7 is made up of two parts: (1) A portion already described, representing a cross-section between Burruel Point and Station 547 on the ridge between the Santa Ana River and the Santiago Creek; (2) A portion representing a cross-section between Station 549, on the said ridge, and Station 551 in the Santiago Cañon. The courses of these sections as shown in these portions of Fig. B are dissimilar, the first being N. 80° W., which appears to be the average dip of the shale between Burruel Point and Station 549; the second being nearly due north, which appears to be the average dip of the sandstone between Stations 549 and 551. This dissimilarity of dip is probably due to non-conformability. From observations on these formations in other localities, it appears probable that the shales overlap the sandstones as hereinafter described. Fig. 7 must not be regarded as indicating the thickness of the shale, for as shown in Fig. B the angle of the dip varies and there are several local disturbances between Burruel Point and Station 549.

2.2.3. The sandstone formation between Stations 549 and 551 is more than 5000′ thick, and about 1300′ of this thickness is represented by strata of sand and conglomerate, as indicated between Stations 553 and 551. These rocks show a somewhat different dip to that of the overlying sandstones; but, in the opinion of the writer, this may be accounted for by local disturbance. Between Stations 549 and 550 the sandstone is for the most part thick-bedded, and grayish, whitish, or yellowish in color; when the sandstone comprising some of the strata is freshly broken it presents a mealy-looking surface, which is very characteristic. At Station 550 the sandstone contains Miocene fossils. (See fossils Nos. 12, 20, 22, 23, 24, 31, Table II.)

2.2.4. Between Stations 550 and 553 the formation is a dark-colored, earth-like shale, interstratified with sandstone; the shale contains a great deal of mica. It is said that at some depth below the surface this shale has been found to be more or less impregnated with petroleum.

2.2.5. Between Stations 553 and 551 the sandstone is comparatively thin-bedded, and is interstratified with conglomerate. As shown in Fig. 7 and Fig. B, the dip of this strata is somewhat different from that of the sandstone overlying the shale. At Station 551 a stratum of calcareous sandstone, containing a few poorly preserved fossils of Miocene age, is exposed.

2.2.6. From the foregoing, it appears that the rocks forming the Puente Hills may be divided into three formations: conglomerates, shales, and sandstones. These formations rest one on another in the order named, the conglomerate being at the top. They represent a geological age extending through a portion of the Lower and the Middle Neocene.* The productive oil-yielding formations consist of certain strata of sandstone interbedding the lower portion of the shale formation of Middle Neocene age, and it is not improbable that the sandstones underlying the silicious shales may also contain petroleum in valuable quantities.

The formations named are traversed by two series of folds, namely: folds having a strike of west of north; and cross-folds having a strike of east of north. As previously noted, the cross-folding has resulted in the formation of blocks, and these have been subsequently tilted.

The southern portion of the Puente Hills constitutes an anticlinal ridge, the structure of which is modified by faults and subordinate folds. The oil-lines which have thus far been developed appear to follow the axes of folds and blocks of strata which have a strike of west of north, and in a general way their course corresponds to the axis of the anticlinal ridge to which reference has been made. At many places along the anticlinal ridge there are springs of oil, exudations of asphaltum, and rock impregnated with petroleum. Especially is this the case at and near the contact of the sandstone and the overlying shale.

From the evidence at hand, it seems that the oil companies operating in the Puente Hills will make the best progress by following the axes of the folds and the strike of blocks of strata on which remunerative wells are situated, by carefully fixing the site of new wells with reference to the dip and strike of the formation as determined by methods hereinafter described; and by restricting the distance between old and new wells to very moderate limits. As a general proposition, the most regular oil-lines will be found on the outer slopes of the main anticlinal fold or ridge herein described, while along the axis of the ridge the oil-lines are likely to be erratic.

In the central and northern portions of the Puente Hills, oil-springs are seldom met with, but in some places the sandstone is more or less impregnated with petroleum, and at the surface it is for the most part a dry, oil-stained rock. Wells hitherto drilled for the purpose of testing these dry, oil-stained sandstones, have been unsuccessful, but it must not be taken for granted that these oil-stained sandstones have been thoroughly prospected.

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* At a few points, there are also some rocks which may be of later age.

PART 3.

LOS ANGELES AND ITS SUBURBS, SAN PEDRO PENINSULA, SAN FERNANDO DISTRICT, TERRITORY BETWEEN NEWPORT IN ORANGE COUNTY AND THE SAN DIEGO COUNTY LINE, AND PROSPECT WELLS IN SAN DIEGO COUNTY.

CHAPTER 1.

GEOLOGICAL FORMATION BETWEEN PUENTE HILLS AND THE LOS ANGELES OIL-FIELD.

3.1.1. There are no remunerative wells between the Puente Hills and the City of Los Angeles. West of the San Gabriel River broad mesas of arable land extend toward Los Angeles, but they afford no opportunity for geological examination. The Rapetto Hills divide the mesa lands from the San Gabriel Valley. These hills do not exceed an altitude of about 700′, and are, for the most part, covered with alluvium. There are sufficient rock-exposures to show that the bedrock is conglomerate, but not sufficient to demonstrate the geological structure. In the south edge of these hills there are a few places where clay-shales are exposed.

3.1.2. The Arctic Oil Company of San Francisco drilled three wells on the Garvey ranch in the Rapetto Hills. The depths of these wells are respectively 600′, 1100′, and 1200′. It is said that after penetrating the conglomerate the formation was clay-shale, but that no petroleum was discovered. The wells have been abandoned.

3.1.3. On the mesa land, in wells sunk for water on the Hellman ranch, near the cross roads south of the Rapetto Hills (see Fig. A), inflammable gas was struck in sufficient quantities to be utilized locally for light and fuel. These wells are less than 200′ deep. It is said that the formation penetrated is principally clay or clay-shale. It is also said that in a well about half a mile northwest of the Hellman wells, oil-bearing shale was struck at a depth of about 100′.

3.1.4. In the hills to the north of the mesa land, the conglomerate extends almost to Monterey Cañon, but the rock exposures are few and far between. West of Monterey Cañon the formation is clay-shale overlain by conglomerate, and a series of earth-covered hills reach to the city limits of Los Angeles.

3.1.5. Within the city limits there are rock-exposures on Soto Street and near Reservoir No. 6 (see Fig. C), showing this reservoir to be situated on the axis of an anticlinal fold, which has a strike of about N. 80° W. A short distance down the south slope of this fold is a seepage of petroleum. A well was drilled at this point by Chandler in 1894. The formation is shale. It is said that there was a good showing of heavy oil at a depth of 150′; but the well was abandoned at 335′, on account of water. In 1898, a well was drilled on the north side of this fold by the De Soto Oil Company, and clay-shale penetrated for 700′. It is said that no oil was struck. Farther westward along the Rapid Transit Railroad there were seepages of petroleum. The formation is shale, and in several places strata of oil-sand are exposed. The strata dip a little west of south at an angle of from 30° to 50°.

Oil-yielding strata have been struck in more than one well in this portion of Los Angeles. Several years ago a well was sunk on the Rapid Transit Railroad, a short distance west of Prospect Park. It is said that at a depth of about 400′ there was a good showing of oil, but that at a depth of 600′ a body of water was struck which "drowned out" the well. In a well sunk for water on property of F. E. Bland, on Judson Street, near State Street, oil was found at a depth of 80′. Also, in a well sunk on the property of C. M. Johnson, on State Street, near its intersection with Bailey, oil was found at a depth of 40′. In a well sunk by Scott & Loftus on St. Louis Street, between Emerson and Scott streets, oil-sand was struck at 560′, but subsequently much water was encountered. Messrs. Scott & Loftus also sunk an 800′ well on Magnolia Avenue, about 400′ east of Soto Street, but only obtained traces of oil. (See record of wells.)

3.1.6. On the west side of the Los Angeles River, the glimpses of the rock formation which can be obtained among the houses show that the clay-shales constitute the bedrock throughout the greater portion of the city. Near the High School and the State Normal School, and possibly in other places, there are "outliers" of conglomerate which rest nonconformably on the shale. These shales outcrop at several places in the western borders of Los Angeles; and on the coast-line at Santa Monica they are represented by the formations described in Bulletin No. 11, 1.1.14. These shales rest on thick strata of sandstone, which are well exposed along the water company's ditch, on the east side of Elysian Park. These sandstones resemble the sandstones seen in Santiago Cañon containing Miocene fossils, which are referable to the Lower Neocene division of the Tertiary system in California.

3.1.7. Throughout a great portion of Elysian Park, on the west side of the Los Angeles River, and north of the San Gabriel branch of the S. P. R. R., on the east side of this river, the formation is principally sandstone, resembling that seen at the eastern end of the Puente Hills and between the Santiago Cañon and the Santa Ana River. There are places, however, where patches of the shale formation either rest as outliers on the sandstone or are interfolded with it.

3.1.8. North of East Lake Park these older rocks are traversed by a fold, the axis of which, if extended westward across the Los Angeles River, would nearly coincide with a line of fault or fissure which runs through the northern extremity of the Los Angeles oil-fields.

Some attempts have been made to prospect these older rocks, but at this writing no remunerative wells have been obtained. A short distance north of Reservoir No. 5, a well was sunk to a depth of 840′ by Headly of Los Angeles; no oil; abandoned. A 640′ well was drilled by T. M. Wilkinson, about a quarter of a mile east of Reservoir No. 5; traces of oil were obtained, but the well was abandoned. (See record of the Wilkinson well.) A well was also drilled at Warneck Park, in East Los Angeles. The formation penetrated is shale; only traces of oil were obtained.

CHAPTER 2.

THE LOS ANGELES OIL-FIELD, 1897–1899, INCLUSIVE.

3.2.1. As the character of the formation in the Second-Street Park oil-field, now called the Central or Old field (see Photo No. 7), was fully described in Bulletin No. 11, it is in order to relate such developments only as are subsequent to those mentioned in that Bulletin. The western end of the field was extended to the corner of Quebec Street and Ocean View Avenue (now called Miramar Street), where trouble was experienced from broken formation, quicksand, and water. These obstacles, and legal difficulties resulting from a complication of miners' rights with city ordinances, for a time discouraged further development in this direction. Eventually prospecting was continued in a westerly direction along what had been shown to be the strike of the formation; this resulted in the developments recorded at the end of this chapter.

In the old field many new wells were sunk in the interspace between the wells previously drilled. Exploitation to a greater depth than that of most of the wells drilled prior to 1896 showed that there was a second stratum of oil-sand. East of Belmont Avenue, this second stratum of oil-sand was found to be productive wherever it was struck, at a depth less than 900′, and west of Belmont Avenue at a depth less than 1050′. Below these depths it was found to contain water.

The relative values of these oil-sands compare as follows: First oil-sand, 125′ thick, about 45′ productive; second oil-sand, 30′ thick, all productive.

PHOTO 7. THE CENTRAL OIL-FIELD, CITY OF LOS ANGELES.

PHOTO 8. THE EASTERN OIL-FIELD, CITY OF LOS ANGELES.

The eastern end of the field was extended until the north line of geological disturbances, mentioned in Bulletin No. 11, was reached at the corner of Victor Street and Bellevue Avenue, near the Sisters' Hospital; then great trouble was experienced from broken formation, quicksand, and water. Subsequently, prospecting was recommenced a few blocks farther eastward, which resulted in the discovery of the eastern extension of the Los Angeles oil-fields. (See Photo No. 8.) In this connection see Bulletin No. 11, 1.1.26 and 1.1.28.

3.2.2. The first well drilled in the new field was sunk by Maier & Zobelein, at the corner of Adobe and College streets. This well was completed in November, 1896, and as soon as it was found to be a success, there was a rush for the new field. By the middle of 1897 the wells in the new field were almost as closely crowded as they were in the old field.

Fig. D shows the relative positions of the old and the new fields; i. e., the Central field, and the Eastern Extension, as they are now called. The black dots show the wells drilled before the end of 1896, and the open circles represent wells drilled during 1897.

3.2.3. The formations penetrated in the Central and in the Eastern Extension fields are very similar. They differ somewhat in different parts of the fields, but an idea of their similarity can be gathered from a comparison of the following records:

Typical Record of Formation in Old, or Central, Field.

Given by Mr. Doheny.

Sandy and clayey shale with strata of hard rock, to	650′
Oil-sand (oil 19° B.) interstratified with sandy clay, to	775′
Tough blue clay, to	975′
Oil-sand (oil 16° B.) to	1020′
Sand, with water.	

Record of Formation in New Field, or Eastern Extension.

Given by Mr. Herschey.

Sandy shale, to	325′
Clay shale (bituminous) to	380′
Hard shale, to	383′
Clay-shale, to	395′
Oil-sand (oil 18.75° B.) to	450′
Hard shale, to	453′
Tough clay-shale, to	483′
Hard shale, to	485′
Oil-sand (oil 16° B.) to	510′
Hard shale	512′
Tough clay-shale, to	552′

3.2.4. The question as to the direction in which the Los Angeles oil-fields were likely to extend was one of great importance, and at every stage in the development of these oil-fields this subject has attracted the greatest public interest. It was discussed in Bulletin No. 11, as far as the evidence in hand warranted, and it was stated that "If the oil-line on which the Second-Street Park oil-fields is situated be extended westward, it would pass a short distance south of the Baptist University." (See Bulletin No. 11, 1.1.25 and 1.1.26.) Events since the publication of the Bulletin named have corroborated what is expressed in the paragraphs referred to.

When the field-work on which the current Bulletin is based was in progress, excitement ran high lest the course of the oil-line should extend from the old oil-fields to West Lake Park; and in response to many requests with regard to the matter the writer has collected a large mass of data pertaining to what were then called the new and the old fields, especially with regard to the depth below the city datum at which the oil-sand has been struck in the different wells. From this data he estimated the dip and the strike of the oil in both fields, and drew certain lines indicating the slope of the oil-sand, as shown in Fig. D. The result is a picture, illustrating the structural conditions pertaining to the oil-sands in both fields.

Since the matter was of immediate interest and, owing to the State Printing Office being closed, there was no likelihood of an early publication of the result of the writer's investigations, he made public his conclusions by means of lectures, which were reported in full by the Los Angeles papers, and placed maps of the localities under discussion in the Chamber of Commerce at Los Angeles, and in other public institutions.

3.2.5. An analysis of Fig. D shows as follows: At the western extremity of the Central field, the formation is disturbed, and the angle of the dip ranges from 40° to 50°, both of which circumstances being in keeping with the surface indications. Farther eastward the formation is more regular, and the angle of the dip increases. At Second-Street Park, more geological disturbance is manifested, the angle of the dip increases, and the strike is irregular, the cause of the disturbances being a cross-fold, which intersects Court Street near Douglas Street. Farther eastward the formation becomes more regular, until the eastern extremity of the field is reached; here the trouble again commences, the cause being a cross-fold or fault, or both.

3.2.6. In the Eastern Extension the formation is more irregular, and the angle of the dip is less than in the Central field. The most regular portion is the central portion of this field, which extends from the Sisters' Hospital toward the corner of Bernard and Yale streets. Along this line the angle of the dip lessens, until at Yale Street it is only about 10°. East of Yale Street the surface of the oil-sand is at first undulating, and then more violently disturbed. In the eastern extremity of the field, this disturbance is particularly well marked. In the northern corner of the Eastern Extension the immediate cause of the disturbance appears to be a fault, which may be seen at the corner of Bernard and Adobe streets, and in Chavez Ravine. This fault probably extends to the corner of Hinton Street and Beaudry Avenue, where the formation for a short space dips to the north.

3.2.7. The course of the contour lines shown in Fig. D corresponds to the prevailing strike of the oil-sand, which is practically N. 85° W. The contour lines also set forth the relation of the old and the new oil-fields. Thus, if we take any line in the Eastern Extension such as the one along which the oil-sand could be struck at a depth of 400′ below the city datum, and carry it westward, it would pass to the north of the Second-Street Park oil-field. Again, if we take any line in the Second-Street Park oil-field, such as the one along which the oil-sand could be struck at the depth of 500′ below the city datum, and carry it eastward, it would pass to the south of the Eastern Extension.

3.2.8. This incongruity may be explained by either of the following causes: (1) It may be occasioned by a fault running in the direction of the dip of the formation; (2) It may be occasioned by a fault running in the direction of the strike of the formation; (3) It may be occasioned by an oil-yielding stratum underlying those which have been struck in the Second-Street Park oil-field.

If the first hypothesis is true, then there is no extension of the eastern end of the Central field, nor of the western end of the Eastern Extension. This is the least probable of the three explanations.

If the second or third is true, it is not improbable that an oil-line would extend from the Eastern Extension beneath the Sisters' Hospital toward the corner of Edgeware Road and Temple Street, running parallel to, and north of, the Central field. There might also be an oil-line running east of the Central field, toward the corner of Alpine Street and Bunker Hill Avenue. Furthermore, a line drawn along the strike of the formation eastward, from the northern limit of the Eastern Extension, would cross the river near the Main-Street bridge, and a line drawn along the strike of the formation eastward from the south limit of the Central field would cross the river a short distance south of the Alhambra-Street bridge. The evidence which supports the hypothesis that there is a fault running in the direction of the strike of the formation between the Central field and the Eastern Extension, is as follows: At the northeast extremity of the Central field, namely, at the corner of Victor Street and Bellevue Avenue, the exposed rocks show a sudden increase in the angle of the dip, from 35° to about 70°; and more directly eastward from the said corner and south of the Eastern Extension, prospectors have found a broken, water-soaked territory, such as one might expect in the vicinity of a fault.

3.2.9. From the foregoing it appears that a body of clay-shale, which, in some places, has been found to contain oil-yielding strata, underlies the greater portion of the City of Los Angeles. This shale, as previously mentioned, constitutes a large portion of the Puente Hills, and is probably the bedrock in the mesa lands between Los Angeles and Whittier; it contains fossils representing the Middle Neocene epoch. As hereinafter shown, the upper oil-measures of the San Joaquin Valley belong to this geological horizon.

The facts herein set forth demonstrate that there is a strip of territory at Los Angeles within which oil-lines have been developed, and that there are numerous other evidences of petroleum, and that this strip of territory extends eastward from the Baptist College and the Maltman wells toward the Second-Street Park oil-field, and thence toward the Scott & Loftus well on St. Louis Street in East Los Angeles.

It is not to be supposed that an unbroken oil-line extends between the points named, for surface indications and drilling records show that this strip of territory is traversed by independent lines of minor geological disturbance, the course of which, in some instances, does not coincide with the prevailing strike of the formation. But it is by no means improbable that oil-lines besides those already discovered may be developed in the strip of territory indicated, and that the extent of such oil-lines would be governed by faults or minor folds.

3.2.10. From the records of the oil-wells in Los Angeles and in the Puente Hills, and from the fact that outcropping oil-sands and oil-springs are, in many instances, found near the contact of the shales and the underlying sandstones, it is evident that remunerative oil-sands interstratify the lower portion of the shale formation, and in some instances probably constitute the uppermost strata of the underlying sandstones.

From what has just been stated it follows that wells sunk in the shale should penetrate that formation and ought not to be abandoned before the sandstone, which in the territory under consideration underlies the shale, has been reached. The detailed observations concerning the dip and strike of the oil-sand at Los Angeles, recorded in this report, corroborate the statements made in Bulletin No. 11 of the California State Mining Bureau.

As before mentioned, the average strike of the oil-sand in both the oil-fields at Los Angeles is N. 85° W., or S. 85° E. If a line were drawn S. 85° E., from the corner of Scott and Figueroa streets, in the Central field, it would cross the Los Angeles River about 300′ south of the railroad bridge at Alhambra Avenue. If a line were drawn in the same direction from the center of the Eastern Extension, it would cross the Los Angeles River about 600′ south of the Main-Street bridge. If a line were drawn S. 75° E. from the corner of Scott and Figueroa streets in the Central field, it would cross the Los Angeles River about half way between the Macy-Street bridge and the railroad bridge at Alhambra Avenue. The last-mentioned line would run a short distance north of the oil-seepages on the line of the Rapid Transit Railroad, and would strike the well drilled by Scott & Loftus on St. Louis Street, in which the oil-sand was struck at a depth of 560′. This line, if continued eastward, would strike the city limits about 600′ north of Wabash Avenue. If a line were drawn N. 85° W. along the strike of the formation, from the corner of Ocean View Avenue and Bonnie Brae Street, at which point the oil-sand was struck at a depth of about 700′ below the city datum, it would pass about 1000′ south of the Baptist College. Assuming that along this line the oil-sand could be struck at a depth of about 700′ below the city datum, and that the angle at which the oil-sand dips at the Baptist College is 20°, the outcrop of the oil-sand would theoretically be at the Maltman oil-wells.

Investigations show that the dip of the exposed rocks in a creek immediately west of the Baptist College ranges from 20° to 25°, and that in some of the Maltman wells the oil-sand has been struck at a depth of less than 100′.

These facts were set forth by the writer in Bulletin No. 11 published in 1896, and in lectures given at a later date, and on maps showing the trend of the oil-yielding formations, which, as previously mentioned, were placed in the Chamber of Commerce and the Mining Exchange at Los Angeles, and in other public places.

How far subsequent events have proved the correctness of the deductions cited, is shown by the developments between the corner of Burlington Avenue and the portion of Ocean View Avenue, now called Miramar Street, and the Baptist College, as recorded in the following chapter.

CHAPTER 3.

THE LOS ANGELES OIL-FIELD, 1899, TO JULY, 1900.

3.3.1. In the autumn of 1899 prospecting was carried on along the strike of the formation from the corner of Quebec and Miramar streets, where the broken formation had been encountered. On Miramar Street, between Burlington Avenue and Alvarado Street, the oil-field was developed for a width of about 600′. The wells are owned principally by the Yukon Oil Company.

The formation at this point is somewhat different from that in the Central oil-field, and is as follows: Dark-colored shale to 300′; sand, with water and a little oil, 500′ to 800′; on the south side of the oil-line, shale to 1100′; oil-sand to 1200′. On the south side of the oil-line water was encountered below the depth of 1200′. About 100′, or less, of the oil-sand is impregnated with oil, but the lower portion of the sand is saturated with water. Farther northward, toward the center of the oil-line, the oil-sand is struck at 900′ and drilled through for about 300′. On the north side of the oil-line the oil-sand was struck at 700′ and drilled through to a depth of 1000′ without striking water; but in one well which was drilled to a depth of 1200′ water was encountered.

It is believed that the angle of the dip is about 45°. At the northern edge of the oil-line the two strata of oil-sand which have been followed in the Central oil-field appear to be squeezed together, forming one body of oil-sand, which has been penetrated for about 300′. The strata of oil-sand are interbedded with thin, irregular strata of clay.

It would seem that in the southern portion of the oil-line the water has, to some extent, displaced the oil and established a level for it about 1250′ below the surface of the ground.

At the corner of Alvarado and Ocean View avenues, the oil-sand was struck between 1180′ and 1250′, and was penetrated to a depth of 1300′, when a small amount of water was encountered.

The wells drilled in this area are quite productive. When first drilled, they started off at about 60 bbls. a day, but in one year the yield became reduced to 20 bbls. a day.

3.3.2. West of Alvarado Street the oil-line widens, probably owing to the lessening in the angle of the dip of the formation, and at Koefed Street it shows a width of about 500′. In this portion of the field it is rather deep drilling. Thus, in the Los Angeles Railway Company's wells, shale and sandstone were penetrated to a depth of about 1010′, at which depth the oil-sand was struck. This was found to be about 150′ thick.

In a well drilled by Mr. Kellerman near the south edge of the oil-line, the oil-sand was struck at 1250′, but at 1285′ a large volume of water was encountered. Mr. Kellerman says that west of Koefed Street the irregularity of the depth at which the oil-sand has been struck leads to the conclusion that there has been considerable geological disturbance.

In this portion of the field the wells vary from 1000′ to 1200′ in depth, and the oil-sand is thicker on the north side of the oil-line than it is on the south side. Near the southern edge of the oil-line there is trouble from water. In drilling there is also trouble from caving formation and the drill-holes have to be kept full of water. There are no productive wells south of Ocean View Avenue.

3.3.3. On Sixth Street, near Hoover, are the wells of the Uncle Sam Oil Company, Hardison, and others. The oil-line has been developed for a width of about 900′. At the south boundary of the oil-line the oil-sand was struck at a depth of about 525′, and found to be from 60′ to 90′ thick; on the north line it was struck at a depth of about 200′, and found to be about 23′ in thickness.

Near Hoover Street the oil-line widens to 1600′, owing probably to the lessening of the angle at which the formation dips. The depth at which the oil-sand was struck at the southern edge of the oil-line in this portion of the field is about 500′, and on the northern edge about 250′.

Immediately south of the Baptist College the oil-line may be said to extend from the Maltman wells, which are probably situated on the outcrop of the oil-sand, to Fifth Street, a distance of about 3000′.

The depth at which the oil-sand has been struck varies from about 300′ on the Maltman tract, which is now owned by the Los Angeles Oil and Transportation and Terminal Company, to about 1000′ in wells drilled by the Wilson Oil Company, on Miami Street, between Fifth and Sixth streets.

Between Hoover Street and Vermont Avenue the principal oil companies are the Wilson, the Green, the Westlake, the Wellington, and others. (See list of Los Angeles oil-wells.)

On the Maltman tract, and on Vermont Avenue, between First and Third streets, are the wells of the Los Angeles Oil and Transportation and Terminal Company. Here there are thirty-five wells from 300′ to 400′ deep. For the most part these are small producers, and the oil has a gravity of about 14.5° B. On the corner of First and Vermont streets a flow of warm water was struck at a depth of 800′.

3.3.4. West of Vermont Avenue are the oil-wells of the Hercules Oil Company, where the oil-sand was struck at a depth of between 300′ to 400′; and at the southeast corner of Vermont Avenue and Third Street are the wells of the Montana Oil Company, where the oil-sand was struck at a depth of about 400′, and the wells of J. Brown, in which the oil-sand was struck at a depth of about 400′.

In the wells of Brown and the Montana Oil Company, the oil has a gravity of about 17° B. Farther to the westward prospect wells have been drilled by the Hercules Oil Company, on Rosedale Avenue, between First and Fourth streets, where the oil-sand has been struck at a depth of about 300′. Similar results were obtained by the National Oil Company.

3.3.5. West of Western Avenue, two prospect wells were drilled by Mitchell, Stilson & Davis, near the corner of Western Avenue and Temple Street; they were abandoned. Subsequently these gentlemen drilled a well farther west, from which a large quantity of oil flowed.

South of the Wilshire Boulevard, wells were drilled by the following: Parker & Proudfoot, to a depth of 1040′; McGee, Tait & Johnson, to a depth of 1260′. The formation is shale. No oil was struck.

West of the boundary of the City of Los Angeles there has been considerable prospecting, the principal drilling being done by Thomas Brothers, who used a hydraulic rig, which drilled 4½″ test-holes. A rock-drill was used to penetrate the hard strata. Mr. Thomas states that on the Rosedale Cemetery tract he drilled six wells, 120′ to 800′ in depth, the formation being sand, hard blue clay and shale, and oil-sand. In one of the wells no oil-sand was struck, but gravel and water were encountered. The gravity of the oil is between 15° and 16° B.

About a quarter of a mile north of the Rosedale Cemetery tract are two wells drilled by Rommel. It is said that one of these wells is 1000′ in depth, and that 60′ of oil-sand was penetrated at the depth of 550′; the oil having a gravity of 18° B.

On the Croswell tract, about a quarter of a mile west of the Rosedale Cemetery tract, Mr. Thomas drilled two wells, one to a depth of 664′ and the other to a depth of 175′. The formation is as follows: Loam, 45′; oil-sand and gravel to 136′; blue clay to 200′; sand to 283′. At the last-mentioned depth a hard rock was struck.

About a quarter of a mile northeast of the Croswell tract, Mr. Thomas drilled a well for Garbutt & Pitcher. In this well the oil-sand was struck at a depth of 23′, and penetrated for about 96′; then clay, sand, and hard, thin strata were passed through to the bottom of the well, where more oil-sand was struck.

West of the Masslein tract, and immediately west of the well drilled for Garbutt & Pitcher, are three wells drilled for Messrs. Clark & Sherman of Los Angeles (Los Angeles Transportation Company). These wells are from 120′ to 521′ deep. In four of them the oil-sand was struck at a depth of 50′ to 85′. In another, which is 460′ deep, the oil was struck at 150′, and oil flowed from the casing. (See record of wells drilled west of the city limits of Los Angeles.)

In well No. 1 of the Pico Oil Company, the following formations were observed: Adobe, 20′; yellow clay to 60′; sand and gravel, with 4′ of oil-sand, to 129′; blue clay to 167′; sand rock and gravel to 450′; blue clay to 530′; black shale to 538′; blue clay to 545′; sand to 550′; blue shale, with traces of oil, to 558′; blue clay to 560′; black shale, with traces of oil, to 564′; blue clay to 566′; black shale to 572′; sand to 610′; blue clay, with traces of oil, to 620′; sand to 622′; blue clay to 635′; sand to 641′; blue clay, with oil, to 668′; blue shale, with oil, to 671′; blue clay, with oil, to 708′; shale, with black oil, to 780′; blue clay, with oil, to 822′. The oil at the bottom of the well was the best obtained.

A well drilled on the Abbott tract showed sand to 43′; gravel to 53′; rocks to 76′; sand and shells to 83′; rocks to 98′; blue sand to 118′; clay to 136′; sand and rocks to 142′; blue clay to 144′; sand and rocks to 167′; clay, rocks, and sand to 281′; blue clay to 347′; sand to 385′; blue clay to 390′; blue clay to 420′; sand to 595′; blue, sticky clay, with oil, to 598′; clay, blue clay, to 723′. More or less oil was observed in the formation between the depths of 598′ and 720′. The formation at the bottom of the well was blue clay.

In most of the wells south of the La Brea ranch much gas has been struck.

The cost of drilling with a hydraulic rig used by Thomas Brothers is: First 300′, 35 cents a foot; below that depth, 50 cents a foot; below a depth of 500′, 85 cents a foot. There is an extra expense when drilling in rock. The hydraulic rig can be used for drilling wells to a depth of 1000′. The hydraulic rig is of value to tell whether or not the formation contains an oil-sand, and the thickness of the oil-sand strata.

In the northern portion of the La Brea ranch, several prospect wells

PHOTO 9. Puente Hills, from the South Fork of the San Gabriel Valley, Los Angeles County.

PHOTO 10. Cliff of Shale, San Pedro Peninsula, Los Angeles County.

have been drilled by the Rhodes Oil Company, and in some of these strata of oil-sand have been penetrated which promise to be productive. (See record of prospect wells west of Los Angeles city limits, also Fig. A.)

The output of oil from the Los Angeles wells was:

During 1897	1,072,000 bbls.
During 1898	1,168,000 "
During 1899	1,032,036 "

These estimates are exclusive of the Maltman wells. (See record of Maltman wells.)

The output for 1897 was principally from the Central field; that for 1898 was about half from the Central field, and half from the Eastern Extension; that for 1899 was about 43% from the Central field, 30% from the Eastern Extension, and 27% from the Western Extension.

CHAPTER 4.

SAN PEDRO PENINSULA, LOS ANGELES COUNTY.

3.4.1. For several years some attention has been given to the possibility of there being oil-yielding formations on the peninsula of San Pedro. Hopes were encouraged by the discovery of a few springs of heavy oil and some outcropping ledges of oil-sand; and two prospect wells were sunk, only to be abandoned. In view of the fact that the harbor construction work, undertaken by the United States Government, would in the near future make San Pedro one of the principal ports of entry in California, the Mining Bureau was requested to examine the San Pedro Peninsula, with a view of ascertaining whether or not there was a reasonable probability of remunerative oil-yielding formations existing thereon. Hence, the work which is the subject of this report was undertaken.

3.4.2. The peninsula of San Pedro comprises an area of about 12 square miles. On the west it is bounded by the coast-line extending from Point Vincent to Point Fermin, and on the east by the coast-line between Point Fermin and the town of San Pedro. From the seashore the land rises toward the interior of the peninsula, showing a series of marine terraces and culminating in the summit of Mount San Pedro (i. e., San Pedro station), at an altitude of 1482′. (See Fig. E.)

3.4.3. Throughout the greater portion of the peninsula the exposed rocks consist of slates or shales, traversed by numerous calcareous or silicious strata, and in places they are impregnated with heavy petroleum. These slates or shales are for the most part bleached to a whitish or yellowish color, and form a great portion of the coast-line. (See Photo No. 10.) Near the town of San Pedro the whitish slate or shale gives place to a tough clayey formation, which is more or less bituminous in places.

In the upper portion of the whitish shale formation there are numerous strata of diatomaceous earth, and in some places the diatomaceous strata appear to rest non-conformably on the strata beneath them. The diatomaceous rocks can be well observed in the foothills west of the town of San Pedro (see Stations 11, 12, 13, 14, Fig. E); also along the northwest portion of the crest of the main ridge of San Pedro Mountain (see Station 50). At the extremity of the peninsula, i. e., at Point Fermin, there are bituminous sandstones. (See Photo No. 11.) At San Pedro the most recent of the rock formations is a series of soft sandstones, which rest non-conformably on the underlying formations. These soft sandstones are well exposed near the town of San Pedro, and on Dead Man's Island they contain numerous fossils of Quaternary age. All the aforementioned formations probably rest on metamorphic rocks (principally glaucophane and quartz schists), which are exposed in a cañon on the Rancho Los Palos Verdes (see Stations 44 and 45), or on eruptive rocks. In the southern portion of the peninsula the only traces of the metamorphic rocks are a few bowlders of glaucophane schist and some sandstone strata, which are practically made up of comminuted schist. Extending through the heart of the San Pedro Mountain is a mass of eruptive rocks, which may be observed at Stations 47 and 38, and at other places. At Station 37, on the coast-line west of Portuguese Bend, calcareous strata overlie eruptive rocks; at Station 40, on the north slope of San Pedro Mountain, the whitish shale is interstratified with eruptive rock; at Station 39 the whitish shale is penetrated by a dike, and at Long's Point sandstone and bleached shale are traversed by numerous small fissures filled with what appears to be decomposed eruptive rock. At the last-named point the sandstone contains numerous nodules of barite.

3.4.4. The topography of the peninsula of San Pedro shows a series of raised beaches, the flat tops of which furnish many excellent examples of marine denudation, modified by subaërial erosion. (See Photo No. 12.) The bituminous slates or shales are crumpled. (See Photo No. 35.)

3.4.5. In the territory under discussion, the geological disturbance has been so great that it would require a lengthy investigation to obtain the data requisite to form a map showing all the structural details, even if there were adequate rock-exposures. Moreover, the results would not contribute sufficient information on the question of petroleum deposits to warrant our department undertaking such a task.

3.4.6. At several points there are slight exudations of heavy bitumen from the bituminous shales; and on the shore-line, between Stations

PHOTO 11. Bituminous Sandstone, Point Fermin, San Pedro Peninsula, Los Angeles County.

PHOTO 12. Wave-Cut Terraces, San Pedro Peninsula, Los Angeles County.

3 and 4, there are two veins of asphaltum which show a thickness of from 2″ to 6″.

3.4.7. At San Pedro two wells have been drilled by prospectors for oil. One of these wells was drilled in 1895 by the San Pedro Oil Company. The record of this well shows: Adobe soil to 100′; dark-colored shale and brea to 400′; light-colored shale to 550′; brown shale to 850′. The water was cased off at 150′. It is said that small quantities of heavy oil were found beneath thin and hard strata. This well was abandoned on account of the loss of the tools, which became fast in the well. San Pedro Oil Company of Los Angeles is the owner.

Another well was drilled about 1 mile south of the center of the town of San Pedro, near the building known as the "Old Pierson Hotel." It is said that this well is 495′ deep, that the formation penetrated is nearly all clay, or clay-shale, with a little brea, and that a stratum of asphaltum was struck at the bottom of the well. It is also said that this well was abandoned on account of the death of the owner.

It is reported that rocks smelling of petroleum have been penetrated by many wells which have been sunk for water at San Pedro. Thus, in a well dug by A. Haller in the outskirts of San Pedro, the formation is: Black adobe soil to 3′; yellowish adobe to 12′; soft sandstone with sea-shells to 14′ (this stratum is nearly horizontal); whitish rock interstratified with brown rock to 22′; hard limestone to 24′; white clay (dipping south) to 26′; white, soft, probably diatomaceous, rock to 34′; black shale (dipping to the north) to 42′.

3.4.8. On the shore-line near the town of San Pedro, as previously mentioned, there are some formations of tough clay and clay-shales; these rocks are dark in color and somewhat bituminous. They bear a physical resemblance to certain oil-yielding shales in the Puente Hills, but the shales near San Pedro are so much disturbed that they fail to show the position of the dark-colored shales with regard to the bleached bituminous shales.

3.4.9. North of Resort Point on the Rancho Los Palos Verdes and along the shore-line toward Redondo, the only rock exposed consists of whitish shale and a soft sandstone which rests non-conformably on the shales. On the Palos Verdes ranch, near the seashore, a well was sunk to a depth of several hundred feet. The formation penetrated is a calcareo-silicious shale. It is said that a small amount of heavy oil was obtained. It was accompanied by much water.

3.4.10. From the foregoing it appears that although bituminous shales are exposed on the peninsula of San Pedro, with the exception of the bituminous sand at San Pedro no definite body of oil-sand was observed, and the shale is irregular and broken. The shale composing a great portion of the San Pedro Peninsula is the hard silicious shale which seldom contains valuable oil-yielding strata.

The rocks throughout portions of the San Pedro Peninsula show metamorphism, and are disturbed by the intrusion of igneous rocks. These features, together with the broken character of the formation in general, bespeak unfavorable conditions for the existence of valuable quantities of oil. This view of the case is strengthened by the fact that the only seepage of petroleum seen in the shale formation is of a very heavy kind, being practically asphaltum; and that the sandstone formation, which overlies the whitish shales at Point Fermin, is impregnated with petroleum. It is possible that if the bituminous sandstone exposed at Point Fermin could be struck at a depth of more than 500′, it might be found to yield oil in valuable quantities. Unfortunately, only a remnant of this sandstone is exposed, and the strike of the formation shows that its only extension lies beneath the ocean. North of township 5 south, the rocky formations are too much obscured by alluvium to admit of geological investigation.

CHAPTER 5.

THE SAN FERNANDO OR NEWHALL MINING DISTRICT.

3.5.1. The San Fernando petroleum mining district, commonly known as the Newhall district, is situated on the north slope of the San Fernando Mountains, about 25 miles northwest of Los Angeles. As far as the records show, this district is the oldest producing oil-field in California. During the year ending June 30, 1900, this district attracted much attention, and several new companies commenced operations therein. During 1899, however, practically the only company producing oil in this field was the Pacific Coast Oil Company, which has been a producing oil company for more than twenty years. The principal wells of this company are in Pico Cañon, about 6 miles southwest of Newhall (see Photo No. 29), in Elsmere Cañon, about 4 miles southeast of that town. The recent developments in the San Fernando district are hereinafter recorded in detail.

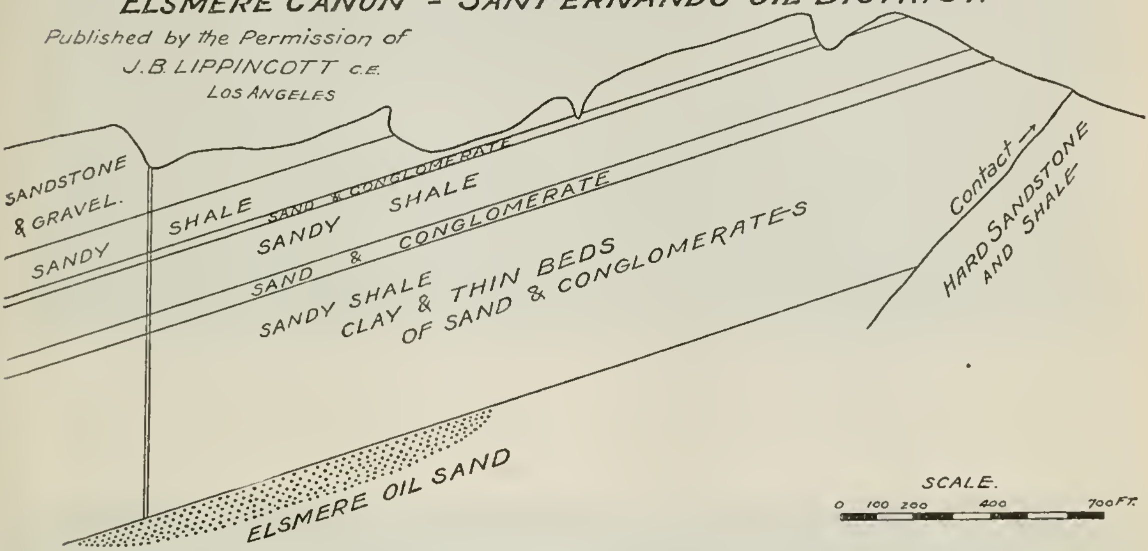
3.5.2. The character of the rocks exposed in this district leads to the conclusion that the principal oil-yielding formations are certain sandstones and shales which form the lower portion of the Middle Neocene formations, and some of the wells may penetrate sandstone of the Lower Neocene series.

3.5.3. At a point in Elsmere Cañon, to which the writer's attention was directed by Mr. H. Hamlin of Los Angeles, sandstones containing fossils of the Middle Neocene epoch are found resting non-conformably on hard sandstones resembling the Eocene sandstones of the Sespe district. The relation of these formations may be seen in Fig. 8.

3.5.4. One remarkable feature of the San Fernando district is that petroleum has been found in the crystalline rocks. The central mass of that portion of the San Fernando range which lies to the south of Placeritos Cañon is formed largely of crystalline rock, and, as hereinafter noted, in June, 1900, several companies were drilling in these crystalline rocks. It is an established fact that a small amount of oil

FIG. 8.

CROSS SECTION SHOWING NONCONFORMABILITY IN ELSMERE CAÑON - SAN FERNANDO OIL DISTRICT.



has been obtained from crystalline rocks in the Placeritos Cañon at Newhall. The sample of this oil seen by the writer was of a very low specific gravity; it was quite transparent and of a light straw color. Since the writer visited the locality, wells have been drilled there which are said to be productive. It is stated that the formation penetrated is crystalline rocks overlying sedimentary strata.

CHAPTER 6.

TERRITORY BETWEEN NEWPORT, IN ORANGE COUNTY, AND THE SAN DIEGO COUNTY LINE.

3.6.1. In 1898 certain representative gentlemen of Orange County requested the California State Mining Bureau to examine the geological formations which form the coast-line between Newport and San Diego County and extend inland toward the Santa Ana Mountains, with a view of determining whether or not that portion of Orange County has value as oil-territory. Since a cursory examination had shown that the geological formations in that area resemble those of the Puente Hills, and some prospects of oil were reported to have been discovered therein, the writer was detailed to make the examination which had been requested.

3.6.2. The territory examined comprises an area of about 300 square miles. It is traversed by two principal ridges of hills, which run in a northeasterly direction. One of these ridges extends along the coast from a point near the southeast corner of Orange County, marked Green Ridge in Fig. F, to San Joaquin Peak in the San Joaquin Hills, which peak rises to an elevation of 1185′. The other ridge extends in a northwest direction from Station 35 (marked in Fig. F as State Monument), about 5 miles from the coast-line, to and beyond Station 70. The ridge nearest the coast is cut through by the San Juan, Aliso, and Laguna creeks. The San Juan and Aliso creeks take their rise in the Santa Ana Mountains, and the Laguna Creek has its source in Laguna Lake on the San Joaquin ranch, and in sundry springs between Laguna Lake and the ocean. Thus, the territory referred to is in part hilly or mountainous, and in part mesa land. Its southern end is nearly all mountainous pasture; but toward the northwest there is a wide mesa devoted to agriculture. There is, also, some good agricultural and orchard land along the valleys of the San Juan and Aliso creeks.

3.6.3. The rocks forming the ridge nearest the coast are a conglomerate characterized by angular masses of glaucophane schist. In some places these masses look as if they were in place, but a close inspection shows that they are cemented to fragments of other rock. This conglomerate also contains numerous pebbles and angular fragments of white quartz. It is well exposed at San Juan Point, whence it can be traced in a northwesterly direction. It is said that the Sea Lion rocks, near San Mateo Point, are composed of a similar formation.

Resting with probable non-conformability on this conglomerate is a whitish sandstone resembling the whitish sandstone seen in Santiago Cañon, and containing fossils which are considered of Lower Neocene age by Dr. Merriam. This sandstone is exposed near the San Mateo and San Juan points (see Photo No. 13); it forms the great mass of the San Joaquin Hills, as is shown on Fig. F.

Resting on this sandstone is a widely extending formation of shale. In many places this shale has a purplish color, and some of it when heated gives out a faint odor of petroleum. The upper portion of this formation is interstratified with thin-bedded sandy strata; the shale passes into a tough clay, yellowish at the surface, but probably of bluish color at no great depth.

The central portion of this formation is tough shale. The lowest

PHOTO 13. Sandstone Formation on Shore-Line, Orange County.

PHOTO 14. Conglomerate Resting Non-conformably on Sandstone, San Juan Capistrano, Orange County.

portions of the formation are white or whitish, and in some places resemble diatomaceous earth. These shales are similar in appearance to the Middle Neocene shales of the Puente Hills.

This shale formation extends inland toward the northernmost ridge of hills previously mentioned. For some distance inland, the prevailing dip is to the north at an angle of less than 20°. Still farther north the shales show an undulating structure, and, for the most part, dip at a very low angle. As the northernmost ridge of hills is approached, the prevailing dip is to the south, but it is irregular and greatly increases.

3.6.4. These shales overlie the sandstone on the north slope of the San Juan Hills and form the bedrock throughout a great portion of the mesa lands. They are exposed at many points along the Aliso Creek toward El Toro. In this direction there is an extensive deposit of white or light-brown shale, the lower portion of which is interstratified with yellowish sandstone, and in some places with ledges of limestone. Some of these limestone deposits are very extensive, and much limestone has been shipped therefrom. In some places the limestones contain large quantities of poorly preserved Neocene fossils. These shales also form a fringe of low cliffs along the coast-line between Laguna and the mouth of the Santa Ana River. The whitish shale underlies the shale described in the preceding paragraph.

3.6.5. On the west bank of the San Juan Creek, near its mouth, a conglomerate formation rests non-conformably on the eroded surfaces of the whitish sandstone. (See Photo No. 14.) It probably belongs to the same geological horizon as the formations observed at Stations 60, 41, 66, 7, and 65, where conglomerate and very soft sandstones are exposed. At Station 7 a tusk and part of the bones of a mastodon were found, and a small collection of fossils was obtained from a well dug in this formation. These fossils are of Upper Neocene (late Pliocene) age, corresponding to the Merced series. (See table of fossils No. IV.) A gray sandstone is exposed on Aliso Creek near El Toro, which belongs to this horizon.

It is probable that this formation is more extensive than is shown on Fig. F, but it can only be indicated where the exposed rocks show it to exist.

3.6.6. In the northern ridge of hills previously mentioned the same sequence of formation is met with as is seen along the coast-line, namely, conglomerate largely made up of fragments of glaucophane schist overlain by whitish sandstone and clay-shale. Along the north base of these hills there appears to be an extensive fault, for there is a sudden drop of about 500′, besides a sharply defined line between the conglomerate and the sandstone.

3.6.7. An inspection of the territory herein described leads to the conclusion that the shale overlaps the whitish sandstone, and for these reasons: In most places the whitish sandstone is found resting on the glaucophane conglomerate, and the shale upon the sandstone, there being quite an interval of sandstone between the conglomerate and the shale. In other places, however, there is no sandstone exposed between the conglomerate and the shale. The alluvium obscures the point of contact between the conglomerate and the formation overlying it, but the short space between the exposed shale and the conglomerate is suggestive of an overlap. This opinion is strengthened by finding whitish shale resting on the conglomerate. Still, no very marked difference between the dip of the sandstone and the dip of the shale was observed.

3.6.8. The writer made a careful reconnaissance of the shore-line between Newport and Laguna, and of the north end of the San Joaquin Hills.

The greater part of this area is covered by mountains, which rise to a maximum height of 1185′. Toward the north the mountains slope down to the Santa Ana Valley, and toward the west to Newport Bay. At the north and west the mountains are bordered by marshes and peat lands of considerable extent. On the south, an ancient strand, now elevated 50′ or 100′ above the ocean, forms a narrow bench between the mountains and the seashore.

The mountains are, for the most part, formed of sandstone, and in a few places eruptive rocks are seen. The eruptive rocks are exposed at the northern end of the San Joaquin Hills, and at Abalone Point they are indicated on Fig. F by horizontal wavy lines.

For a distance of about 4 miles along the shore-line southeast of Newport Bay, the sandstone is bordered by shale, which, as before mentioned, corresponds to the shale formation in the Puente Hills. In some places this shale is highly silicified.

3.6.9. At Rocky Point these shales rest on hard sandstone impregnated with petroleum, and at several places in a distance of about half a mile along the shore-line north of Rocky Point, strata of oil-sand are exposed which are overlain by shale. The oil-sand and the shale are inclined at a great angle.

About one mile north of the town of Newport two formations are exposed. The lower of these consists of shales resembling the shale formation of the Puente Hills. The prevailing strike of these shales, as shown by the exposed rocks, is N. 50° W., and the angle of the dip ranges from 15° to 30°. A reconnaissance of this locality shows that the shale has been thrown into undulations producing a variable dip of comparatively low angle. At one point a stratum of dry oil-sand 2′ in thickness is interbedded with the shale, and in several places this shale is interstratified with thin strata of dry oil-sand a few inches in thickness. At several places the shale is traversed by fissures filled with dry oil-sand.

The uppermost formation consists of soft sandstone and yellowish clay-shale, some hard calcareous strata, and some which appear to be made up largely of diatomaceous material. Some of the strata contain Quaternary fossils. (See table of fossils No. V.)

The prevailing strike of this formation is east of north, and the angle of the dip ranges from 10° to 20°.

The lowest stratum of this formation is a soft sandstone impregnated with petroleum. The source of the petroleum appears to be the underlying shales.

3.6.10. From the foregoing it appears that the only portion of the territory investigated between Newport and the San Diego county-line, which would justify exploitation by the drill, is the territory around Newport Bay.

Since this territory was examined by the writer prospect wells have been drilled at Newport Bay by the Newport and the Santa Ana oil companies. (See Orange County—Prospect Wells.)

CHAPTER 7.

PROSPECT WELLS IN SAN DIEGO COUNTY.

3.7.1. *Monarch Oil Company* (of San Diego) has a well situated about half a mile east of False Bay, near San Diego. In October, 1900, this well was 800′ deep. Drilling.

3.7.2. *La Jolla Oil Company* has a well situated about midway between La Jolla and Pacific Beach, and about three-quarters of a mile from the ocean. In October, 1900, this well was 120′ deep. Drilling.

3.7.3. *San Diego Oil Company* has a well about one mile east of Encinitas, and in October, 1900, this well was about 400′ deep. Drilling.

3.7.4. *Carlsbad* (well near). The writer is informed that a company is drilling between Carlsbad and Oceanside.

PART 4.

PRODUCTIVE AND PROSPECT WELLS IN LOS ANGELES AND ORANGE COUNTIES.

CHAPTER 1.

PRODUCTIVE OIL-WELLS IN LOS ANGELES COUNTY.

4.1.1. The portions of Los Angeles County wherein productive oil-wells have been obtained are: the City of Los Angeles, that portion of the Puente Hills which lies west of Brea Cañon, and Newhall.

THE LOS ANGELES OIL-FIELD.

4.1.2. The Los Angeles oil-field may be said to be divided into three sections:

The Central (or old) field (see Photo No. 7), which extends from the corner of Victor and Temple streets to the corner of Bonnie Brae Street and Miramar Street, formerly called Ocean View Avenue;

The Eastern field (see Photos Nos. 6 and 8), which extends from the Sisters' Hospital to the Catholic Cemetery; and

The Western field, which extends in a westerly direction from the corner of Bonnie Brae and Miramar streets to the city limits.

These fields cover an area of rather more than 3 miles in length, and vary in width from about 500′ to more than 1000′. Within this area about 1200 wells have been drilled, and at the end of June, 1900, the number of producing wells was 663.

4.1.3. The productive wells were distributed as follows:

	Central Field.	Eastern Field.	Western Field.
Number of producing wells June 30, 1900	338	150	175
Product during 1899, in barrels	446,720	315,316	270,000

Total product of Los Angeles oil-field in 1899 was 1,032,036 bbls.

OIL-PRODUCERS IN LOS ANGELES CITY.

4.1.4. The following is a list of companies engaged in oil-mining in the City of Los Angeles in July, 1900, together with a statement of the number of productive wells:

	No. of Wells.
American Crude Oil Co.; Easton & Eldridge, 121 S. Broadway	14
Alderson, J. H.; 807 S. Hope Street	5
Acme Oil Co.; 405 and 407 N. Main Street	1
Alton, John; Farmers and Merchants Bank	5
Arizona Oil Co.; 227 Byrne Building	8
Alpha Oil Co.; 342 Byrne Building	7
Bayer & Roberts; 746 S. Broadway	4
Big "5" Oil Co.; care Columbia Savings Bank	3
Bernard, C. A.; cor. Alameda and Second streets	5
Burns, John; 932 Court Circle	2
Blunt, C. A.; 149 Kern Street	1
Berry Barton Oil Co.; 235 W. Third Street	1
Bobst, M.; 429 Victor Street	1
Brown, John; cor. Vermont Avenue and Third Street	2
Burlington Oil Co.; Doran & Brouse, cor. First Street and Belmont Avenue	15
Consolidated Oil Co.; Frost Building, room 610	38
Chase Nursery Co.; care Odonnell Oil Co., Hellman Block	3
Continental Oil Co.; Laughlin Building	8
Carr, Mrs. J.; cor. Lake Shore Avenue and First Street	1
Cates, A. M. (receiver); 310 Currier Block	2
Carter, H. V.; rooms 12-18, 254 S. Broadway	2
City Brick Co.; 125 E. Second Street	4
Crown Oil Co.; cor. Kern and Colton streets	5
City Water Co.; office, Los Angeles Street	2
Croswell Oil Co.; Edgeware Road and Omaha Street	4
Croswell, M. S.; Edgeware Road and Omaha Street	6
C. & H. Oil Co.; C. B. Boothe, 226 Los Angeles Street	3
Clampit, E. A.; 1442 Court Street	5
Connell, D. A.; cor. Ionia and Holliday streets	2
Cake, M. E.; cor. Grand Avenue and Seventh Street	4
College Oil Co.; 1633 W. First Street	5
California Crude Oil Co.; 419 and 420 Douglas Block	Drilling July 5, 1900
Doran & Brouse; cor. First Street and Belmont Avenue	6
Davis & Harrison; 815 Alpine Street	11
Daggett & Fletcher; 1342 Calumet Avenue	14
Davis, Cook & Co.; Alameda Street	1
Davis, Frank; 815 Alpine Street	4
Dryden, Wm.; 1071 W. Jefferson Street	2
Delta Oil Co.; McCarthy Bros., Henne Block	1
Enterprise Oil Co.; 135 W. First Street	1
Eagen, S.; care S. Clark, cor. Rockwood Avenue and Lake Shore	1
Easterday Bros.; cor. Temple Street and Boylston Avenue	3
East Side Oil Co.; care I. W. Stewart, Gardner & Zellner Block	2
Evans, T. H.; care Tubbs & Evans, New Depot Street	1
Evansville Oil Co.; cor. First Street and Union Avenue	1
Elton, C.; W. First Street	1
Fergusson, Mrs. M. L.; 649 S. Hope Street	1
Frazier, Mrs.; 123 E. Fourth Street	1
Ford, G.; 608 E. Fifth Street	2
Green & Whittier; 1633 W. First Street	4
Green, B. E.; 1633 W. First Street	2

	No. of Wells.
Green, R.; 1633 W. First Street	7
Gorham & Boeck; cor. Court and Tolucca streets	7
Graham Sisters; 131 N. Union Avenue	2
Green & Young; 1633 W. First Street	4
Giegrich, G.; 526 Bernardo Street	1
Green Mountain Oil Co.; Bartlett Music Co.	Drilling July 20, 1900
Headley, A. H.; cor. Bellevue and Ida streets	2
Huntley, E.; 1155 Temple Street	7
Harrison, H. H.; 821 Hinton Avenue	2
Hollingsworth, H. T.; 347 Wilcox Building	2
Hughes & Strasburg; 15 Baker Block	1
Hansen, C.; 815 N. Figueroa Street	2
Hammond, Mr.; 717 S. Union Avenue	1
Harris, R. T.; Santa Ana, Orange County	2
Hardison & H.; Ojai Building	8
Hervey, Mrs.; cor. Omaha Street and Edgeware Road	1
Hughes Bros. Oil Co.; 15 Baker Block	1
Hubbell Oil Co.; Bullard Block	2
Hall, Chas. Victor, Oil Co.; Wilcox Block	34
Joyce, T. F.; 971 Yale Street	7
Knight & Son; 315 Boylston Avenue	22
Korber, K.; 1320 Omaha Street	1
Kellerman, J. M.; Ocean View Avenue	1
Kellum, F. R.; 235 W. Third Street	1
Los Angeles Transfer Co.	1
Los Angeles Transfer and Terminal Co.; 222 W. Fourth Street	43
Lamb & Hanna; 504 Douglas Block	1
Los Angeles R. R. Co.; office, Central Avenue and Sixth Street	19
Lowry, W. P.; 985 Buena Vista Street	2
Lawrence, G.; 334 S. Main Street	1
Lamb, W. A.; 1929 Ocean View Avenue	2
Leslie & Spurling; W. P. Book, care Batcheler, Henne Block	2
Leslie, C. C. L.; 132 Quebec Street	1
Lake Shore Oil Co.; Laing & Wiggin	1
Longstreet & Carhart; 2403 S. Grand Avenue	3
Lewis, T. L.; Rockwood Street and Belmont Avenue	1
Los Angeles Oil and Trans. Co.; 201 Bradbury Building	5
Maier & Zobelein; Aliso Street Brewery	7
Martin, J. B.; 1447 Bush Street	3
McGarry, D. M.; 103 S. Broadway	1
Maunatt, I.	4
Magee, Mrs.; D. M. McDonald (Hellman Block)	1
Mattern, DeCamp & Co.; Frost Building	1
Montana Oil Co.; Bartlett & Jack, 360 S. Broadway	3
McDonald, Nance & Co.; Hellman Block	3
Mellen & Book; cor. Ocean View and San Joaquin Street	2
Nelson, R. T.; 2403 S. Grand Avenue	2
North, E.; 1726 W. First Street	4
Newman & Johnson; 109 S. Broadway	2
Oil Lake Fuel Co.; 601 Laughlin Building	1
Off Crude Oil Co.; 114 South Union Avenue	6
Odonnell Oil Co.; 225 Hellman Block	7
Odonnell, T. A.; 225 Hellman Block	1
Oceanic Oil Co.; Byrne Building	5
Parker Oil Co.; 224 Henne Block	47
Pennsylvania Oil Co.; 324–326 Laughlin Building	8
Phœnix Oil Co.; 717 S. Union Avenue	1
Parker & Morrill; care M. Morrill, cor. Court and Douglas and Thurston Well	8

	No. of Wells.
Puente Oil Co.; Room 14, Baker Block	3
Powell, J. J.; care Mr. Lloyd, New Wilson Block	2
Palm Oil Co.; Stimson Block, Rommel Oil Co.	4
Park Oil Co.; care Easton & Eldridge Co., S. Broadway	16
Pollard, John; 315 Boylston Avenue	1
Poindexter & Wadsworth; 305 W. Second Street, Frost Building	1
Robinson, Geo.; 232 W. First Street	1
Ruddy, Burns & M.; care C. H. Mathay, Alvarado and Ninth streets	1
Rommel Oil Co.; Stimson Block	3
Robinson, G. W., M. D. Oil Co.; care of Mr. Morrison, Metcalf & Temple	22
Reese, A. D.; corner College and Buena Vista streets	6
Rex Crude Oil Co.; Easton & Eldridge Co., S. Broadway	63
Schwarzendahl, L.; 1663 W. First Street	2
Sommers & McClannahan; 517 California Street	1
Skinner & Morgan; care Morgan-Perry Lumber Co.	3
Slocan, J. H.; care California Hardware Co.	1
Shirley, I. W.; Gardner & Zellner Block	12
Saunders, W. P.; 2315 S. Flower Street	2
Stratton & Tiedemann; Louis Supplee, Byrne Building	2
Sierra Oil Co.; 206 Douglas Block	7
Slocan Oil Co.; 14 Baker Block	11
Traction Co.; Traction Office	1
Tomlinson, Mrs.; 1316 Omaha Street	1
Tubbs & Evans; 1643 Central Avenue	4
Thompson, R.; 1320 Omaha Street	1
Uncle Sam Oil Co.; Hardisson & H., Ojai Building	11
United States Crude Oil Co.; C. J. George, 208 Laughlin Building	3
Victor Oil Co.; care Walter L. Young, 453 Cottage Home Street	1
Van Fossen & Cummings; D. C. McGarvin, 220½ S. Spring Street	2
Van Every & Co.; 109 S. Broadway	3
Van Trees, Mr.; 120 S. Witmer Street	2
Weller, Z. H.; 919 Kensington Road	8
Wing, K. W.; Belmont Avenue	2
West Lake Oil Co.; Clark & Bryan, Stimson Block	26
Wilson, W. D.; Hellman Block	15
Westlake, Walter; care 601 Laughlin Building	1
Wellington Oil Co.; 224 Henne Building	16
Whittier Consolidated Oil Co.; 225 Hellman Block	5
Young & Shaw; 453 Cottage Home Street	4
Young, Walter L.; 453 Cottage Home Street	1
Yukon Crude Oil Co.; Easton & Eldridge Co.	15

PRODUCTIVE WELLS WEST OF CITY LIMITS OF LOS ANGELES.

4.1.5. *Hercules Oil Company* (T. H. Dunham, president) has two 365′ wells on Rosedale Avenue, between First and Fourth streets. Oil-sand struck at 300′ and 311′ respectively.

4.1.6. *Los Angeles Oil and Transportation and Terminal Company* has seventeen wells, 300′ to 400′ deep, on Maltman tract, between First and Third streets, Vermont Avenue and Hoover Street. Average yield, 7 bbls. per day. Gravity of oil, 14.5° B. Formation penetrated: Yellow clay to 30′; dark brown sand to 70′; brown shale and sulphurous shale to 100′; then blue clay and shale to 250′; then oil-sand to 300′. Dip to the southwest at an angle of about 20°. Five of these wells are within the city limits.

4.1.7. *San Gabriel Electric Light Company* has two wells 400′ deep on the northwest corner of Vermont Avenue and Fourth Street. Each well yields 12½ bbls. a day.

4.1.8. *Schmidt* (*Fred*) has three wells on the Luring tract, Third Street and Vermont Avenue. (See Transfer Oil Company.)

PRODUCTIVE OIL-WELLS IN THE PUENTE HILLS, LOS ANGELES COUNTY.

Only those wells are included in this list which were productive when the Puente Hills were visited by the writer in May, 1900. Unfinished wells are recorded under the head of "Prospect Wells."

4.1.9. The oil-fields in that portion of the Puente Hills which lies within Los Angeles County are the Whittier, the La Habra, and the Puente oil-fields.

The Whittier Oil-Field.

4.1.10. The Whittier oil-field represents that portion of the Puente Hills which extends from the San Gabriel River to the La Habra ranch. In May, 1900, the following companies were operating, or had drilled wells in the Whittier district:

4.1.11. *The Central Oil Company* (of Los Angeles). (See Photo No. 3.) The wells of this company are in Sec. 23, T. 2 S., R. 11 W., S. B. M., about a mile southeast of Whittier. In May, 1900, this company was pumping sixteen wells, 700′ to 1250′ in depth, producing 10 to 70 bbls. a day. Gravity of oil, 18° B. These wells supplied sufficient gas for fuel. All of the producing wells of the Central Oil Company are situated on the south limb of the fold marked BB in Fig. A. The formation penetrated by the wells of the Central Oil Company is represented by the following well-records:

Well No. 1 (completed December, 1897): Big flow of water at 275′; blue clay and oil-sand to 485′; 5 bbls. oil in 24 hours; stratified shale and sand, good showing of oil, at 730′; 10 bbls. oil; water; hard shell to 735′; blue clay, sand, and shale to 865′; thin shale, with good showing of oil of 21° B., at 865′; sand to 879′. Well drilled to 400′; oil-sand at 955′; well pumped 70 bbls. oil in 10 days; total thickness of sand penetrated, 90′. Well deepened to 894′; total thickness of sand penetrated, 105′; well pumped 60 bbls. oil in 10 days. In July, 1898, well pumped 25 bbls. oil a day.

Well No. 2 (550′ N. 20° W. of No. 1): Clay to 175′; big flow of water at 275′; stratified formation (caving) to 384′; good showing of light oil in sand at 650′; slate, with hard shell, at 890′; sand and shale to 910′; very light oil at 990′; good oil-sand at 1007′; hard shell to 1012′; thick slate to 1035′; sand and clay to 1070′; slate and shale to 1135′. Much gas. Well choked and filled up to 1070′. Well produces 8 bbls. oil of 26° B. a day.

Well No. 3 (completed July, 1898), about 325′ S. of No. 1: Clay and gravel to 340′; hard shell to 350′; broken shale, trace of oil, to 425′; fine, soft sand to 500′; brown sand to 640′; white shale, trace of oil, to 710′; white shale to 730′; soft, white sand to 780′; brown sand to 785′; blue sulphur and shale to 880′; oil and sand to 930′. Well filled to within 70′ of top. Well pumped 80 bbls. oil a day for two weeks. In July, 1899, 40 bbls. oil a day.

Well No. 5 (completed July, 1898): Blue sand to 100′; brown shale to 150′; sulphurous sand and water to 235′; brown sand to 310′; white shale to 375′; white sand, some oil, to 430′; white quicksand to 450′; blue quicksand to 490′; hard pebbles and sand to 520′; mud vein (2′) at 525′; fine sand to 545′; fine sand to 560′; blue shale to 575′; hard shell to 585′; soft, white slate to 620′; fine oil-sand to 685′.

Well No. 6: Water and gravel to 60′; white sand to 80′; blue slate to 250′; sand to 300′; hard shell to 308′; slaty blue shale to 325′; hard, blue shell to 335′; soft slate and sulphurous water to 400′; soft slate to 535′; oil-sand to 550′; slate to 565′; oil-sand to 790′; hard shale to 795′; sand to 840′.

The oil from these wells is conveyed by pipe-line to Los Nietos on the Santa Fé Railroad, a distance of about $4\frac{3}{4}$ miles.

4.1.12. *The Chandler Oil-Wells* are about 2 miles east of Whittier. In well No. 1, drilled in 1891, the formation is: Conglomerate to 200′; blue clay to 250′; fine sand and oil to 270′; blue clay and strata of sand and oil to 300′. Gravity of oil, 18° B. Well started at 3 bbls., and in 1897 was producing the same amount. No. 2 is 250′ south, 16′ east from No. 1, and at a lower elevation. Formation: Blue clay to 400′; hard stratum to 401′; sand and clay to 561′; sand contained oil and water.

4.1.13. *Clarendon Heights Oil Company* (of Whittier). The wells of this company are in Savage Cañon, about half a mile east of Whittier. In May, 1900, this company had two wells, 285′ and 336′ deep, respectively. These wells yield about 10 bbls. a day. Gravity of oil, 13° B.

4.1.14. *Fidelity Oil Company* (of Los Angeles). The wells of this company are about 1 mile northeast of Whittier. In May, 1900, this company had one productive well, and a second well was being drilled.

4.1.15. *Holden* (*T. D.*) (of Los Angeles) has a well one mile east of the Central Oil Company. Brea to 10′; conglomerate to 100′; sandy shale and thin strata of conglomerate to 900′; sandstone to 1000′; shale to 1050′; sulphur water at 800′. Abandoned.

4.1.16. *Home Oil Company* (of Los Angeles). The wells of this company are in Sec. 22, T. 2 S., R. 11 W., S. B. M., and are about three quarters of a mile northeast of Whittier. In May, 1900, this company had three productive wells and one dry-hole. The first well was drilled on the south side of Turnbull Cañon, about half a mile northeast of Whittier. The formation is: Well No. 1—Yellow sandstone to 100′;

soft shells with hard shells of blue sand-rock to 180′; black clay or clay-shale to 250′; tough clay, streaks of gray sand, to 360′; dark-gray sandstone to 400′; sandy clay-shale, streaks of gray sand, to 950′; water was struck at 105′, 250′, 400′, and 500′. Abandoned.

Subsequently this company drilled three other wells about one quarter of a mile east of their first well, with the following results: Second well, oil-sand to 400′; clay-shale to 550′; 3 bbls. Third well, oil-sand and shale to 960′; oil below 200′; 40 bbls. Fourth well, oil-sand and shale to 700′. Drilling in May, 1900.

4.1.17. *Turner Oil Company* (of Los Angeles). The territory of this company adjoins that of the Home Oil Company on the east. In May, 1900, this company had two productive wells, 1125′ and 550′ deep, respectively.

4.1.18. *Warner Oil Company* (of Whittier). The territory of this company adjoins that of the Central Oil Company on the west. In May, 1900, the Warner Oil Company had one well 1108′ deep, said to yield 48 bbls. a day. A second well was being drilled.

4.1.19. *Whittier Crude Oil Company* (of Whittier). The wells of this company are about 1 mile northeast of Whittier. In May, 1900, this company had two producing wells, one 1000′ and the other 1250′ deep.

The La Habra District.

4.1.20. This district lies between the Puente and Whittier oil-fields. The only company operating in the La Habra district is the Union Oil Company.

4.1.21. *Union Oil Company* (of Santa Paula, Ventura County) has two wells on La Habra ranch. One well is 1270′ deep, and produces about 3 bbls. of oil a day. In May, 1900, another well was being drilled, and was 1097′ deep. The formation penetrated by these wells is clay and sandy shale, with strata of oil-sand. Gravity of oil, 20° B.

The Puente District.

4.1.22. This district extends from La Brea Cañon to La Habra. The Puente wells, which have been successfully operated for more than a decade, are situated in the higher portion of the Puente Hills, about 2 miles west of Brea Cañon and 7 miles from Puente Station on the Southern Pacific Railroad.

4.1.23. *The Puente Oil Company* (of Los Angeles; J. A. Graves, president) has sixty producing wells, varying from 1000′ to more than 2000′ in depth, which yield from 5 to 40 bbls. of oil daily. The formation penetrated is shale, with strata of oil-sand, varying from 5′ to 20′ in thickness and yielding an oil of about 23° B., to a depth of about 1000′. Below this depth the oil-sand strata are thicker, and some of the deepest wells have passed through oil-sand for a distance of 100′ to 300′. The oil derived from these deeper formations has a gravity of from 30°

to 35° B. The oil from the Puente wells is conveyed by pipe-line to Chino refinery. (See chapter on Pipe-Lines and Refineries.)

PRODUCING WELLS IN SAN FERNANDO OR NEWHALL MINING DISTRICT.

Only such wells are mentioned as were producing oil in June, 1900.

4.1.24. *Kellerman and others* (of Los Angeles) have a well near the south line of Sec. 6, about 2 miles southeast of Newhall. This well is about 1400′ deep. The formation is mostly sandstone, with a little shale. The first oil was struck at 820′; gravity of oil, 25° B. A second stratum of oil was struck at 1140′; this oil had a gravity of 30° B. A third stratum was struck at 1450′; gravity, 35° B. It is said that this is a 10-bbl. well.

Pacific Coast Oil and California Star Oil Company (of San Francisco). The productive wells of this company are situated in the Pico, Elsmere, and Wiley cañons, and prospect wells are being drilled in Rice Cañon.

4.1.25. *Pacific Coast Oil Company's* wells in Pico Cañon are about 7 miles southwest of Newhall. (See Photo No. 29.) Here there are forty wells, varying in depth from 700′ to 1950′. The formation is sandstone and shale, the sandstone predominating. The gravity of the oil varies from 41° to 42° B. The oil is conveyed by pipe-line to Ventura, in Ventura County; distance 44 miles. (See chapter on Pipe-Lines, etc.)

4.1.26. *Pacific Coast Oil Company's* wells, in Elsmere Cañon. In this cañon there are fifteen wells, ranging from 400′ to 900′ in depth. Only seven of these wells are productive, and yield 7 to 45 bbls. a day ; the formation being gravel, sandstone, and a little shale.

4.1.27. *Pacific Coast Oil Company's* wells in Wiley Cañon are about 3 miles southwest of Newhall. Here there are thirteen wells, ranging from 600′ to 1626′ in depth, but only three of these wells are productive. The formation is shale and sandstone, the shale predominating. Gravity of the oil, 30° B. The total product of the Pacific Coast Oil Company's wells is about 150,000 bbls. a year. The gravity of most of this oil ranges from 41° to 42° B.

4.1.28. *White Oil Company* (of Los Angeles; G. S. Deline, secretary) has a well 530′ deep, said to yield 25 bbls. a week; also a well 1030′ deep. These were the first wells drilled in the crystalline rocks. The outcropping rocks at the wells are crystalline schists, and in them a 30′ tunnel has been run for water, which yields enough for drilling. About 150′ down the hill from the tunnel is the 1030′ well previously referred to. The owners state that a hard crystalline rock was penetrated to a depth of about 50′. At that depth the rock became darker, and several seams of clayey material were passed through. Three of these seams were found to be oil-yielding. About 100′ north of the

1030′ well, a well has been drilled to a depth of about 500′. The officers of the company state that the formation in this well resembled that in the 1030′ well. They say that this well yields about 25 bbls. of oil a week. A sample of this oil was furnished the writer by Messrs. Freeman & Nelson. It showed a gravity of 37° B. This oil finds ready sale for medicinal purposes. North of the well the formation is crystallized limestone and gneiss.

CHAPTER 2.

PROSPECT AND UNFINISHED WELLS IN LOS ANGELES COUNTY.

Only those wells are mentioned which were drilled, or being drilled, in June, 1900.

PROSPECT WELLS WEST OF LOS ANGELES CITY LIMITS.

4.2.1. *Brea Ranch Well.* Formation, broken shale to 600′; at 900′ heavy oil flowed; mud to 1400′. J. E. Sanford, driller.

4.2.2. *Davis* (*C. B.*) has a well 400′ deep on Western Avenue, a short distance south of Mitchell & Stilson well. Formation, shale to 400′. Abandoned.

4.2.3. *Houser Tract Wells*, on Pico Street, 6 miles west of city. Well No. 1, sulphur water at 230′. Well No. 2, artesian water at 355′.

4.2.4. *Ivy Station Well*, 7 miles from Los Angeles, on S. P. R. R. to Santa Monica, on Washington Boulevard and road to Palms; 153′ deep; gas.

4.2.5. *John & Strong Well*, Eighth Street and Dewey Avenue; 850′ deep.

4.2.6. *Keating Wells.* No. 1 on Bonita Meadows ranch, between Adams Street and S. P. R. R. This well was drilled in 1898. The formation penetrated was adobe to 60′; black sand to 200′; quicksand to 250′; clay and sandstone to 450′; blue clay to 910′; sand and clay to 960′; hard sandstone to 1030′; clay to 1256′; traces of oil and gas at 1000′. No. 2, between Pico and Washington streets.

4.2.7. *Lewis Well* (Flora and Santa Monica Company), half a mile east of Cole Grove. Shale and sandstone to 400′; oil and sand to 412′; shale and sandstone to 600′; oil-sand to 620′; shale and sandstone to 800′. Two flows of artesian water were shut off in this well.

4.2.8. *Lombard & Lockhart* have three wells: No. 1, on ranch of C. Greve; 12 acres; 891′ deep; no oil. No. 2, on ranch of Joseph Whitworth; 14 acres; 417′ deep. No. 3, on ranch of Joseph Whitworth; 14 acres; at 417′ hard rock. Abandoned.

4.2.9. *Mansfield (Houser Station) Wells,* 7 miles west of Los Angeles. Well No. 1, 550′ deep; 60′ oil-sand at bottom. Well No. 2, old gas-well; burned many years in house. Well No. 3, 53′ deep, 31′ sand; gas in 1″ pipe, burning.

4.2.10. *Mitchell & Stilson* have a well 600′ deep on Western Avenue and Temple Street.

4.2.11. *New Mexico Development Company* has a well on the Arnaz ranch; down 600′; drilling.

4.2.12. *Pico Oil Company.* Well No. 1, on James Whitworth ranch, 7 miles west of Los Angeles. Formation: Adobe to 20′; yellow clay to 60′; sand and gravel with 4′ of oil-sand to 129′; blue clay to 167′; sand, rock, and gravel to 450′; blue clay to 530′; black shale to 538′; blue clay to 545′; sand to 550′; blue shale, traces of oil, to 558′; blue clay to 560′; black shale, traces of oil, to 564′; blue clay to 566′; black shale to 572′; sand to 610′; blue clay, traces of oil, to 620′; sand to 622′; blue clay to 635′; sand to 641′; blue clay, oil, to 668′; blue shale, oil, to 671′; blue clay, oil, to 708′; black shale, oil, to 780′; blue clay, oil, to 822′.

4.2.13. *Pitcher-Garbutt Oil Company* has two wells on Masselin ranch, 7 miles west of Los Angeles. Well No. 1, 901′ deep; oil-sand at 40′; pumped by hand. Well No. 2, 1073′ deep; standard rig; shale at 852′; oil-sand at 951′.

4.2.14. *Rhodes Wells.* No. 1, on Brea ranch, about 4 miles west of Los Angeles. Formation: Soil to 10′; yellow clay-shale to 73′; sand and bowlders to 85′; blue clay to 149′; shell to 154′; blue clay to 176′; shell to 177′; decomposed black shale to 192′; shell, or hard flinty blue shale, to 193′; oil-sand to 213′; gray shale to 214′; oil-sand to 237′; sand-rock to 239′; oil-sand to 282′; sand-rock to 284′; heaving beach sand to 324′; coarse black sand with asphaltum to 350′; hard rock to 351′; lightish-colored sand to 381′; hard oil-rock to 382′; oil-sand (showed well) to 432′; soft oil-rock of shale to 436′; coarse sand to 463′.

Well No. 2, on Brea ranch, about 800′ south of Rhodes Well No. 1. Formation: Soil to 10′; red sand to 50′; yellow clay and shale to 133′; shell to 137′; sand and bowlders (water strata) to 147′; blue shale to 185′; shell to 186′; shale to 215′; shell to 216′; clay to 255′; brea to 256′; shale to 284′; shell to 285′; shale to 302′; shell to 304′; shale and clay to 362′; shell or rock to 363′; shell to 370′; oil-sand (6′ shale about center) to 449′; rock to 452′; oil-sand to 484′; rock to 485′; sand to 527′; sand-rock to 535′; sand to 546′; shale to 548′; oil-sand to 596′; hard shale or rock to 600′. This well was drilled to a depth of 600′ by a hydraulic rig. Two days after removing the pipes the oil stood within 12′ of the surface. The gravity of the oil is 12° B.

Rhodes Well No. 3, on Brea ranch, about 800′ southeast of No. 1. Formation: Soil to 10′; yellow clay and shale to 74′; sand and bowlders (water strata) to 89′; shale to 104′; shell to 106′; blue clay to 173′; shell to 179′; decomposed black shale to 211′; shell of hard blue shale to 212′; oil-sand to 245′; gray shale to 248′; oil-sand to 264′; hard shale or sand-rock to 265′; oil-sand to 267′. Casing would drive no further. Took out 20 bbls. twenty-four hours after cleaning well. Gravity of oil, 11° B.

4.2.15. *Rodeo Oil Company Wells.* No. 1, on Abbott ranch, west of Houser Station, 7 miles west of Los Angeles. Formation: Sand to 43′; gravel to 53′; gravel, with oil, to 76′; sand and shells to 83′; rocks to 98′; blue sand to 118′; clay to 136′; sand and rocks to 142′; blue clay to 144′; sand and rocks to 157′; clay to 160′; rocks and sand to 281′; blue clay to 347′; sand to 385′; clay blue to 390′; blue clay, traces of oil, to 420′; sand to 595′; blue sticky clay, oil, to 598′; heavy sticky blue clay to 723′; oil from 598′ to 723′; stopped in blue clay. Well No. 2 showed oil-sand at 400′.

4.2.16. *Rommel Company* has a well 750′ deep on the Gay tract. Oil from 75′ to bottom of well. Gravity, 25° B. Well flowed 10 bbls. per day while drilling. This company has also one well in Rimpau tract, east of Houser Station, about 6 miles west of Los Angeles. This well is 1000′ deep. It is said that a stratum of oil-sand 60′ thick was struck at a depth of 550′, and that it yielded an oil of 22° B.

4.2.17. *Rosedale Cemetery Wells,* 6 miles west of Los Angeles. On the cemetery grounds there are five wells. Well No. 1, 550′ deep; 60′ oil-sand, at bottom. Well No. 2, 800′ deep; water; no oil. Well No. 3, 160′ deep; 20′ oil-sand, at bottom. Well No. 4, 160′ deep; 30′ oil-sand, at bottom. Well No. 5, 120′ deep; 66′ oil-sand.

4.2.18. *Selby Oil Company* has a well on the southwest corner of Third and Rosedale streets, near Los Angeles; 400′ deep; clay-shale. Western Electric Works, 334 S. Main Street, drillers.

4.2.19. *Star Oil Company* has a well on the corner of Lee Street and Vermont Avenue, near Los Angeles; 1300′ deep; heavy oil.

4.2.20. *Thomas* (*H. C.*) has two wells on the Croswell tract, 6 miles west of Los Angeles. Well No. 1, 654′ deep; it is said that in this well oil-sand was struck from 45′ to 160′. Well No. 2, 175′ deep; it is said that in this well oil-sand was penetrated for 138′.

4.2.21. *Weid Well,* on Weid Estate, near Colegrove. Sand and gravel at 80′; blue shale at 800′; oil-sand, coarse; oil and water to 840′; water not cased off. Drilled by T. E. Sanford, 1013 Temple Street.

4.2.22. *Wicks and others* have a well 400′ deep on the Arnaz ranch, 7 miles southwest of Los Angeles. No. 1, 400′ deep. Little oil. Abandoned.

4.2.23. *Williams* (*C. H. L.*) (The National Oil Company) has a well on the southwest corner of First and Rosedale streets, near Los Angeles. Drilling.

PROSPECT WELLS—EAST LOS ANGELES.

Only such wells are mentioned as had been drilled, or were being drilled, in June, 1900.

4.2.24. *Bland (F. E.)*, on Judson Street, between State and Lord streets. In a well drilled for water at this point, oil was struck at a depth of 80′.

4.2.25. *Far East Oil Company* has a well one third of a mile north of Evergreen Cemetery. Formation: Adobe to 500′; shale, dark shale, and clay to 540′; sand, with water and traces of oil, to 590′; shale (dark) to 630′; sand and water to 670′; blue shale to 930′.

4.2.26. *Headly Well*, north of Reservoir No. 5, East Los Angeles. Well, 840′; no oil.

4.2.27. *Johnson (Mrs. C. M.)*, on State Street, corner Bailey. Well, 40′; oil.

4.2.28. *Rees Well*, near the corner of Britannia and Sheridan streets. Black mud, with occasional streaks of yellow clay, to 70′ (at this depth a thin stratum of water-bearing gravel was penetrated); shale to 85′; brea to 92′; shale, alternating in light and dark-brown color, to 400′; water-bearing sand to 403′; shale, impregnated with oil, to 800′; fine sand to 803′; blue shale to 525′. At this depth the casing had been reduced to 4″, and the well was abandoned.

4.2.29. *Scott & Loftus Wells.* No. 1, on St. Louis Street, between Emerson and Scott streets. Gravel to 45′; blue clay to 315′; sandy shale to 420′; water at 450′; tough clay to 475′; sandy shale and a little oil and gas to 555′; oil-sand to 560′; sandy shale to 800′; sand and water to 875′. Seven barrels a day, 17° B.

No. 2, 400′ east of Soto Street, on Magnolia Avenue. Gravel to 20′; blue clay to 625′; sulphur water and blue clay to 650′; sandy shale to 800′; sand and water to 803′. No oil.

4.2.30. *Whiting (Dwight) and others* have a well about 250′ east of the intersection of the El Monte wagon road and the San Gabriel branch of the S. P. R. R., about 4 miles east of Los Angeles. Formation, shale and sandstones. In May, 1900, this well was 500′ deep. A thin stratum of oil-sand was passed through at a depth of 300′.

4.2.31. *Wilkinson (J. M.)* has a well one fourth of a mile east of Reservoir No. 5. Well, 670′. Said to have shown traces of oil at 640′. Yellow shale to 25′; blue shale to 175′; blue shale and hard shells to 365′; blue clay-shale to 410′; gray shale to 500′; blue mud and strata of shale and a little oil to 640′.

PROSPECT AND UNFINISHED WELLS IN THE PUENTE HILLS.

Only those wells are mentioned which were drilled, or being drilled, in May, 1900.

4.2.32. *Chino Well No. 1* was drilled by the Chino Valley Beet Sugar Company of Chino in 1897. It is on the Chino ranch and near the southeast corner of Sec. 35, T. 2 S., R. 9 W., S. B. M. This well is 1000′ deep. The formation is sandstone, with a few thin strata of shale. No oil was struck, and well is abandoned. There is an exposure of oil-sand in a ravine about a quarter of a mile west of this well.

4.2.33. *Chino Well No. 2* was drilled in 1897–98 by the Chino Valley Beet Sugar Company near Station 100 in Sec. 3, T. 2 S., R. 8 W., S. B. M. The formation penetrated is: Red clay and sandy shale to 70′; white sand with water to 77′; shale to 240′; white sand and water to 248′; dark shale to 272′; gray sand, water, and much gas to 310′; light-colored shale to 410′; dark shale to 440′; oil-sand to 465′ (at this depth a small amount of heavy oil was struck); dark-colored shale to 475′; sand and water to 500′; clay-shale to 590′; coarse sand to 600′; fine sand to 610′; coarse sand to 620′; fine gray sand to 630′; gray sand to 640′; coarse sand to 650′; fine sand with water to 670′; brown shale to 675′; and shale with thin strata of sandstone, all smelling of petroleum, to 1000′. Abandoned.

4.2.34. *Gird Well*, on Chino ranch near the south line of T. 2 S., R. 8 W., S. B. M.; drilled in 1890. This well is near a seepage of heavy oil at a point on the Chino ranch marked Station 40 on Fig. A. Near the well a stratum of oil-sand is exposed. For the following record of the well referred to the writer is indebted to the courtesy of Mr. J. Kellerman, well-driller: Soft brown shale to 120′; white sand with water to 185′; rotten shale with water to 400′; soft sand to 450′; sand and shale to 950′; sand with brackish water to 1020′; sand and shale to 1200′. This well was abandoned on account of the water. The water was accompanied by a small amount of oil.

4.2.35. *Gird Well*, near quarry of bituminous sand. Several years ago a well was drilled about half a mile northeast of the Gird quarry of bituminous sand near where the Brea Cañon road crosses the east line of T. 2 S., R. 9 W., S. B. M. It is said that this well is 800′ deep and that two or more strata of oil-sand were penetrated which yielded some heavy oil, but that the oil was cased off and the well deepened in order to obtain water from strata underlying the oil-sand.

4.2.36. *Joyce Oil Company* (of Whittier) has a well in Savage Cañon west of the Clarendon Heights well. In May, 1900, the Joyce well was unfinished.

4.2.37. *Murphy Oil Company* (of Los Angeles). In 1897 this company drilled a well about 1 mile southeast of Whittier. The formation penetrated is as follows: Soft yellow sandstone to 35′; sandstone and tough blue clay to 40′; tough blue clay to 476′; limestone stratum to 481′; quicksand and showing of oil to 487′; sandy shale to 527′. Abandoned. In 1898 the Murphy Oil Company drilled two wells about 100 yards southeast of the Chandler wells. In the first of these wells conglomerate was penetrated to a depth of 660′. Mr. Plotts, superintendent, states that it yielded about 6 bbls. of heavy oil a day. In the other wells conglomerate was passed through for 850′ and then soft shale to a depth of 1760′. No oil was found in this well, and the locality was abandoned. In May, 1900, this company was drilling a well a few hundred feet south of the wells of the Central Oil Company.

4.2.38. *North Whittier Oil Company* (of Los Angeles). In May, 1900, this company commenced drilling on the spur of hills between Turnbull and Sycamore cañons, at a point northwest of the wells of the Home Oil Company and about 1 mile north of Whittier.

4.2.39. *Shirley & McGray* (of Los Angeles) have a well in Savage Cañon and west of the Clarendon Heights well. In May, 1900, the Shirley & McGray well was 700′ deep. The formation penetrated is conglomerate.

4.2.40. *Whittier Oil Company* (of Whittier). In 1897 this company drilled two wells in the mouth of Savage Cañon, about half a mile southeast of Whittier. The formation is: Well No. 1—Soil and gravel to 70′; sand-rock and conglomerate to 300′; oil-sand and conglomerate to 400′; sandy shale to 660′. Abandoned. Well No. 2 (about 350′ south of first well)—Soil to 10′; yellow sand-rock to 20′; conglomerate to 110′; water at 170′; sandy shale to 1100′. Abandoned.

PROSPECT AND UNFINISHED WELLS IN NEWHALL DISTRICT.

Only those wells are mentioned which were drilled, or being drilled, in June, 1900.

4.2.41. *Alpine Oil Company* (of Los Angeles; R. R. McKinney, president) has two wells situated in the S.E. ¼ of Sec. 12, T. 3 N., R. 16 W., S. B. M. One of these wells is 760′ in depth. The formation penetrated is sandstone, with thin strata of shale. Oil-sand was struck at the bottom of the well. In driving the casing, water broke in and drowned out the well. When this property was visited a second well was being drilled, and a depth of 750′ had been reached.

4.2.42. *Bervelle & Bradshaw* (of Los Angeles) have a well situated in East Cañon, the south branch of Rice Cañon. Well said to be 400′ deep. No oil; much water.

4.2.43. *California Oil Company* (of Los Angeles; J. R. Thomas, president) has a well in the N.W. ¼ of Sec. 17. Formation said to be granite.

4.2.44. *Commercial Oil Development Company* (of Los Angeles; Robert McGarvin, president). This company is drilling in the N.E. ¼ of Sec. 13, about 2½ miles south of Newhall.

4.2.45. *Eureka Crude Oil Company* (of Los Angeles; J. H. Hellman, president) has a well in S. ½ of Sec. 13, T. 3 N., R. 16 W., S. B. M. This well was being drilled in June, 1900.

4.2.46. *Good Luck Oil Company* (of Los Angeles; W. W. Lowe, president) has a well in the S.E. cor. of Sec. 7, T. 3 N., R. 15 W., S. B. M. The manager stated that the following formation was penetrated: Decomposed granite to 30′; quartzose rock to 58′; blue clay to 65′; gravel to 69′; blue clay to 72′; granite and blue clay to 670′; granite and blue clay, containing traces of oil, to 675′.

4.2.47. *Iola Oil Company* (of Los Angeles; R. H. Knight, president) has a well in the E. ½ of Sec. 12, T. 3 N., R. 15 W., S. B. M., and at the time the locality was visited had been drilled to a depth of 200′. Formation said to be granite rock.

4.2.48. *New Century Oil Company* (of Los Angeles; C. W. Smith, president). When the territory was visited, this company was about to drill in the N.E. ¼ of the S.E. ¼ of Sec. 4, T. 3 N., R. 15 W., S. B. M. Formation, granitic rock.

4.2.49. *Pioneer White Oil Company* (of Los Angeles; G. W. Freeman, president) has a well in the S.E. ½ of Sec. 3, T. 3 N., R. 15 W. At the time the locality was visited this well had been drilled to a depth of 100′. Formation, granitic rock.

4.2.50. *Rice Cañon Wells* (owned by the Pacific Coast Oil Company of San Francisco) are about 3 miles southwest of Newhall. In this cañon the Pacific Coast Oil Company has drilled two wells in the N.W. cor. of Sec. 22. These wells range from 500′ to 800′ in depth. The 500′ well is a 3-bbl. well, but in the 800′ well the water could not be shut off.

4.2.51. *Rice* (*W. P.*) has a well situated on his property in Rice Cañon. In this well sandstone and shale were penetrated to a depth of 550′, when oil-sand was struck which yielded 3 bbls. of oil a day. The well was then deepened to a depth of 700′, when water was encountered.

4.2.52. *Towsley Cañon Wells.* The Graves Oil Company and others have drilled, all told, three wells in this cañon; considerable oil was struck, but the wells were abandoned on account of water.

4.2.53. *Yankee Doodle Oil Company* (of Los Angeles; H. C. Dillon, president) has a well in the N.E. cor. of Sec. 7. When visited, this well had been drilled to a depth of 200′.

4.2.54. *Zenith Oil Company* (of Los Angeles; F. A. Garbutt, president) is drilling on land of H. C. Needham, about 1¾ miles southeast of Newhall.

MISCELLANEOUS PROSPECT WELLS IN LOS ANGELES COUNTY.

Only such wells are mentioned as had been drilled, or were being drilled, in June, 1900.

4.2.55. *Arctic Oil Company* (of San Francisco) has three wells on the ranch of R. Garvey, Rapetto Hills; drilled 1897–98. One well 600′

deep, one well 1200′ deep, and one well 1100′ deep. Abandoned. Drilled by Kellerman.

4.2.56. *Bell Station Well*, at Terminal Railroad, Los Angeles County. Soil and sandy loam to 600′; gravel and water to 580′; bed of shells to 920′; gravel and water to 980′; bed of sea-shells to 1320′. At the bottom of the well the formation was gravel and sand with water. George Catey, well-driller, Los Angeles.

4.2.57. *Bluett & Mullen* (of Los Angeles) have two wells in Palomaras mining district, Castac Cañon, about 10 miles northwest of Newhall. This well is in the S.W. ¼ of Sec. 18, T. 5 N., R. 16 W., S. B. M. Formation as follows: Drift to 80′; soft sandstone to 30′; shale and sandstone to 300′; dark shale to 350′; shale and sandstone to 500′; hard shell and gray sandstone to 512′; soft, dark shale to 600′. Water was not shut off, but traces of oil were brought up by the sand-pump. Gas was struck at 500′; it burned with a flame 15′ above a 5⅝″ casing. About 10′ north of this well, a well had been previously drilled. The formation was the same as in the first recorded well to a depth of 550′. Below that depth gray and white sandstone was drilled through to a depth of 940′.

4.2.58. *Castac Oil Company* (of Los Angeles) has one 800′ well in Palomaras district, Castac Cañon, about 12 miles northwest of Newhall, which was drilled without casing. Formation, shale and sandstone. At 600′ dry asphaltum was penetrated for 20′. Abandoned.

4.2.59. *Climax Oil Company* has a well on the road to Verdugo, 1½ miles north of Garvanza, 160′ deep. Formation, sandstone. In July, 1900, this well was unfinished.

4.2.60. *Hellman Ranch Well*, about 9 miles east of Los Angeles. Formation, clay and discolored water to 140′; quartz rock to 142′ (gold bearing?). Drilled by Palmer, Los Angeles.

4.2.61. *Pacoima Oil Company* (of Los Angeles) has a well in Sec. 20, T. 3 N., R. 14 W., S. B. M., about 4½ miles north of San Fernando, Los Angeles County. Well, 800′ deep. Drilling.

4.2.62. *Rosecrans Wells.* C. E. Rosecrans has kindly given the following information concerning the wells on the Rosecrans tract, in Secs. 18 and 19, T. 3 S., R. 13 W., S. B. M., and other wells in the vicinity:

Gas wells: Well No. 1 was sunk fourteen years ago for water. Formation: Soil, sand, gravel, etc., to 100′ (water at 40′); shale to 115′ (water under the shale); black sand to 135′. Gas under high pressure was struck beneath the shale, and the water standing 40′ below the top of the casing was constantly agitated. The gas continues to force its way through 60′ of water, with a pressure roughly estimated at 35 pounds. This gas is used for lighting and cooking in a house on the Rosecrans tract. Well No. 2, a short distance northwest of No. 1, is 90′ deep; formation, similar to that of No. 1. From this well, in which the shale was not fully penetrated, a small amount of gas has escaped for more than nine years. Well No. 3, about 300′ northwest of No. 2, had a little gas in it, but it is now filled up.

Ten years ago, about 1½ miles southeast of the Rosecrans wells, on the Duncan property, in the Hayward tract, a well was drilled for artesian water, to a depth of 400′. Gas collects in this well. Brea is found in the vicinity of this well and has been used by the owner for fuel for many years.

In 1899, about half a mile west of the Rosecrans gas wells, in Sec. 18, a 4″ hole was drilled for artesian water. Formation: Soil, clay, sand, and gravel to 180′; sand-rock or shale to 195′. Owing to an accident this well was abandoned and a new well drilled 15′ away. A formation similar to that of the abandoned well was passed through to 330′, but the drill used was not strong enough to penetrate the strata below that depth. In this well below 180′ the formation seemed dry, hard, and clayey, and the shale oily. At about 197′ there was a showing of carbonaceous matter.

Recently a test well for oil was commenced in Sec. 19, about 700′ southwest of the gas wells. In this well gas was struck at about 95′ and at about 145′. At 250′ an oil-sand stratum 10′ thick was struck. At about 420′ a few feet of grayish oil-sand was encountered, and the driller stated that when drilling below this depth he saw traces of oil on the drill. At a depth of from 110′ to 220′ an abundant supply of water, which rose to within 40′ of the top of the casing, was struck.

On the Rosecrans ranch, in Sec. 23, there is an oil seepage from an irrigation well. This well is 380′ deep.

4.2.63. *Schuyler Ranch Well*, 2 miles southwest of San Dimas; 300′ deep. It is said that a small amount of oil was struck in this well. Abandoned.

4.2.64. *Sickleworth Ranch Well*, 1 mile north of Puente; 800′ deep. Formation: Tough clay; strata of sand and gravel with water at the following depths: 120′, 400′, 650′, 720′. Water stands at 54′. George Catey of Los Angeles, driller.

4.2.65. *Wells near Azusa*. Two prospect wells have been drilled. It is said that traces of oil were obtained.

OTHER PROSPECT WELLS IN LOS ANGELES CITY.

4.2.66. *Bartelow Well*, on Moulton tract, corner of East Main and Daly streets, East Los Angeles; 300′ deep; no oil. Abandoned.

4.2.67. *Chandler Wells*, northeast corner of Macy and Center streets; 775′ deep; formation, principally shale; 1½ bbls. of oil; much water. Abandoned.

4.2.68. *Maier & Zobelein Brewing Company's Well*, on Aliso near Amelia Street; 10″ pipe. Formation: Sand and gravel to 23′; wash to 76′; red sand and bituminous shale to 98′; bituminous shale to 678′; hard, silicious rock to 684′; water flowed at 825′; shale, with thin strata of limestone, 16″ to 16′ thick, to 1266′; 8″ pipe; sand and gravel to

1366′; water forced sand into pipe; yellowish gravel to 1432′; blue clay to 1454′; white gravel to 1458′; sand and shells, principally sand, to 1600′. Abandoned.

4.2.69. *Moulton Well,* on Moulton tract, corner of East Main and Daly streets; 887′ deep; formation said to be sandstone (granite and quartz). Much gas; no oil. Abandoned.

CHAPTER 3.

PRODUCTIVE OIL-WELLS IN ORANGE COUNTY.

Only those wells are classed as productive which were so in May, 1900.

4.3.1. The portion of Orange County wherein productive oil-wells have been obtained is commonly known as the Fullerton oil-field. This oil-field comprises an area on the south slope of the Puente Hills, between Brea and Soquel cañons. In May, 1900, the following oil companies were operating in this district:

4.3.2. *Brea Cañon Oil Company* (of Los Angeles; D. Murphy, president). (See Photo No. 4.) The territory of this company is situated near the mouth of Brea Cañon. When this territory was visited by the writer there was one producing well, which had proved very remunerative. It was drilled in 1899, and it is said to have yielded several hundred barrels a day during the first six months. Two other wells were being drilled. The formation is soft, sandy shale, containing much oil. A very fine-grained material, somewhat resembling quicksand, forces itself into the casing with the oil. The formation penetrated by the Brea Cañon Oil Company's wells dips to the south.

4.3.3. *Columbia Oil Company* (of Los Angeles). The territory of this company is in Sec. 5, T. 3 S., R. 9 W., S. B. M. This company has four wells; depth, 775′ to 950′; yield, 6 to 100 bbls. a day. The life of these wells may be gathered from the following data: Well No. 1, when completed in May, 1899, yielded 25 bbls. a day; in May, 1900, it yielded 6 bbls. Well No. 4, when completed in February, 1899, yielded 150 bbls. a day; in May, 1900, it yielded 100 bbls. These wells adjoin the wells of the Santa Fé Railroad Company on the east. The formation penetrated resembles that noted in the wells of the Santa Fé Railroad Company.

4.3.4. *Consolidated Olinda Oil Company* has two wells in the Fullerton district. No. 1, 1000′ deep, is a 10-bbl. well. No. 2, 1300′ deep; drilling. Formation, sandstone and shale, the latter predominating.

4.3.5. *Fullerton Consolidated Oil Company* (of Los Angeles; C. V. Hall, president). The wells of this company are in Sec. 8, T. 3 S., R. 9 W., S. B. M. Here there are two producing wells. Gravity of oil, 18° B. The formation penetrated by these wells is shown by the following records: Well No. 1: Conglomerate to 40′; clay-shale and sand to 820′ (at this depth a stratum of oil-sand a few feet in thickness was struck); clay-shale, sandy strata, and oil-sand to 165′. Well No. 2: Conglomerate to 325′; below that depth a similar formation was penetrated to that noted in well No. 1.

4.3.6. *Fullerton Oil Company,* formerly Rex (of Los Angeles; J. T. Fay, president), has five wells in Sec. 9, T. 3 S., R. 9 W., S. B. M. These wells range from 400′ to 1000′ in depth. At the time these wells were visited only one well was producing. One of these wells was used for water-supply; in one the tools had been lost and it was abandoned, and the others were in process of drilling.

4.3.7. *Graham & Loftus* (of Fullerton). The wells of this company are in the N.W. ¼ of Sections 8 and 9, T. 3 S., R. 9 W., S. B. M. In May, 1900, they had five wells 600′ to 1875′ deep. The production of these wells ranges from 6 to 122 bbls. daily; gravity of oil, 21° B. Some idea as to the life of these wells may be gathered from the following facts: One well, which yielded 25 bbls. a day when completed, ten months later yielded only 6 bbls. a day. Another well when completed yielded 200 bbls. a day; after ten days it yielded only 125 bbls. Another, which was drilled to a depth of 1465′, when completed yielded 500 bbls. the first day and 700 bbls. the second day; the yield then decreased, and after twelve months it yielded only 60 bbls. a day. The character of the formation penetrated by these wells is shown by the following well-records: Well No. 2: Yellow clay to 50′; blue clay and oil-sand to 150′; oil-sand and sandy shale to 240′; clay-shale to 300′; oil-sand to 730′; sandy shale to 965′; oil-sand with gas to 1005′; sandy shale and oil-sand to 1090′; oil-sand and shale to 1400′; oil-sand penetrated to 1465′. Well No. 3: Yellow clay to 50′; clay-shale to 300′; sandy shale to 360′; conglomerate and shale to 550′; clay-shale to 920′; sandy shale to 1130′; sandy shale and oil-sand to 1250′; oil-sand to 1370′; sandy shale and oil-sand to 1500′; oil-sand to 1565′; sandy shale and oil-sand to 1790′; oil-sand to 1875′. Mr. Loftus states that his wells are located within a few hundred feet of one another. They show a great variation in yield. He attributes this to the size of the grains forming the oil-sand. He says the fine oil-sand is the most productive.

4.3.8. *The Santa Fé Railroad Company* has nineteen wells in the Fullerton oil-field. (See Photo No. 5.) These wells range from 670′ to 1700′ in depth, and produce from 7 to 100 bbls. a day; black oil, gravity 20° B. The general character of the formation penetrated by these wells is: Conglomerate about 20′; blue clay and shale; between the depths of 400′ and 850′ the shale was interstratified with oil-sand. Below this depth the underlying formation consists of strata of shale interbedded with thin strata of limestone and oil-sand. In one well, about 2000′ southeast of the main group of wells, conglomerate was penetrated for 200′; then shale with strata of oil-sand to a depth of 1800′.

The oil from this well is of a dark-green color and shows a gravity of about 30° B. This well yields more gas than do the other wells belonging to this company. The Santa Fé wells yield enough gas to fire the steam boilers and for domestic use. The strata penetrated by the wells dip to the north, but the drilling records show that there is a great irregularity in the angle of the dip.

4.3.9. *Union Oil Company* (of Santa Paula, Ventura County) owns a large tract of land near the mouth of Brea Cañon, and in May, 1900, had drilled three wells to a depth of 200′, and the casing was full of oil; gravity of oil, 21° B. The formation penetrated appears to be a soft, sandy shale.

The Fullerton oil-field is the only producing oil-field in Orange County, and in 1899 it produced 108,077 bbls. of oil. In May, 1900, the oil from the greater portion of the Fullerton oil-field was conveyed by tank cars on a spur of the Santa Fé Railroad. The Union Oil Company had just completed a pipe-line which extends from the Fullerton oil-field to Bixby; distance, 26 miles. This is a 4″ pipe-line, and has a head of 450′. The gravity of the oil which will be run through this line averages 21° B.

CHAPTER 4.

PROSPECT WELLS IN ORANGE COUNTY.

Only such wells are mentioned as had been drilled, or were being drilled, when Orange County was visited by the writer in May, 1900.

4.4.1. *Egan Ranch Wells*, near Capistrano, in S.E. ¼ of N.W. ¼ of Sec. 36, T. 7 S., R. 8 W., S. B. M. Formation of Well No. 1: Gravel to 26′; clay to 34′; gravel and bowlders to 55′; conglomerate "cement" to 67′; sand and bowlders to 102′; black shale, with a little gas and oil, to 315′. Well No. 2 (about 1000′ northeast of No. 1): Gravel to 26′; clay to 30′; gravel and bowlders to 58′; conglomerate to 65′; black shale to 253′.

4.4.2. *Jenson Ranch Well*, near Wanda railroad station; 130′ deep. At 80′ stiff blue clay formation was struck; gas, water, traces of oil.

4.4.3. *Marius Meyer* (of Fullerton) has a well 1½ miles north of Santa Fé Springs. The formation is gravel and pebbles to 80′; clay and sand to 310′. When completed this well threw a column of gas and water and stones to the height of 300′ above the casing.

4.4.4. *Newport Oil Company's Wells* are on the shore of Newport Bay, about 1 mile north of Newport. The records of these wells are:

Well No. 1: Sand, black and white, to 50′; brownish shale to 120′; brownish clay-shale, spotted with asphaltum, to 180′; liquid asphaltum to 230′; shale, fine and coarse sand, asphaltum, to 245′; coarse, granitic white sand, to 260′; blackish shale, globules of oil, to 300′; blackish shale, little asphaltum and oil globules, to 375′; alternate streaks of shale and dark sand to 495′; white, coarse sand, to 585′; alternate strata of shale and sand, sulphureted water, to 700′; cemented sand and gravel to 702′; white sand and salty water, quicksand and gravel, to 775′.

Well No. 2: Soil to 8′; coarse yellow sand to 60′; dark shale to 220′; hard shell to 240′; black shale and sulphur water to 280′; black shale to 300′ (seepage of asphaltum); black shale to 400′; hard shell to 402′; hard shell with asphaltum to 460′; black shale to 520′; black shale to 740′; sand and salt water to 765′.

Well No. 3: Surface soil to 16′; white rock to 45′; soft shale and sulphur water to 140′; soft shale and water to 350′; soft black shale to 505′; hard black shale to 610′; hard stratum of white shale to 617′; hard black shale, salt water, to 770′; hard white rock to 773′; hard black shale to 800′; hard shale to 830′; soft blue shale to 885′.

4.4.5. *Orange County Oil Company* (of Santa Ana; W. A. Becket, president). This company is operating on the north side of Santiago Cañon, about 5 miles east of Olive, and in May, 1900, had drilled to a depth of about 500′ and found traces of oil.

4.4.6. *Puente Crude Oil Company* (of Los Angeles; E. Kendall, secretary). In May, 1900, this company was drilling a well on the east side of the Spadra road, near Brea Cañon. When this locality was visited this well had been drilled to a depth of 500′. The formation penetrated was shale and slate.

4.4.7. *San Joaquin Ranch.* Lot 284: Well drilled in 1894 by W. Manser of San Bernardino County. Formation: Soil and clay to 150′; clay to 246′; gravel and sand to 247′; yellow and red clay to 269′; black sandstone to 303′; black and white rock to 304′; blue slate to 308′; hard blue slate to 309′; blue slate, very hard, to 314′; cemented rock to 484′.

Lot 323: Well drilled in 1894 by W. Manser. Formation: Clay to 62′; gravel and water to 66′; soft clay to 102′; hard clay to 116′; clay to 124′; gravel and water to 134′; hard clay to 150′; gravel to 160′ (sand and water); clay to 214′; gravel and water to 220′; clay to 234′; gravel and water to 236′; clay to 254′; hard clay to 322′; sandy clay to 340′; gravel to 342′; clay to 350′; sand, gravel, and water to 360′ (water rose to within 23′ of top of casing); hard clay to 402′; gravel to 404′; hard clay to 416′; soft clay to 512′; hard clay to 540′; soft mud to 556′; gravel and clay to 566′; hard clay to 638′; gravel, sand, and clay to 646′; clay to 660′; sand to 672′; clay to 676′; sand with gravel to 686′; clay to 719′.

4.4.8. *Santa Ana Oil Company* has a well 1400′ deep, on east side of Newport Bay.

4.4.9. *Soquel Oil Company* has a well on the N.W. ¼ of Sec. 10, southeast of the Sante Fé Railroad Company's wells. The rocks penetrated evidently belong to the whitish sandstone formation and dip to the south. Drilling.

PHOTO 15. Concretion from Whitish Sandstone Formation, Piru, Ventura County.

PHOTO 16. Broken Concretion from Whitish Sandstone Formation,
Piru, Ventura County.

PART 5.

VENTURA COUNTY.

CHAPTER 1.

THE TERRITORY BETWEEN SESPE AND PIRU CREEKS.

5.1.1. The geological work done in Ventura County by the writer during the last campaign of the Mining Bureau consists of an examination of the formations overlying the oil-measures developed by the Union Oil Company in the Sespe district; and of an examination of certain oil-yielding rocks of Eocene age, which are referred to in Bulletin No. 11 as the lowermost oil-yielding rocks in that district. (See Fig. G.)

5.1.2. The field-work recorded in this chapter was undertaken in order to examine the formations overlying the oil-yielding rocks of the Sespe district, and to examine recent developments in the lowermost oil-yielding rocks of that district.*

5.1.3. As described in Bulletin No. 11, oil-measures of distinctively Eocene age underlie the Sespe brownstone formation, and consist of certain whitish and brownish sandstones and dark-colored shales. (See Photo No. 27.) The oil-yielding rocks exploited by the Union Oil Company in the Sespe district consist of sandstones and certain dark-colored shales which overlie the Sespe brownstone formation, and which represent the upper portion of the Eocene formation.

5.1.4. The investigation of the formations overlying the oil-yielding rocks of the Sespe district involved an examination of the territory lying between the Sespe and Piru creeks. The territory under consideration extends south and east of the Sespe district; and it is, for the most part, quite mountainous, many of the higher elevations rising to an altitude of from 2000′ to more than 3000′, and furnishing only roughest pasture. (See Photos Nos. 19, 20, 21, 22.) The mountains are traversed by numerous cañons, the principal ones being Piru Cañon, Hopper Cañon, and Pole Creek Cañon. In a general way these cañons run at an angle to the strike of the formation. (See Fig. G.)

*The greater portion of the territory in which these lowermost oil-yielding rocks are exposed is now included in a new district called the Devil's Gate oil-district.

5.1.5. Overlying the dark-colored shales of the Sespe district is a formation consisting of whitish sandstone, with some shale and conglomerate. This sandstone resembles the whitish sandstone found in the Puente Hills and at Santiago Cañon; at the latter place it contains Miocene fossils. These sandstones are characterized by calcareous concretions (see Photos Nos. 15, 16, and 23); they contain a few Miocene fossils, and in some places they are impregnated with petroleum. As shown in Fig. G, this whitish sandstone occupies a large area in the higher mountains between the Sespe and Piru creeks. It belongs doubtless to the Lower Neocene division of the Tertiary system in California.

5.1.6. The whitish sandstone is overlain by a shale formation which is very silicious and in most instances shows a calcareous reaction. (See Photo No. 17.)

The silicious character of these shales is very apparent where the erosion has been rapid, or where the slides have exposed cliffs of freshly broken strata. Where the erosion has been gradual, the shale decomposes and loses its cherty appearance, and, to a casual observer, resembles the clay-shales in the upper portion of this formation. Above the cherty shales there is a thick stratum of sandstone. (See cross-sections at Hopper Creek, Figs. 9 and 10.) Above this stratum of sandstone, the shale varies from sandy to clayey, and for the most part is either reddish or brownish in color. (See Photo No. 18.) In some places these shales exhibit a slaty cleavage, and apparently have been bleached by the action of sulphureted vapor. The physical appearance and geologic age of the clay-shales correspond to that of the clay-shale formations seen in the Puente Hills and at Los Angeles. As hereinafter described, the lower portion of this shale formation is interbedded with sandstone, which is frequently impregnated with petroleum. The writer obtained a small collection of fossils from the clay-shales which are sufficient to identify the formation as of Middle Neocene age. It is probable that the cherty shales, like the whitish sandstones which underlie them, represent the Lower Neocene in the territory under consideration.

The shale of Middle Neocene age forms the greater portion of the foothills between the Sespe and Piru creeks, and a large portion of the mountains east of Piru Creek is composed of shale and sandstone belonging to this formation.

As is elsewhere mentioned, there is reason to believe that these shales overlap the whitish sandstone formation. West of the Castac Creek, shales and sandstone, resembling in physical appearance the Neocene formations, rest on granitic rocks; and in San Francisco Cañon similar looking shales and sandstones, which contain fossils representing the Middle Neocene epoch, rest on metamorphosed sedimentary rocks.

Extending from the Tar Creek Divide almost to Piru Creek, there is a body of shale resembling the Neocene shale, and resting on the dark-

PHOTO 17. Silicious Shales, Hopper Cañon, Ventura County.

PHOTO 18. Clay-Shales, Hopper Cañon, Ventura County.

colored shales of the Sespe district. It would require a closer examination than it was practicable to give in the time at the disposal of the writer, in order to determine whether this body of shale is part of the Sespe formation or belongs to the Middle Neocene series. The writer could find no fossils in it, and, physically, it resembles the last-mentioned formation.

5.1.7. In the lowest tier of foothills between the Sespe and Piru creeks, a conglomerate formation is exposed. This conglomerate overlies the shale formation. Between the Sespe Creek and the village of Piru it may be observed only in a few places, but at Piru it forms a bluff of considerable altitude. In the foothills east of Piru Creek this conglomerate is the prevailing formation, and in some places is found resting on the shales of the Middle Neocene series. The writer obtained a small collection of fossils from this conglomerate, and Dr. Merriam refers them to the Middle Neocene epoch.

5.1.8. As stated in Bulletin No. 11, the whitish sandstone, the shale, and conglomerate formations, compose the foothills at the base of Mount Cayetana, which rises to the westward of the Arroyo Sespe, and resting on the conglomerate are sandy formations and some clay-shales containing numerous distinctively Pliocene fossils, clearly representing the Upper Neocene formation.

5.1.9. It is somewhat difficult to outline the contact between the whitish sandstone and the Middle Neocene shales, partly on account of the complexity of the geological structure, and partly because throughout a large area the upper portions of the ridges are composed of shale, while the ravines cut through into the sandstone, forming an area between the whitish sandstones and the Neocene shales in which both the sandstone and the shale formations are represented. (See Photo No. 21.)

5.1.10. Between the Sespe and Piru creeks there appear to be two systems of folds: dominant folds having a strike of east of south, such as the fold marked DD (see Fig. G), and minor folds, which have a strike east of north, the latter folds being the more numerous. These folds are described in detailed accounts given of the Piru and Hopper cañons, but the time at the disposal of the writer did not admit of their being traced through their entire length.

Between the Piru and Hopper cañons the geological structure is complicated by fault-lines extending, for the most part, in the direction of the strike of the formation. The complex folding and the fault-lines have broken up the strata into blocks, which have subsequently been tilted, causing a diversity of strike at variance with the strike of the original folds. The effect of these fault-lines will be spoken of later on. In some places it is evident that the rocks are deeply fissured, although no evidence of displacement can be observed. At some of these points sulphureted vapors have decomposed and bleached the rocks and formed deposits of sulphur. (See Photo No. 19.) This solfataric action is similar to that observed in the Puente Hills near Whittier, and at the Sulphur Mountains in Ventura County. The last-mentioned locality was described in our Bulletin No. 11.

At the point marked "Sulphur Mine" in Fig. G, about 3 miles east of Fillmore, a company exploited one of these deposits with a view of obtaining sulphur for commercial purposes. After removing the surface of decomposed and bleached rock, which was more or less impregnated with sulphur, a very thin stratum containing about 30% of sulphur was found. At a depth of 3′ the rock was too hot to be safely handled with the bare hand.

5.1.11. As previously mentioned, there are numerous evidences of petroleum in the formations overlying the Eocene rocks. In some places, notably west of Piru Creek, there are places where the whitish sandstones are more or less impregnated with petroleum, forming a dry oil-sand; and the oil-yielding strata at the Modelo and Sunset oil-wells are composed of sandstones which may be classed as belonging to this series of rocks. At the Fortuna and Piru oil-wells, the oil-yielding strata may be referred to the lower portion of the Neocene shale formation. Sandstones belonging to this series and highly impregnated with petroleum, are exposed on the Piru ranch, in Hopper and Pole cañons, and at many other places. At one point on the Piru ranch the conglomerate is impregnated with petroleum.

5.1.12. The Hopper Cañon was selected as a suitable locality at which to investigate the rocks overlying the Sespe formation, for, throughout a great portion of its course, it cuts through these rocks in a direction which is nearly at right angles to their strike. Moreover, there are two groups of producing wells in this cañon, and prospect work has resulted in trails being cut which facilitate geological research.

5.1.13. The formation and structure observed between the mouth of Hopper Cañon and the Fortuna oil-wells, are shown in Fig. 9. The first bench of the foothills to the east of Hopper Cañon is formed of conglomerate, and the dip of the strata is a little east of south at an angle of about 60°. This conglomerate rests on the Neocene shales, which are much disturbed, and which dip both east of south and west of south. The shale rests on sandstone, and this rests on hard silicious shale. At Station 132 (see Fig. 9) there is an anticlinal axis. This is the axis of fold marked BB in Fig. G. On the northern limb of this fold the silicious shale shows a thickness of more than 1500′ and is capped with sandstone. There is evidently a fault along the axis of BB, for an air-saddle drawn from the contact of the shale and sandstone on the north side of the fold would not connect with the point of contact between the shale and sandstone on the south side of the fold.

PHOTO 19. Rocks Bleached by Gas Outburst in Clay-Shale Formation, East of Fillmore, Ventura County.

PHOTO 20. Piru Peak, from Piru Cañon, Ventura County.

FIG. 9

CROSS SECTION BETWEEN STA. 200. N.E. OF BUCKHORN R.R. DEPOT, & STA. 201 NEAR BRADLEY & HUTTON'S WELL IN HOPPER CAÑON.

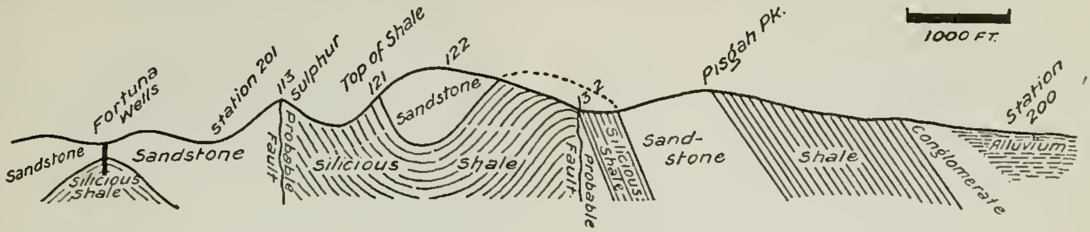


FIG. 10.

CROSS SECTION

BETWEEN HUTTON PEAK & HOPPER CAÑON

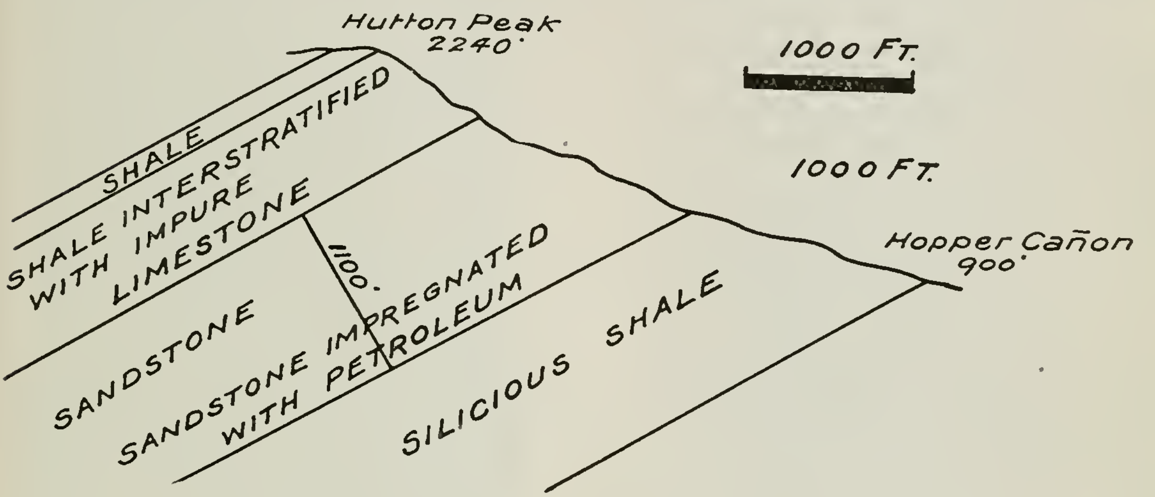
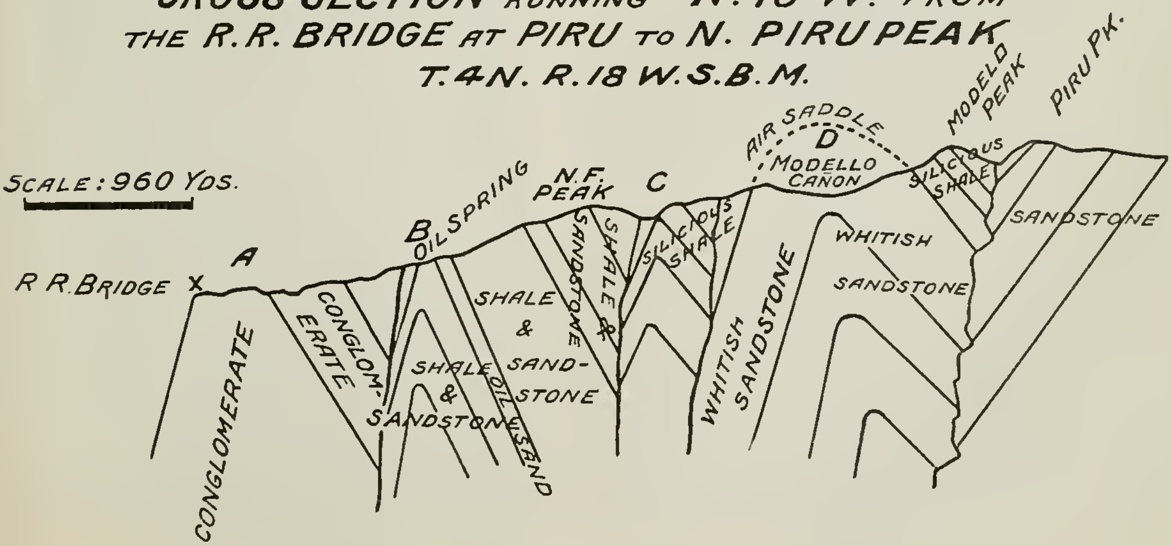


FIG. 11

CROSS SECTION RUNNING N. 10 W. FROM THE R.R. BRIDGE AT PIRU TO N. PIRU PEAK T. 4 N. R. 18 W. S. B. M.



Station 122 is on a ridge which rises to an elevation of more than 188′. This ridge is capped with sandstone, which lies on the silicious shale formation in the syncline between fold BB and a short fold marked EE in Fig. G, which latter fold lies farther to the north. Between Stations 121 and 113 the formation is silicious shale, which, in this locality, constitutes the south limb of fold EE, the dip being east of south at an angle of about 55°. At Station 113, the axis of fold EE is exposed. There is probably a fault at this point, for the rocks are decomposed by sulphureted vapor and impregnated with bituminous matter and sulphur; on the north limb of this fold the formation is sandstone. Farther to the north, another short fold is shown, marked FF. This fold has a more northerly course than folds EE and BB. Both limbs of fold FF are formed of sandstone, but it is said that in the Fortuna oil-wells, which are situated on this fold, a silicious shale resembling that shown on folds BB and EE has been penetrated for several hundred feet.

The formations immediately overlying the silicious shale may be observed at Hutton Peak, on the west side of Hopper Cañon, where an escarpment rises to an altitude of more than 2200′. (See Fig. 10.)

5.1.14. A cross-section, giving a view of the formations exposed at this point, is shown in Fig. 10. At Hutton Peak, clay-shale interstratified with impure limestone shows a thickness of 990′, and dips to the west of north at an angle of about 40°. This shale rests on a light-colored sandstone about 1100′ in thickness. The lowermost strata of this body of sandstone are more or less impregnated with petroleum. This sandstone rests on silicious shale. There is no doubt that the sandstone shown in Fig. 10 corresponds to the sandstone seen at the Fortuna wells. The formation shown in Fig. 10 corresponds to the formations underlying the conglomerate between Stations 200 and 132, Fig. 9; but in Fig. 10 the entire thickness of the clay-shale does not appear, for there is a large body of shale occupying a syncline between Hutton Peak and the point marked "Minarets" on Fig. G.

5.1.15. When this locality was visited by the writer, Messrs. Bradley & Hutton were drilling a well in the silicious shale near the axis of fold EE. Several years ago a well was drilled in Hopper Cañon near the axis of fold BB. It is said that there was a showing of oil all the way down to a depth of about 700′, but a remunerative quantity of oil was not obtained.

5.1.16. Investigations in the vicinity of Piru and Hopper cañons lead to the conclusion that the silicious shale shown in Fig. 9 constitutes either the lowermost portion of the Neocene shales previously mentioned or the uppermost portion of the Lower Neocene formation. A comparison of the silicious shales seen at the Modelo oil-wells with those in Hopper Cañon warrants the conclusion that both are of the same geological horizon. The writer has dwelt somewhat at length on these silicious

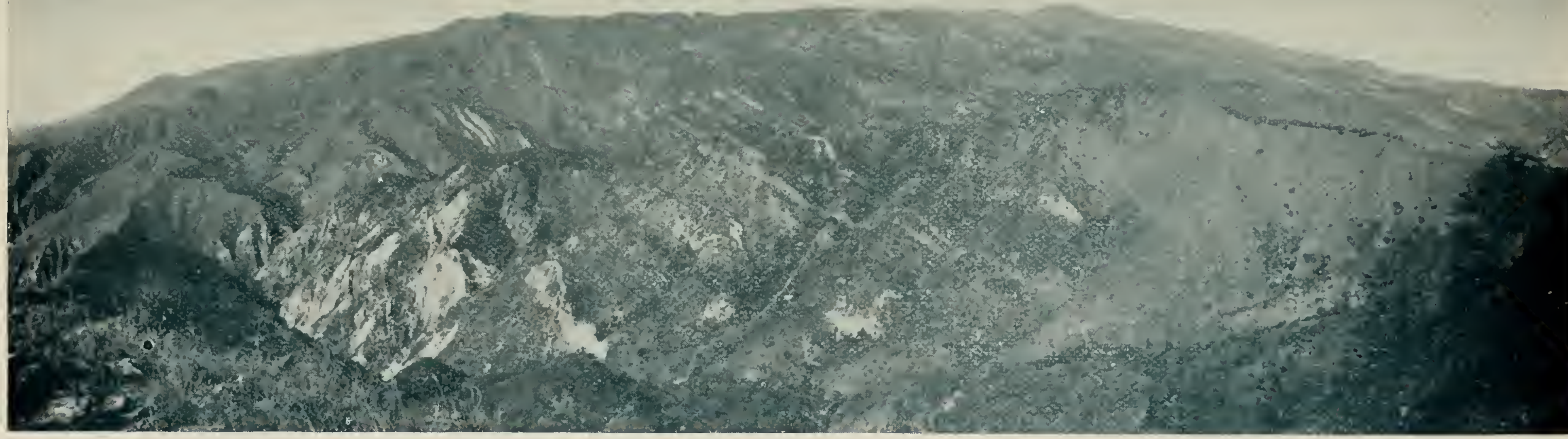


PHOTO 21. View Looking West from Modelo Peak, Ventura County, Showing Relation of Neocene Shales to Whitish Sandstone Formation.

PHOTO 22. View Looking Northwest from Piru Peak, Ventura County, Showing Relation of Neocene Shales to Whitish Sandstone Formation.

shales because they constitute a landmark in the Neocene formations of the locality under discussion, and probably correspond to the whitish shales noted in other localities.

5.1.17. Between Hopper Cañon and Piru Creek, the whitish sandstone, the shale, and the conglomerate formations are well exposed. (See Photos Nos. 21 and 22.) On San Felician Creek, near the southeast corner of the Piru ranch, a few fossils were obtained from the shales, and are referred by Dr. Merriam to the Middle Neocene epoch. (See table of fossils.) East of Piru Creek, the conglomerate forms the greater portion of the foothills. These conglomerates contain Neocene fossils, in which Pliocene forms preponderate. The pebbles forming the conglomerate are principally granitic, and contain much black mica. As a general rule, the pebbles are not very firmly cemented together.

5.1.18. At Piru Creek, and throughout the territory adjacent thereto, the writer traced the aforementioned formations. The whitish sandstone is exposed in Packard Cañon, and although it is in many places covered up with the shale overlying it, yet it can be traced westward to the main body of whitish sandstone which lies between Piru Creek and the Sespe district.

East of Piru Creek, a sandstone formation may be followed for half a mile or more. West of Piru Creek the same formation is exposed along the upper portion of Modelo Cañon, and extends thence to Hopper Cañon. There are several other points at which a whitish sandstone is exposed by faults in the formation, or by the erosion of the overlying shales. In many instances it is difficult to determine whether to regard the exposed sandstone as belonging to the whitish sandstone of the Lower Neocene, or as strata of sandstone belonging to the lower portion of the Middle Neocene, the only difference being that the Lower Neocene sandstone is harder than that of the Upper Neocene formation.

5.1.19. The typical shales of the Middle Neocene formation extend about half a mile east of Piru Creek, and northward up Piru Creek to a point about a mile north of Holser Cañon. These shales are exposed about a quarter of a mile south of Holser Cañon, and extend about half a mile farther southward. On the west side of Piru Creek the Middle Neocene shales and sandstone form the lower portion of the mountain slope between Packard and Modelo cañons; south of Modelo Cañon they constitute the prevailing formation between Piru and Hopper cañons, and west of Piru Peak they may be seen resting on the whitish sandstone formation. (See Photo No. 22.) As previously mentioned, the sandstone in the lower portion of the Middle Neocene formation is in some places more or less impregnated with petroleum. On the accompanying sketch-map of the territory between Piru and Hopper cañons, such oil-sands are marked by three stars, and oil-springs by one star. (See Fig. G.)

5.1.20. The conglomerate overlying the Neocene shales extends over a large area south and east of Piru Creek; and constitutes, for the most part, the lower foothills on the north side of the valley of the Santa Clara River between Piru and Hopper cañons.

5.1.21. The geological structure of the territory under discussion is that of closely compressed anticlinal folds, which are so modified by faulting that in some instances it would seem more appropriate to describe them as faults rather than folds; but since they are lines of disturbance along which an anticlinal structure prevails, they are herein treated as separate folds. As shown in Fig. 11, which represents a cross-section through the mountains between the railroad bridge at Piru and Piru Peak, there are four short but distinct folds in a distance of less than three miles. These folds are marked on Fig. G as AA, BB, CC, and DD, respectively.

5.1.22. The general course of folds AA, BB, and CC is about N. 75° E., while that of DD appears to be west of north. Folds AA, BB, and CC appear to be cross-folds to fold DD. The position of these folds may be noted by referring to Fig. G.

5.1.23. An inspection of Fig. 11 shows that folds AA, BB, CC, and DD are inclined folds, although fold CC shows little inclination, owing to faults at or near its axis. The general inclination of the axis of these folds is toward the south at an angle of about 10° from the vertical.

5.1.24. An investigation of these folds shows that their structure becomes very irregular as Piru Creek is approached. Some idea of this irregularity may be gathered from a short description of the lines of disturbance represented by folds AA, BB, CC, and DD.

5.1.25. Fold AA was observed only at Station 3 near the railroad bridge at Piru. If the axis of this fold were prolonged to the west, it would pass out into the valley of the Santa Clara River at Piru; if prolonged to the east, it would pass into the hills east of Piru Creek.

5.1.26. Fold BB, as observed at Station 4, is an inclined fold, its southern limb being the steepest. The axis of this fold may be followed westward from Station 4 to Hopper Creek, where the fold is upright. At Station 4, the fold is evidently faulted at its axis, the upthrow being to the north. Near Station 4, there is an oil-spring and a wide outcrop of oil-sand. The southern limb of the fold is a very short one and is inclined at a very great angle. Oil-springs are marked with one star on the accompanying map. Farther eastward along this fold, all traces of a southern dip disappear as Piru Creek is approached. The direction and angle of the dip are very irregular, and there is an immense outcrop of sand more or less impregnated with petroleum. It is not improbable that at this point fold BB is overturned; i. e., bent over toward the south to such an extent that all the strata dip toward the north.

PHOTO 23. CONCRETIONARY STRATA, WHITISH SANDSTONE FORMATION, NEAR FORTUNA OIL-WELLS, VENTURA COUNTY.

PHOTO 24. OVERTURNED FOLD, MODELO CAÑON, NEAR PIRU, VENTURA COUNTY.

Farther eastward along fold BB, the structure is very complex, and there is evidence of faulting. At Station 5 in Modelo Cañon, an anticlinal structure is seen, which lines up fairly well with the axis of fold BB; and it may not, perhaps, be too presumptuous to regard the fold at Station 5 as a continuation of that fold. Near Station 5 there is a bed of brea. Brea-beds are marked by two stars on the accompanying map. If a line were drawn from the axis of fold BB in Hopper Cañon along the line of strike in Modelo Cañon to Station 5, and then extended eastward to Piru Cañon, it would be found to reach Piru Creek not far from Station 6, where a well-defined anticlinal axis is exposed; but the inclination of this axis is to the north. (See Photo No. 34.) The rocks composing fold BB are, for the most part, shales, and contain sandstones, which, as before mentioned, constitute the lower portion of the shale formation.

5.1.27. Fold CC can be traced only a short distance west of Modelo Cañon. Near Station 7, on the north side of Modelo Cañon, an anticlinal structure is seen which coincides with the course of the axis of fold CC; but a short distance farther to the northeast the structure is that of a well-defined overturned fold. (See Photo No. 24.) The rocks constituting fold CC are shales and sandstones, the latter being exposed in the bottoms of the deep cañons.

5.1.28. Fold DD is exposed at Station 9 at the head of Modelo Cañon. (See Photo No. 33.) It is probable that the Sunset oil-wells in Hopper Cañon are situated on this fold. As previously mentioned, the Modelo wells are in the Modelo Cañon. Most of these wells are situated on the north slope of the fold, but some are on the south side. (See Photo No. 25.) The owners of the Modelo wells state that similar oil-yielding formations have been struck on both the north and the south sides of this fold. There are good reasons for believing that the strike of the axis of fold DD is west of north, and it is so marked on Fig. G. The rocks constituting fold DD are mainly whitish sandstone, which, as before mentioned, is capped with silicious shale a short distance north of the Modelo oil-wells. In some places the sandstone is impregnated with petroleum. It is said that one of the wells of the Modelo Oil Company penetrates oil-soaked sandstone for more than 500′.

5.1.29. Between fold AA and Piru Peak there appear to be four fault-lines. One of these is a short distance south of the axis of fold DD, a second is a short distance south of the axis of fold CC, a third on the south limb of fold DD, and a fourth between Modelo and Piru peaks. (See Photo No. 20.) Fig. G shows the position of the axis of fold DD, to the north of which a mass of sandstone, capped with shale, rises abruptly for about 1000′.

Reference to Fig. 11 shows that on Modelo Peak strata of shale pitch to the north at an angle of about 50°; and that on Piru Peak strata of hard sandstone pitch to the south at an angle of about 50°. Taking into consideration the relative positions of the points referred to, it is evident that displacements must have occurred. (See Photo No. 20.)

5.1.30. North of Modelo Cañon, the geological structure is complex. Both the shale and the white sandstone formations are represented. Sands impregnated with petroleum are exposed at several points, notably as follows: In Lime Kiln Cañon, where, in the whitish sandstone formation, strata showing oil-stain may be observed; at Station 13 in Piru Cañon; at Station 12 in Piru Cañon, in the shale formation; and in Packard Cañon, where the shale is decomposed and impregnated with sulphur.

5.1.31. At Station 13, at the Narrows of Piru Creek, the axis of another fold is exposed, the strike of the fold being N. 80° E., or thereabouts. The formation exposed at Station 13 is whitish sandstone, and near the axis it is impregnated with petroleum.

5.1.32. In the vicinity of Station 14, on the east side of Piru Creek, there is a notable instance of local variation in geological structure, for the direction in which the strata dip is S. 50° E. It appears that a block of strata has been affected by some earth movement, probably block-tilting, which has given the strata a more easterly dip than that which prevails in the adjacent territory. The block of strata referred to shows a maximum thickness of about 2000′, as calculated from the exposed rocks. The formation is shale and sandstone. It is overlain by conglomerate, which is exposed farther eastward. At the point referred to, nearly all the sandstone strata are, or have been, impregnated with petroleum.

CHAPTER 2.

RECENT EXPLOITATIONS OF THE EOCENE FORMATIONS ON SESPE CREEK.

5.2.1. In the foregoing chapter certain formations were referred to as being the lowermost oil-yielding rocks in the Sespe district. The territory in which prospect wells have been drilled in this formation embraces what was formerly a portion of the Sespe oil-district in the vicinity of the Devil's Gate. (See Figs. G and H.) This territory is now included in the Devil's Gate oil-district. The boundaries of the district are as follows: "From center stake of south line of Sec. 1, T. 4 N., R. 20 W., S. B. M., continuing west 6 miles; thence north 8 miles; thence east 6 miles; thence south 8 miles, crossing the Big Sespe River to place of beginning, being part in T. 4, and part in T. 5 of aforesaid meridian."

(W. Cardwell of Temple Block, Los Angeles, Recorder.) Through the above-described territory the Sespe Creek has worn a cañon, the walls of which in some places rise to the height of more than 1000′ above the bed of the stream as shown in Bulletin No. 11, published by the California State Mining Bureau, Part 2, Chapter 1, Paragraphs 17 and 18. The formations which have been cut through by the Sespe Creek in the territory referred to consist of the Sespe brownstone formation, and an underlying formation consisting of a series of whitish and buff-colored sandstones and dark-colored shales; all these rocks being of Eocene age. (See Photo No. 27.)

As stated in Bulletin No. 11 (see Part 3, Chapter 2, Paragraphs 7 and 14), the writer is of the opinion that the formation underlying the Sespe brownstone contains a distinct oil-yielding horizon. When he investigated the Sespe district in 1896, he found oil-springs in this formation at the following places: On the Redstone Peak anticline, at Tar-Hole, near the Devil's Gate, and at the oil-wells then owned by the California Oil Company—all in the Sespe district; also at Echo Falls, north of the Silverthread oil-district.

In 1896, the only wells penetrating this formation were two on the Razzle Dazzle claim in the Sespe district, then belonging to the California Oil Company, and two abandoned wells of no great depth in Echo Cañon north of the Sisar Valley. At this writing, four wells have been drilled on the property formerly owned by the California Oil Company. These wells vary from 700′ to 1100′ in depth, and are said to produce about 1000 bbls. of oil a month.

As described in Bulletin No. 11, an anticlinal fold, the axis of which is well exposed at the head of Coldwater Cañon, may be traced eastward through the Tar-Hole claim and the Razzle Dazzle oil-claim. The southing of the axis of the fold between the Tar-Hole claim and the Razzle Dazzle is principally due to the fact that the south limb of the fold is much steeper than the north limb, and that the Razzle Dazzle is situated at a considerably greater elevation than the Tar-Hole claim.

5.2.2. The wells on the Razzle Dazzle claim, which are now operated by the Big Sespe Oil Company, penetrate formations immediately underlying the Sespe brownstone formation. (See record of Big Sespe Oil Company.)

5.2.3. The wells which are being drilled by Henley, Crawford & Co. are situated on the Tar-Hole and Mile-Square claims, respectively. These wells penetrate rocks which lie at a depth of more than 500′ below the Sespe brownstone. (See Photo No. 27.) The well sunk on the Tar-Hole claim is in the S.E. ¼ of Sec. 35, T. 5 N., R. 20 W., S. B. M. It is on the east bank of the Sespe Creek and north of the Devil's Gate. The drilling record of this well shows that the following strata were penetrated: Reddish shale to 80′; reddish shale with heavy oil to 132′; blue shale and whitish sandstone to 240′; hard white sandstone (fissured) to 420′; blue shale and whitish sandstone to 562′. Enough gas to run a 30 H. P. boiler was struck at a depth of 382′. This well yielded about 40 bbls. of heavy oil a day. All the oil came from the reddish shale between the depths of 80′ and 132′. After well No. 1 had been drilled, well No. 2 was commenced. As shown in Fig. H, both these wells are situated near the axis of a fold. This fold was described in Bulletin No. 11 as the Coldwater Cañon fold. (See cross-section in Fig. H.)

Mr. Henley, who has made a careful study of the formations exposed at and near the last-mentioned wells, states that they are composed of the following strata:

Red shales	Sespe brownstone formation.
Fine-grained, dark-brown sandstone (good building-stone)	
Thick-bedded conglomerate and brown sandstone	
Red, oil-bearing shales	
Pearl-colored sandstones	Formation underlying Sespe brownstone.
Blue shales with strata of whitish sandstone	
Oyster shells. (This formation yields some oil.)	
Red shale	
White coarse sandstone	
Red shales (oil)	
Whitish sandstone	

5.2.4. There are several springs of petroleum issuing from the formations exposed in the Sespe Cañon to the north of the Henley & Crawford wells. Oil-claims have been located as far north as the Redstone Peak anticline. On the Sulphur Spring claim there is an extensive seepage of petroleum from strata of shale immediately underlying the Sespe brownstone formation. It is probable that this petroleum has its source in the same strata as those which yield the petroleum found on the Razzle Dazzle claim. North of the Sulphur Spring claim, the Sespe Creek traverses the syncline between the Coldwater and Redstone anticlines, and there appears to be a cross-fold running nearly north and south, the axis of which is cut through by the Sespe Creek. All the seepages along the Sespe Creek come from the formation immediately underlying the Sespe brownstone. Where the Sespe Creek has cut through the axis of the Redstone Peak anticline, there are springs of warm water accompanied by petroleum.

5.2.5. From the foregoing it appears that the rocks exposed in the territory between the Sespe and Piru creeks may be classed as follows:

First—Eocene rocks. These include the light-colored and whitish sandstones underlying the Sespe brownstone, the Sespe brownstone, certain drab sandstones, and dark-colored shales. In this series of rocks there are two horizons in which petroleum has been discovered: (1) In the formations underlying the Sespe brownstone and in the lower strata of the brownstone formation; (2) In the upper strata of the Sespe brownstone formation, in the drab sandstones, and in the dark-colored shales. These formations were described in Bulletin No. 11, Part 2, Chapter 1.

Second—Lower Neocene (Miocene) rocks. These include a series of whitish sandstones, shales, and conglomerates, the whitish sandstone predominating. Petroleum is found in this formation at the Modelo and the Sunset oil-wells; and at several points these sandstones are more or less impregnated with petroleum.

Third—Middle Neocene formations. These include silicious shales, sandstones, clay-shales, and conglomerate, the shales predominating. In this series, petroleum is found in the sandstones interstratifying the lower portion of the shale formation. Petroleum is found in this formation at the Fortuna oil-wells and on the Piru ranch.

It is admitted that in California the Neocene formations lie non-conformably on the Eocene rocks, although the non-conformability is not everywhere apparent. The thickness of the formations mentioned is a difficult problem, owing to complex geological structure, and to our ignorance as to the amount of erosion which has taken place; still, some approximate estimates are in order. Thus, if the outcrop of the Eocene formations is traversed from the Sespe Creek to the bottom of the whitish sandstone, one might be led to assign to the Eocene formations exposed in the Sespe district a thickness of about 2 miles. In such case there is no doubt that the true thickness would be exaggerated, the great apparent thickness being due to faulting. If the whitish sandstone (Lower Neocene) formation is traversed from the Sespe Creek to the Agua Blanca Creek, the thickness might be estimated at nearly 1 mile, but in this case, also, the apparent thickness is exaggerated by faulting. It is probable that that portion of the Neocene series which includes the silicious shales, the sandstones immediately overlying them, and the clay-shales, is at least 5000′ in thickness.

CHAPTER 3.

PRODUCTIVE OIL-WELLS IN VENTURA COUNTY.

(Record made in June, 1900.)

5.3.1. The productive oil-fields on the south side of the valley of the Santa Clara River in Ventura County are: The Tapo Cañon field; the field operated by the South Pacific Oil Company in Eureka Cañon; the Torrey Cañon field; and the Bardsdale field. These oil-fields are situated, in the order in which they are named, on a ridge of mountains between the Santa Clara and Simi valleys. The writer has not made a detailed examination of the formations penetrated by the wells in these fields, but the character of the exposed rocks leads to the conclusion that, for the most part, they belong to the Neocene shale formation described in this Bulletin.

The productive oil-fields on the north side of the Santa Clara Valley, in Ventura County, are: That operated by the South Pacific Oil Company on the south slope of Mount Cayetana; the Sespe district; the Hopper Cañon; that operated by the Modelo Oil Company in Modelo Cañon, and a portion of Piru Cañon. The wells in the Sespe district receive their oil from rocks of Eocene age. All the other remunerative wells on the north side of the valley of the Santa Clara River receive their oil from the lower portion of the Neocene series.

The productive oil-fields of the Santa Paula district are: The Ex-Mission oil-field, in which are the Adams Cañon, the Salt Marsh, the Wheeler, and the Scott & Gilmore wells; the Silverthread field, in which are the wells of the Los Angeles Transportation Company, the Bard, and the Astarte wells. This district includes also the Mark Jones or O'Hara wells on the east side of Santa Paula Creek. As stated in Bulletin No. 11, there is some doubt as to the age of the oil-yielding formations in the Santa Paula district. The character of the exposed rocks, however, warrants the assumption that most of the wells in the Santa Paula district receive their oil from the rocks belonging to the lower portion of the Neocene series.

PRODUCTIVE OIL-WELLS ON THE SOUTH SIDE OF SANTA CLARA RIVER.

5.3.2. *Tapo Cañon Oil-Wells* (Union Oil Company of Santa Paula, Ventura County, owners) are situated on the San Francisco ranch. This cañon is tributary to the Santa Clara Valley, and the wells are situated about 2 miles southeast of Camulos. The territory here named was developed during 1897–98–99, but produced no oil until 1900. In April, 1900, there were twelve wells in Tapo Cañon, varying from 300′ to 600′ in depth; yield about 300 bbls. a month; gravity of oil, 14.5° B; character of formations, sandstone and shale. It is said that less than half of these wells are productive. In Tapo Cañon there is one well 750′ deep, situated about a quarter of a mile south of the twelve wells previously mentioned. In April, 1900, this well was unfinished, but some oil had been struck. There is a 1200′ tunnel in Tapo Cañon, but it was abandoned, because, as the writer was informed, there was too much gas to allow of its completion.

5.3.3. *The South Pacific Oil Company* (of Los Angeles). The wells of this company (formerly belonging to the Eureka Company) are about 2 miles south of Piru in Lime Kiln Cañon, which is a tributary of the Santa Clara Valley. Here are fifteen producing wells, from 240′ to 850′

deep. In these wells oil was struck at a depth of from 85′ to 850′, and the yield of the wells varies from 5 to 60 bbls. of oil a day, the total amount being about 1600 bbls. a month. Some idea as to the life of these wells may be gathered from the fact that a few of the best wells started off at a yield of 60 bbls. a day, but after two years dropped to 20 bbls. a day. Seven men are employed at these wells. The gravity of the oil varies from 20° to 30° B.

5.3.4. *The Torrey Cañon Wells.* Torrey Cañon is a tributary of the Santa Ana Valley, and the wells here referred to are situated about 3 miles south of Piru. In May, 1900, four crews were drilling in this cañon, where there are now thirty-two producing wells, six having been abandoned. These wells vary from 500′ to 2000′ in depth; yield about 1500 bbls. a month, not counting the oil consumed at the wells for steam purposes. The gravity of the oil is about 28° B.

5.3.5. *The Bardsdale Wells* (Union Oil Company of Santa Paula, owners) are about 3 miles southwest of Fillmore, on the south side of the Santa Clara Valley. They are twenty-four in number, from 500′ to 1600′ in depth, and are said to yield about 6000 bbls. a month. Gravity of oil, about 28° B.

PRODUCTIVE OIL-WELLS ON THE NORTH SIDE OF THE VALLEY OF THE SANTA CLARA RIVER.

5.3.6. *The South Pacific Oil Company* (of Los Angeles). The wells of this company (formerly Loma oil-wells) are situated on the south slope of Mount Cayetana, about 4 miles east of Santa Paula. Here there are four producing wells from 600′ to 1200′ deep; yield said to be 1800 bbls. a month; gravity of the oil, 33° B.

5.3.7. *The Sespe District* is in the mountains on the north side of the valley of the Santa Clara River. The wells in this district, owned or controlled by the Union Oil Company, include the Kentuck, the Little Sespe, Four Forks, and the Tar Creek oil-wells. Here there are fifty-three wells, about twenty-two of which are productive. They yield about 6000 bbls. of oil a month; gravity of the oil varies from 27° to 35° B.

5.3.8. *Big Sespe Oil Company* (of Los Angeles, formerly the California Oil Company). The wells of this company are in the Sespe district. There are four wells from 600′ to 1000′ deep, and they yield 1000 bbls. of oil a month.

5.3.9. *Fortuna Wells* (Buckhorn Transportation Company, owners; A. Smith, of Los Angeles, president) are in Hopper Cañon about 2 miles north of Buckhorn Station. In April, 1900, this company had eleven producing wells, varying from 90′ to 600′ in depth; monthly yield, about 800 bbls.; gravity of oil, about 13.5° B.

5.3.10. *Sunset Oil Company's Wells* (Clark, Sherman & Co. of Los Angeles, owners) are in Hopper Cañon about 3 miles north of Buckhorn Station. In April, 1900, this company had five wells, varying from 300′ to 600′ deep; monthly yield, about 500 bbls.

5.3.11. *Piru Oil Company* (of Piru, Ventura County) has three wells on the Temescal ranch near the mouth of Piru Cañon. These wells are from 400′ to 900′ deep. The formation is shale and sand. Total yield, 6 bbls. a day; gravity of oil, 20° B. Thirty men are employed at the Torrey Cañon wells. These wells yield enough gas for pumping, but not for drilling.

PRODUCTIVE OIL-WELLS IN THE SANTA PAULA DISTRICT.

5.3.12. *The Ex-Mission* group of wells is situated on the south slope of the Sulphur Mountains. As previously mentioned, this group includes the Adams Cañon, the Salt Marsh, the Wheeler, and the Scott & Gilmore wells. These wells are all either owned or controlled by the Union Oil Company, there being in all fifty-five wells, of which about thirty-seven are producing, and are said to yield about 2250 bbls. a month; gravity of oil, 25° to 30° B.

5.3.13. *Adams Cañon Oil Wells* (Union Oil Company of Santa Paula, owners) are about 6 miles northwest of Santa Paula and on the south side of the Sulphur Mountains. There are in the Adams Cañon thirty-five wells, varying from 130′ to 360′ in depth. The deepest well was drilled in 1900. Below the depth of 500′ the temperature in this well increased, and during the latter portion of the work the tools became too hot to be handled with the bare hands. The gravity of the oil in Adams Cañon is 26° B.

5.3.14. *The Salt Marsh Wells* are 1 mile west of Adams Cañon. Here are twelve wells, varying from 200′ to 2100′ in depth; gravity of oil, about 26° B. The oil was struck in a muddy, whitish sand.

5.3.15. *The Wheeler Cañon Wells.* No product.

5.3.16. *Scott & Gilmore Wells* are eighteen in number, and are from 200′ to 1000′ in depth; gravity of oil, about 23° B. There are thirteen men employed on the Ex-Mission leases. It is said that there are on the Ex-Mission grant fifty-four tunnels, which yield, all told, about 250 bbls. a month.

5.3.17. The wells of the Silverthread district are situated on the north side of the Sisar Valley. They include the wells of the Capitol Crude Oil Company, the Sisar Oil and Asphalt Company, and the Astarte wells.

5.3.18. *The Capitol Crude Oil Company's Wells* (Los Angeles Transportation Company, Los Angeles, owners) are situated on the north side of the Simi Valley. Here there are fifteen wells, eleven of which are productive, yielding about 1200 bbls. a month.

5.3.19. *The Bard Wells* adjoin the Capitol Crude Oil Company's wells on the west. Here there are twelve producing wells, which yield about 1200 bbls. a month.

5.3.20. *The Astarte Wells* (Union Oil Company of Santa Paula, owners). Five of these wells are productive, yielding 1000 bbls. a month; gravity of oil, about 21° B. Two men are employed.

5.3.21. *Mark Jones Oil Company* (O'Hara) wells are on the southwest slope of Mount Cayetana. Here there are five wells, said to produce about 400 bbls. of oil a month.

THE NORDHOFF DISTRICT.

5.3.22. *The Peri Oil-Wells* (Union Oil Company of Santa Paula, owners) are situated 1 mile west of Nordhoff. Here there are five wells, but it is said that only one of them is productive, yielding 2 bbls. a day. The formation is sandstone.

CHAPTER 4.

PROSPECT WELLS AND PROSPECTING IN VENTURA COUNTY.

(Many other prospect wells have been commenced in Ventura County since the writer visited that county in May, 1900.)

5.4.1. *Berkeley Oil Company* (E. North, superintendent). In June, 1900, this company commenced operations in Leckler Cañon.

5.4.2. *Bradley & Hutton* (of Los Angeles) have one well in Hopper Cañon, about 1½ miles north of Buckhorn railroad station. In May, 1900, this well was 1000′ deep. Formation, silicious shale.

5.4.3. *Calleguas Wells* (Union Oil Company of Santa Paula, Ventura County, owners). In 1898 and 1899, thirty-two wells were drilled on the Calleguas ranch, about 12 miles south of Santa Paula, at the west end of the Simi Valley. The formation is said to be volcanic tuff. Oil was struck at a depth of from 150′ to 200′, and the wells appeared to promise a large production. Below the oil-yielding strata, water was struck, which displaced the oil, forcing it through some formation which has not yet been traced. This oil was orange color; so, also, was the residuum resulting from distillation, but when exposed to the air, the residuum blackened in a few days. The gravity of the oil is 14° B.

5.4.4. *Crude Oil Company* has a well situated on the ranch of M. Fine, about 1½ miles northwest of Fillmore. This well is 580′ deep, and is situated in Sec. 24, T. 4 N., R. 20 W., S. B. M.

5.4.5. *East Piru Oil Company.* In June, 1900, this company commenced operations in Leckler Cañon.

5.4.6. *Henley, Crawford & Co.* (of Sespe, Ventura County) have two wells in Sespe district a short distance north of the Devil's Gate. Well No. 1 is on the east side of Sespe Creek. Shale and sandstone of the Eocene age were penetrated to a depth of 562′. It is said that this well would yield 4 bbls. of heavy oil, but it is not pumped. Well No. 2 is on the west side of Sespe Creek. In this well the formation is similar to that penetrated by well No. 1, with traces of oil. In May, 1900, well No. 2 was 300′ deep.

5.4.7. *Kellerman Oil Company* (of Los Angeles) has two wells in Nigger Cañon, about 1 mile north of Piru. The first well is said to be about 900′ deep, and to be capable of yielding a few barrels of oil a day. This well is drilled on the axis of fold marked BB in Fig. A. The second well is drilled about 300′ north of the old well. It was not completed in June, 1900.

5.4.8. *McIntyre & Co.* (of Fillmore, Ventura County) have a well on the west bank of Sespe Creek, in the S.E. ¼ of the S.W. ¼ of Sec. 12, T. 4 N., R. 20 W., S. B. M.

5.4.9. *Nuevo Camulos Oil Company* has a well 950′ deep in Holser Cañon, about 3 miles northeast of Piru. Formation, shale and sandstone, with traces of oil. This well was not completed in June, 1900.

5.4.10. *Piru Oil Company* (of Piru, Ventura County) has a well on Fig Hill, Temescal ranch, and one at the Temescal ranch house. Formation of Fig Hill well: Adobe and shale to 20′; gravel to 35′; tough clay to 55′; hard shale to 90′; hard rock to 100′; sharp sand to 130′; soft sand to 170′; soft, fine sand to 355′; water; adobe and sand to 417′; shale to 432′; oil-sand to 452′; not specified to 597′; sand and shale to 620′; shells and sand to 665′; caving sand to 695′; soft sand to 715′; adobe to 740′; sand to 760′; adobe to 795′; hard sand to 800′; caving sand to 810′; hard sand to 821′; shale to 827′; running sand to 840′; oil-sand to 1030′; brown shale to 1035′; oil-sand to 1195′. This well yielded a small quantity of heavy oil, probably about 2 bbls. a day.

Formation of well at Temescal ranch house: Shell and shales, and broken oil-sand to 550′; black shale to 610′; hard oil-sand to 615′; black shale and oil-sand to 650′; black shale and shells to 675′; oil-sand and shale to 725′; hard shale to 730′; fine oil-sand to 788′; flinty shell to 790′; shale to 795′; oil-sand to 825′; oil-sand and shells to 840′; hard shells and sand to 868′; coarse sand to 900′; sand, shale, and conglomerate to 1200′. A small quantity of heavy oil was found in this well.

5.4.11. *Ramona Oil Company.* In June, 1900, this company was drilling at a point 4 miles northeast of Piru.

5.4.12. *Santa Ana Oil Company.* In June, 1900, this company was drilling at a point about 1 mile north of Piru.

5.4.13. *Western Oil Company* (of Pasadena; G. H. Coffin, secretary) has a well on the Ayers ranch, 9 miles northwest of Ventura. In June, 1900, this well was said to be 500′ deep, and to have struck a small quantity of oil. At that date it was not completed.

5.4.14. *Ranch No. 1* (Cora C. Howe, owner), located 9 miles north of Ventura. In June, 1900, a well was being drilled at the western end of Sulphur Mountain on this ranch.

5.4.15. *Santa Ana Ranch.* In June, 1900, a well was being drilled on this ranch by Messrs. Clark, Markham & Sherman, and others. It is situated on the south side of San Antone Creek, about 8 miles northeast of Ventura.

5.4.16. During the current year (1900) there has been much exploration of the more inaccessible portions of Ventura County in search of oil-lands, and trails have been cut over brush-covered mountains which heretofore have been almost inaccessible even to travelers on foot. One of the most interesting territories that has attracted the attention of the oil-prospector in Ventura County is Anacapa Island.

5.4.17. *Anacapa Island.* This island, which is about 25 miles north of Ventura, comprises an area of about 1140 acres. It has been located as oil-land by E. L. Barnard of Ventura, and others. It is said that there are numerous springs of bitumen and heavy oil on this island, and that oil rises from the ocean at several points adjacent to its shores. The formation is said to be sedimentary and eruptive rock.

PART 6.

SANTA BARBARA COUNTY.

CHAPTER 1.

THE SUMMERLAND OIL-FIELD, AND PRODUCTIVE WELLS IN SANTA BARBARA COUNTY.

6.1.1. In this county, the Summerland oil-field and the property of the Occidental Oil Company is the only oil-bearing territory yet developed, but prospect wells drilled in various portions of the county encourage the hope that the oil-fields of Santa Barbara County will eventually be found to be quite extensive.

6.1.2. There has been great development in the Summerland oil-field since it was reported on by the writer in 1896. In 1895 there were only 28 producing wells, with a production for that year of rather less than 1700 bbls. In June, 1900, there were more than 300 producing wells, and the annual production for 1899 was about 208,000 bbls.

The development of the Summerland oil-field has corroborated the opinions concerning it expressed by the writer in Bulletin No. 11, published by the State Mining Bureau in 1896; and the field has been extended in the directions suggested by the geological examinations recorded in the bulletin referred to. It is, however, somewhat remarkable that the oil-field has not been extended farther along the strike of the formation. The greatest development has been made in the direction of the dip, which necessitated the building of wharves into the ocean, from which numerous wells have been drilled. (See Photo No. 26.) This corroborates the statement made by the writer in Bulletin No. 11, p. 54, that the oil-yielding formations at Summerland extend south into the ocean. (See Fig. I.)

6.1.3. In drilling beneath the water, a casing larger than that needed for the drill-hole is put down to the floor of the ocean and forced into the bedrock until the ocean water is securely shut out of the drill-hole. This is called a conductor, and the casing of the well is put down inside of the conductor.

6.1.4. In wells sunk on the shore-line, the formation is yellow clay to 100′; sand with water to 120′; blue clay to 150′; sand with water to 180′; blue clay to 230′; oil-sand to 280′ (the oil from this strata shows a gravity of 12° to 14° B.); blue shale to 300′, and oil-sand to 400′.

The wells drilled beneath the ocean commence in blue clay. Along the shore-line the dip of the oil-sand varies from a few degrees east of south to a few degrees west of south, and the angle of the inclination is about 40°. At a distance of 300′ from high-water mark, the oil-sand was found to be lying nearly flat and to inclose pockets of clay. At a distance of about 600′ from the shore-line, a third bed of oil-sand was found overlying the uppermost stratum of oil-sand which had been penetrated near the shore.

6.1.5. The stratification of the oil-sand and the inclosing rocks, as shown by the well records, leads to the conclusion that the stress to which these formations have been subjected has produced great irregularity of structure. It is probable that the oil-yielding formations at Summerland belong to the Middle Neocene series, and that they rest non-conformably on the silicious shales of the Lower Neocene, which are exposed in the ridge of hills immediately north of Summerland, and near Carpinteria, about 6 miles to the east of Summerland. (See Bulletin No. 11, Part 3, Chapter 1.)

6.1.6. The depth of most of the Summerland wells ranges from 150′ to 300′. There are a few which are between 400′ and 500′ in depth, and there is one well which is 600′ deep. The cost of these wells is generally about $1 a foot, not including the cost of casing.

6.1.7. In June, 1900, there were at Summerland 305 producing wells, 59 abandoned wells, and 15 well-sites at which drilling operations had been commenced. These wells yield from 1 to 60 bbls. of oil a day, the average yield being 5 bbls. a day. The value of the oil in 1899 was 90 cents a barrel, f. o. b. at Summerland. The cost of production is said to range from 25 to 35 cents a barrel. The gravity of the oil varies from 10° to 16° B. Nearly all the lighter oils come from the deepest wells. The oil from the shallower wells contains a high percentage of water and sand.

6.1.8. The following is a list of companies engaged in oil-mining at Summerland in March, 1900, together with a statement of the number of productive wells:

OIL-PRODUCERS—SUMMERLAND OIL-FIELD.

Names.	No. of Wells.	Names.	No. of Wells.
Alameda O. & D. Co.	6	Oxnard Oil Co.	11
Baker, Geo.	2	Robinson	34
Churchill Bros.	11	Santa Barbara Oil Mining Co.	21
Duncan, J. T.	12	Seacliff Oil Co.	18
Duquesne Oil Co.	21	Seaside Oil Co.	34
Hancock & Parsons	3	S. P. Oil Co.	12
Lillis, J. C.	19	Steel, A. M.	2
Loomis, W.	5	Sunset Oil Co.	22
Miller, H. R.	6	Treadwell, J. B.	19
Miller, T. F.	5	Wilson, J. C.	34
Moore, W. M. S.	19	Williams Estate	9

6.1.9. As previously mentioned, many of the wells at Summerland are drilled beneath the ocean. They are connected with the mainland by wharves. (See Photo No. 26.) The length of these wharves is given in the following table:

NAMES OF OWNERS OF WHARVES IN SUMMERLAND.

(Record made in March, 1900.)

Duncan, J. T.	230′	Oxnard Oil Co. (branch)	340′
Duquesne Oil Co. No. 1	628′	S. P. Oil Co. No. 1	520′
Duquesne Oil Co. No. 1	305′	S. P. Oil Co. No. 2	520′
Lillis, J. C.	560′	Sunset Oil Co.	405′
Lillis, J. C.	340′	Treadwell, J. B.	1230′
Oxnard Oil Co.	734′	Weber, Churchill	336′

6.1.10. *The Occidental Oil Company* (of Santa Barbara) has six wells and one oil-tunnel in the Santa Ynez Mountains about 5 miles northeast of Summerland. It is said that only one of these wells is pumped, and that this well, together with the oil-tunnel, yields about 50 bbls. a month.

CHAPTER 2.

PROSPECT WELLS IN SANTA BARBARA COUNTY.

Only such wells are mentioned as had been drilled, or were being drilled, in June, 1900.

6.2.1. *Arctic Oil Company* (of San Francisco). Well No. 1, 7 miles south of Rincon Creek, 1825′ deep; formation, red sandstone; no oil. Well No. 2, 50′ distant from well No. 1, 2100′ deep; formation, red sandstone; no oil. Well No. 3, on the S. P. R. R., 1¼ miles east of Carpinteria; conglomerate and sandy shale to 700′; shale and sandstone to 1200′; liquid asphaltum; well abandoned.

6.2.2. *Buel Ranch Well*, 5 miles west of Santa Ynez; 900′ deep; much gas. Formation: soft white rock to 35′; asphaltum to 235′; shale and a little water to 470′; black sand to 480′; sand and water to 505′; shale and water to 510′, and quicksand and water. Water rose to within 40′ of the surface. Well abandoned. In June, 1900, a second well had been commenced.

6.2.3. *Careaga Well*, on Los Alamos ranch, about 6 miles west of Los Alamos. In September, 1900, the writer was informed that oil had been struck at a depth of 1140′.

6.2.4. *Casmalia Well* (M. Calligan, superintendent) is situated in

PHOTO 25. MODELO OIL-WELLS, VENTURA COUNTY. (Photo taken in 1898.)

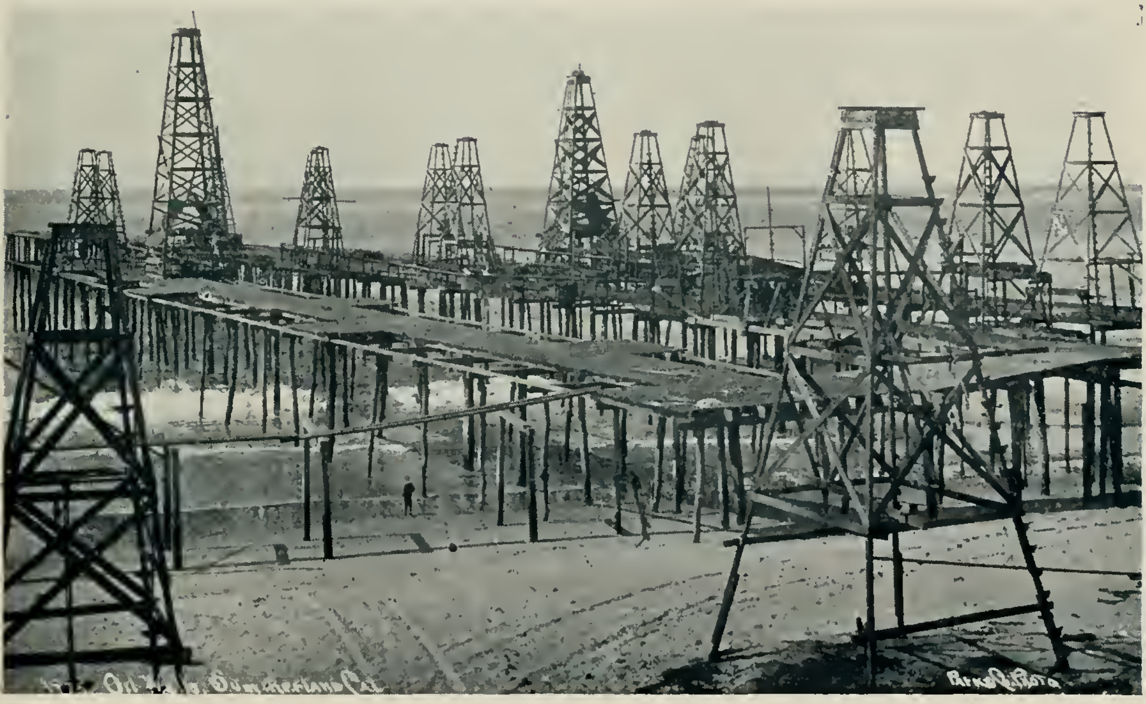


PHOTO 26. VIEW ON SHORE-LINE, SUMMERLAND OIL-FIELD, SANTA BARBARA COUNTY.

Schuman Cañon, about 3 miles northeast of Casmalia station, on the S. P. R. R. In July, 1900, this well was 200′ deep. The formation is said to be a chalky-looking rock and shale. Drilling.

6.2.5. *Den Ranch Wells*, 3 miles west of Goleta. It is said that three wells have been drilled to a depth of between 200′ and 500′. Said to be abandoned.

6.2.6. *J. Heath* (of Carpinteria, Ventura County) has a well on the Hill ranch, on seashore near the mouth of Rincon Creek. Formation, shale to a depth of 400′. It is said that oil was struck at a depth of 150′, more oil showing as the well was deepened.

6.2.7. *Illinois Oil and Asphalt Company* (of Santa Barbara; A. L. Nelson, manager) has a well on seashore at Montecito. Formation: Yellow clay and sand to 200′; gas, blue clay, and quicksand to 260′; blue shale to 280.′ In June, 1900, this well was unfinished.

6.2.8. *Robinson Well*, on Joe Martin's ranch on seashore near Serena. Abandoned.

6.2.9. *Santa Barbara and Naples Oil and Land Company* (of Santa Barbara; E. W. Hayward, president). The territory operated by this company is about 15 miles west of Santa Barbara, near the seashore. In June, 1900, this company was drilling a well, the formation penetrated being principally shale to a depth of 450′, with some showing of gas and oil.

6.2.10. *Stevens, Clark & Duncan Well*, at Loon Point, about 1 mile east of Summerland; 500′ deep. Water and traces of oil. Abandoned.

6.2.11. *Treadwell Well*, on seashore between Loon Point and Serena. Said to be 500′ deep. Traces of oil. Abandoned.

PART 7.

THE SAN JOAQUIN VALLEY.

CHAPTER 1.

GEOLOGICAL SKETCH.

7.1.1. As is well known, the San Joaquin Valley constitutes the southern portion of the Central Valley of California. It is bounded on the east by the Sierra Nevada Mountains, and on the west by the Coast Ranges. The productive oil-fields that have been developed in this region are in the foothills of the Coast Ranges and the lowermost foothills of the Sierras at the southern extremity of the San Joaquin Valley. (See Fig. M.)

7.1.2. The formations to which the oil-yielding rocks of the San Joaquin Valley belong are the Eocene (Cretaceous B) and the Neocene; the latter formation having been deposited during an era which embraced the Miocene and Pliocene periods. Of recent years, geologists have decided that it is best to include the Miocene and Pliocene formations of California under the head of Neocene, and to divide the Neocene formations into the Upper, Middle, and Lower Neocene. The Eocene rocks are for the most part rather hard sandstones and dark-colored shales, with some strata of hard limestone. The sandstone is characterized by numerous concretions. In this formation are the most important beds of coal known in California. The only place in the Central Valley where valuable oil-measures have been developed in this formation is at Oil City, near Coalinga, on the western side of the San Joaquin Valley in Fresno County. At Oil City, an oil, remarkable for its low specific gravity, has been obtained from formations underlying rocks containing fossils of Eocene (Tejon) age.

7.1.3. At the time these rocks were deposited, the coast-line of California was east of the area now occupied by the foothills of the Sierras. The Central Valley of California was covered by the ocean, and the Coast Ranges were only partly elevated above the water. The early Neocene times must have been a period of depression, which allowed the deposition of the shale formation over a great portion of this region of the State. During the latter part of the Neocene epoch there was a marked period of elevation.

7.1.4. The Lower Neocene formations consist of a series of sandstones and shales containing Miocene fossils, and a series of shales which are remarkable inasmuch as they are composed principally of silica. In places they appear to be made up largely of diatomaceous remains. The exposed rocks are usually bleached, and they are sometimes found to be either white or whitish for a considerable depth below the surface. Professor Lawson, who has studied these shales, believes that they are made up largely of volcanic ash ejected by the volcanic eruptions which prevailed in California during the Neocene period. These shales are interbedded with numerous strata of chert and cherty limestone. They also contain a few strata of sandstone and diatomaceous earth. The sandstones are usually more or less impregnated with petroleum. In many places springs of heavy, tar-like bitumen issue from these shales, forming beds of impure asphaltum. Wells sunk in this formation in most instances yield a heavy, tar-like oil, and some of the wells drilled in the shales near Oil City yield an oil of medium gravity. There is little doubt that the Lower Neocene rocks rest non-conformably on the Eocene formations, for we find them resting on different material in different portions of the Coast Ranges. In most cases, however, they rest on the Eocene rocks, and very frequently it is difficult to detect any absolute non-conformability between the Lower Neocene and the Eocene rocks at their points of contact. In some places, as at the Sunset oil-wells in Kern County, the whitish shales show a thickness of several thousand feet. In the San Joaquin Valley these shales form a conspicuous feature in the scenery throughout a large portion of the foothills of the Coast Ranges. The only fossils found in the shale by the writer are marine diatoms, scales and bones of fish, and casts of *Pecten peckhami*, a Lower Neocene (Miocene) fossil.

7.1.5. Resting with apparent non-conformability on the colored shales are the Middle Neocene formations, in which are the most important oil-measures yet developed in the San Joaquin Valley. These are composed of a series of comparatively soft sandstones, bluish shales, and clay strata. The Middle Neocene formations contain numerous fossils, which, in point of age, range from Miocene to Recent. Collections of fossils were made from these formations in the foothills near Coalinga, in the Kettleman Hills, in the lower foothills of the Coast Ranges at Mud Creek in the San Emidio ranch, and at other places on the western side of the valley; specimens were also found in the lower foothills of the Sierras in the Kern River district. (See Bulletin No. 3.) A study of the Middle Neocene rocks in the direction of their vertical range shows a preponderance of Miocene fossils in the lower portion of the formation, and of Pliocene in the upper portion.

On the eastern side of the San Joaquin Valley, the Neocene rocks differ somewhat in character from those forming the foothills of the Coast

Ranges. The sandstones are interbedded with clay, and are made up largely of granitic material; volcanic ejectamenta appear also to have contributed to their composition.

The evidence of non-conformability between the Lower and Middle Neocene formations noted by the writer in the San Joaquin Valley is as follows: At Oil City near Coalinga, the whitish shale is very much disturbed; it stands at an angle of from 40° to nearly vertical, while the overlying formations are for the most part very little disturbed, and stand at an angle of less than 20°. East of the coal mines at Coalinga, sandstones containing fossils of Middle Neocene age rest on rocks which evidently belong to the Eocene series, although no fossils were found therein, and there is no intervening formation of white shale. On the east side of the valley, rocks containing fossils referable to the Middle Neocene age rest on granitic rocks. Moreover, in one place, at least, on the western side of the valley, the Middle Neocene rocks were found to contain fragments of bleached silicious shale. Throughout the greater portion of the San Joaquin Valley, the Neocene formations are covered with alluvium. These formations are evidently many thousands of feet thick, but the rocks are so covered with alluvium that it is difficult to determine the extent to which faults may have increased the apparent thickness.

7.1.6. The relation of the Neocene formations to the Eocene rocks is illustrated by Figs. K, L, 12, and 14. As recorded elsewhere in this Bulletin, a non-conformability between the Neocene and Eocene formations is observed in Los Angeles, Orange, and Ventura counties. The question of conformability and non-conformability between the Eocene and Neocene formations is very important. If the Neocene formations rested conformably on the Eocene, the oil-prospector would know that there might be a good chance of finding oil in the formations immediately underlying the Lower Neocene rocks, even though the Eocene rocks did not crop out at the surface.

7.1.7. The Neocene formations on the eastern side of the valley are much less disturbed than those on the western side. On the eastern side they are usually inclined at a very slight angle, generally less than 15°, while on the western side the inclination is seldom less than 20°, and sometimes as high as 70°. The reason of this is that the earth-movement which so greatly disturbed the rocks of the Coast Ranges at the close of the Neocene period, affected but slightly the Neocene formations in the foothills of the Sierras. The development of the remunerative oil-field at Kern River, on the eastern side of the San Joaquin Valley, where the formations are so slightly disturbed, warrants the assumption that other localities may be found where oil-yielding rocks which have been subjected to but very little disturbance form a wide and extensive oil-line. The place to look for such conditions is on the east side of the San Joaquin Valley. As previously stated, a great drawback to prospecting in the lowermost foothills of the San Joaquin Valley is alluvium, which to a great extent covers the Neocene formations. It is also possible that comparatively undisturbed Neocene formations may be found in the foothills of the Sierras to the south of Tehachapai Pass.

CHAPTER 2.

PETROLEUM IN KERN COUNTY.

7.2.1. During the past two years there has been great development in the oil-yielding formations of Kern County, on both the eastern and western sides of the San Joaquin Valley. (See Fig. J.) On the western side numerous productive wells have been drilled in the Sunset oil-district and the McKittrick district. On the eastern side of the valley an extensive and promising oil-field has been developed in the Kern River district.

The geological formations in these localities were described by the writer in Bulletin No. 3, published by the California State Mining Bureau in 1894. Since there are still numerous demands for this bulletin, which is out of print, the writer feels that it is in order for him to quote liberally from what he then wrote.

7.2.2. "Petroleum and gas-bearing formations are found on both sides of the San Joaquin Valley in Kern County. In the Sunset oil-district and at Asphalto, on the western side of the valley, the petroleum and gas-yielding rocks are extensively exposed, and oil and asphaltum industries are carried on. In the Sunset oil-district there are also deposits of sulphur and gypsum. On the eastern side of the valley oil, bituminous matter, and gas are found, notably in T. 29 S., R. 28 E., M. D. M. Inflammable gas is found at the Barker ranch in Sec. 5, T. 29 S., R. 28 E., M. D. M. On the eastern side of the valley the showing of hydrocarbons (as indicated by the outcropping rocks) is insignificant when compared with that of the western side. This may be accounted for in part by the fact that, as previously mentioned, the geological disturbance of the Tertiary rocks of the western side is very great, while on the eastern side it is very slight. On the eastern side of the valley the Tertiary formation is well represented, as shown by the fossils collected in the vicinity of the Rio Bravo ranch. The writer obtained a small collection of fossils at the San Emidio ranch from strata overlying the formations which yield oil in the Sunset district, and a few from the oil-yielding rocks themselves."

"The numerous Pliocene fossils collected near the Rio Bravo ranch led to the conclusion that the formation exposed in that vicinity is more recent than at San Emidio, although it would not be safe to assert such a generalization without obtaining a greater number of specimens from both localities. It is probable that Tertiary strata underlie the more recent formations in the valley lands of Kern County, unless there has been a much greater erosion of the Tertiary rocks than there is any reason to suspect." According to recent nomenclature, the fossiliferous rocks at Mud Creek, in the foothills of the Coast Ranges, and at Kern River, in the foothills of the Sierras, may be referred to the Middle Neocene series.

"As may be seen by examining the record of the strata penetrated by the wells which have been sunk for water in the valley lands of Kern and Tulare counties (see our XIth Report, pp. 233, 485), the recent filling of the valley appears to contain sufficient clayey strata to serve as a cover under which gas could be stored in underlying porous formations. A review of the situation, therefore, warrants the opinion that deep borings in the valley lands of Kern County would be quite likely to penetrate gas-yielding and possibly oil-yielding strata." As shown in the Bulletin from which the above quotations are made, the geological formations in the foothills of the Sierras at Kern River are of similar age to the rocks forming the first bench of foothills of the Coast Ranges at Mud Creek, on the western side of the San Joaquin Valley.

7.2.3. It is not surprising that evidences of petroleum should be found in the outcropping rocks of both localities, and that the discoveries of petroleum at Sunset and McKittrick were a prelude to the development of the Kern River oil-field.

CHAPTER 3.

KERN RIVER OIL-DISTRICT.

7.3.1. During the past twelve months an extensive and promising oil-field has been developed near the Kern River on the eastern side of the San Joaquin Valley in Kern County. (See Fig. J and Photo No. 28.) It is interesting to note that the initial developments in this field were made in a township to which attention had been drawn by the California State Mining Bureau, on account of the evidences of petroleum therein contained. Indeed, the outcrop of bituminous sand which led to the drilling of the first well in the Kern River oil-field was described, and its position noted, in the VIIth Report of the California State Mining Bureau, page 63, and in Bulletin No. 3 on "The Oil and Gas Yielding Formations of the Central Valley of California."

The Kern River oil-field, as far as it has been developed, comprises an area of about 12 square miles, and is situated partly in T. 28 S., R. 27 and 28 E., and partly in T. 29 S., R. 28 E., M. D. M. Within

PHOTO 27. Sespe Brownstone and Underlying Formations, Looking Southeast from Tar Hole, Sespe Cañon, Ventura County.

PHOTO 28. Kern River Oil-Field, from the South Bank of Kern River, Kern County.

this area in August, 1900, about 130 wells had been drilled, and many others had been commenced. These wells are drilled in groups, and some of the groups are nearly a mile apart. The depth of these wells varies from 450′ to more than 1000′. The formation penetrated is: First, alluvium or drift, which in few places exceeds 50′ in thickness; then a stratum of blue clay from 25′ to 350′ thick; beneath the blue clay is a water-sand from 10′ to 100′ in thickness; beneath the water-sand the formation consists of alternate strata of clay and sand. The well records show that most of these sands contain oil, and that in some instances they aggregate a thickness of more than 300′. The records shown in the accompanying table give an idea of the formation penetrated in the Kern River oil-field.

TABLE OF WELL RECORDS

Showing Formations Penetrated in the Kern River Oil-Field.

Reed Crude Oil Co.	*Reed Crude Oil Co.*	*Petroleum Center Oil Co.*	*Independent Oil and Development Co.*
Sec. 34, T. 28, R. 28.	Sec. 34, T. 28, R. 28.	Sec. 8, T. 28, R. 28.	Sec. 28, T. 28, R. 28.
Drift 30′	Drift 25′	Drift 50′	Sand and clay 450′
Blue clay 384′	Blue clay 315′	Clay and sand 300′	Oil-sand 550′
Water-sand 391′	Brown sand 400′	Oil-sand 450′	
Blue clay 450′	Oil-sand 480′		
Dry oil-sand 475′	Blue clay 495′		
Blue clay 500′	Oil-sand 588′		
Dry oil-sand 530′			
Blue clay 570′			
Oil-sand 643′			
Blue clay 658′			
Oil-sand 698′			

Gardner Oil Co.	*Comet Oil Co.*	*Canfield Oil Co.*	*Sacramento Oil Co.*
Sec. 26, T. 28, R. 27.	Sec. 28, T. 28, R. 28.	Sec. 29, T. 28, R. 28.	Sec. 29, T. 28, R. 28.
Sand and a few streaks of clay, water, and traces of oil 720′	Drift and blue clay 240′	Drift and blue clay 250′	Drift and blue clay 400′
	Oil-sand 380′	Conglomerate 300′	Water-sand 500′
	Cement 480′	Blue clay 360′	Blue clay 515′
	Oil-sand 720′	Oil-sand 725′	Oil-sand 730′

Graves Oil Co.	*Globe Oil Co.*	*Comet Oil Co.*	*Continental Oil Co. of Los Angeles.*
Sec. 29, T. 28, R. 28.	Sec. 30, T. 28, R. 28.	Sec. 30, T. 28, R. 28.	Sec. 29, T. 28, R. 28.
Drift, etc. 380′	Drift, etc. 300′	Drift and blue clay 390′	Drift, etc. 340′
Dry oil-sand 450′	Water-sand, blue clay, and dry oil-sand 550′	Water-sand 470′	Oil-sand 352′
Oil-sand 520′	Blue clay 580′	Blue clay 562′	Oil-sand and clay streaks 800′
Clay and shale 570′	Oil-sand 831′	Oil-sand 962′	Oil-sand, very rich 848′
Oil-sand 620′			Not through sand.
Clay and shale 627′			
Oil-sand 710′			
Clay and conglomerate 714′			

TABLE OF WELL RECORDS—Continued.

Spillacy, Wood & Co.	*Century Oil Co.*	*Petroleum Center Oil Co.*	*Shasta Oil Co.*
Sec. 30, T. 28, R. 28.	Sec. 24, T. 28, R. 27.	Sec. 24, T. 28, R. 27.	Sec. 14, T. 28, R. 27.
Oil-sand at 700′	Drift and reddish sandstone 300′	Sandy clay 200′	Volcanic ash 10′
	Cemented sandstone 330′	Soft sandstone 400′	Granitic sand 115′
	Brea 331′	Clay, sand, and water 775′	Blue clay and sand 170′
	Blue clay and sandstone 400′	Oil-sand; still drilling.	Shaly, sticky clay 190′
	Oil-sand 402′		Coarse blue sand 200′
	Hard-sand 452′		Coarse sand and blue clay 270′
	Clay 472′		Conglomerate, sand, and water 470′
	Water-sand; unfinished.		Conglomerate and gas 515′
			Water-sand 695′
			Clay 710′
			Water-sand 750′
			Sticky clay and oil and much gas 760′

These records were kindly furnished by the companies mentioned.

It is a difficult matter to estimate the thickness of oil-sand strata in a well which is yielding oil, especially when the formation is caving; but some of the operators in the Kern River field state that they have estimated the thickness of the oil-sand in their wells by carefully casing off all the strata as they went down, and that they found the oil-sand to be more than 300′ in thickness. It is unlikely that the oil-sands in the Kern River oil-field will prove of uniform thickness or uniformly saturated with petroleum, but the development at this date indicates that the Kern River oil-field is the largest developed oil-field in California.

The owners of the wells in the Kern River field state that their wells will produce from 40 bbls. to more than 100 bbls. of oil a day. Owing to lack of transportation, there has not been a sufficiently continuous production to warrant a definite statement by the writer as to the yield of the wells in this field. The oil is a black oil, and it is said to have a gravity of from 14° to 17° *B*. Much running sand accompanies the oil. Some companies separate the sand from the oil by running both into a slump-hole, where the sand settles; the oil is then pumped from the surface. Other operators pump the oil and sand into flumes furnished with riffles which are from 4″ to 8″ in height. The flumes are from 80′ to 300′ in length, and the riffles are from 8′ to 14′ apart, according to the grade of the flume. In a few instances, the oil is of such gravity that it has to be steamed in the well before it can be pumped. In a general way it may be said that there is very little gas in the Kern

River oil-field, although in some instances it is claimed that enough gas could be collected to supply fuel for steam purposes. The gas appears to be held in solution in the oil, and separates from it when brought to the surface.

In August, 1900, a spur was run from the main line of the S. P. R. R. to the Kern River oil-field.

7.3.2. There are very few rock-exposures in the Kern River oil-field. These show strata of clay and soft sandstone. The sandstone is light-colored and formed principally of granitic material. These rocks resemble the formations which may be seen resting on the granite a few miles northeast of the oil-field.

Between the oil-field and the granite the sandstone contains fossils which identify the formation as Middle Neocene. The best rock-exposures seen in the oil-fields are on the bank of Kern River, in Sec. 2, T. 29 S., R. 28 E., M. D. M. At this point strata of sandstone, somewhat impregnated with petroleum, dip to the west of south at an angle of less than 10°. It is difficult to estimate the precise direction of the dip of the oil-sand, even when the depth at which the oil-sand was struck has been given. The reasons of this difficulty are: First, it is impossible to tell whether or not the first oil-yielding stratum referred to in the different well records is the same stratum; second, it is evident that the strata vary in thickness within a short distance; third, the angle of the dip is so slight that it is necessary to use the records of wells which are far apart for the purposes of calculation; fourth, there is every reason to believe that the strata penetrated in the Kern River oil-field undulate.

Notwithstanding the difficulties referred to, the writer collated the well records kindly furnished him by the well owners in this oil-field. From these records it appears that in the northern portion of the field the strike of the oil-sand is about N. 30° W., the dip being S. 60° W. at an angle of less than 10°; and in the southern portion of the field, the strike is about N. 70° W., the dip being S. 20° W. at an angle of less than 10°. It is probable that N. 60° to 70° W. is the prevailing strike of the Neocene formations in the Kern River district.

7.3.3. In August, 1900, when the Kern River district was visited by the writer, the Kern River might be said to bound the developed portion of the Kern River oil-field on the south and east. The rock-exposures on the banks of the river show no evidence of any fault or line of geological disturbance to which the course of the channel of the Kern River might be attributed, and the terraced banks of the river indicate a long period of gradual erosion. There is a reasonable probability, therefore, that remunerative oil-yielding formations will be discovered on the south side of Kern River.

7.3.4. The history of the discovery of the Kern River oil-field is as follows: In June, 1899, J. Elwood & Sons dug a well on the ranch of Thomas Means near the outcrop of oil-sand mentioned in the VIIth Report of the California State Mining Bureau as being on the north side of the Kern River in Sec. 3, T. 29 S., R. 28 E., M. D. M. The Elwood well showed some oil at a depth of 35′. It was drilled with a hand auger to a depth of 60′, and yielded half a barrel of heavy oil a day.

In June, 1899, Elwood & Sons contracted with M. McWhorter to drill a well on Sec. 3, near the well which they had dug. At a depth of 350′ a 20-bbl. well was obtained. In July, 1899, E. R. Doheny & Butler organized the Petroleum Development Company, and purchased the land on which the discovery well had been drilled. This company drilled a 500′ well, which yielded 40 bbls. a day. In the same month, J. B. Treadwell sunk a well on the S. ½ of Sec. 3. This well was 450′ deep and remunerative.

Many other parties then commenced drilling. In December, 1899, the Kern River Oil Company drilled a well on Sec. 4, T. 29 S., R. 28 E., M. D. M. This well is 600′ deep, and yielded an oil of 14° B. specific gravity. It showed the extent of the oil-territory. There was a great rush to locate oil-claims, and every available piece of land adjacent to the discovery well was rapidly taken up.

7.3.5. The Barker ranch lies immediately north of the developed portion of the Kern River oil-field. Several prospect wells have been drilled on this ranch, as herein recorded. Up to August, 1900, no oil has been struck in these wells; but considerable quantities of gas, which from its odor is composed largely of sulphureted hydrogen, have been encountered. (See Barker Ranch, Prospect Wells.)

7.3.6. Active prospecting is also being carried on at Poso Creek, which is about 7 miles north of Kern River; and some shallow wells have been drilled on Cottonwood Creek, which empties into the Kern River about 7 miles east of the Kern River oil-field. In August, 1900, the writer could not learn that oil had been struck at either of these localities. (See prospect wells on Poso and Cottonwood creeks.)

7.3.7. The following is a list of operators in the Kern River oil-district in September, 1900, together with a statement of the number of drilling wells, completed wells, and derricks:

LIST OF OPERATORS IN THE KERN RIVER OIL-FIELD, SEPTEMBER 1, 1900.

Sec.	T.	R.	Names of Operators.	Drilling Wells.	Oil-Wells Completed	Derricks.
3	29	28	J. B. Treadwell	3	19	22
......	29	......	Petroleum Development Co.	2	15	20
......	29	......	San Joaquin Oil Development Co.	1	1	6
2	29	28	Petroleum Development Co.	----	1	1
......	29	......	Reed Crude Oil Co.	----	----	1
......	29	......	Hercules Oil Co.	1	----	1
4	29	28	Petroleum Development Co.	1	1	2
4	29	28	Revenue Oil Co.	----	5	5
......	29	......	Central Point Consolidated	1	8	10
......	29	......	Four Oil Co.	1	1	2
......	29	......	Kern River Oil Co.	1	4	6
......	29	......	Aztec Oil Co.	2	6	12
......	29	......	Grand Central Oil Co.	----	1	1
5	29	28	San Joaquin Oil and Development Co.	3	5	12
......	29	......	Monte Cristo Oil and Development Co.	2	2	5
20	28	28	Atlas Oil Co.	1	----	1
......	......	......	Reed Crude Oil Co.	1	----	2
28	28	28	Reed Crude Oil Co.	4	6	14
......	28	......	Comet Oil Co.	1	1	3
......	28	......	Independent Oil Co.	1	2	4
......	28	......	Petroleum Center Oil Co.	1	3	4
......	28	......	California Mutual Oil Co.	1	----	1
......	28	......	Kern Oil Co.	----	1	1
29	28	28	Graves Oil Co.	2	2	4
......	28	......	Sacramento Oil Co.	2	2	5
......	28	......	Canfield Oil Co.	2	4	7
......	28	......	Continental Oil Co., Los Angeles	1	1	3
30	28	28	Green & Whittier	1	2	3
......	28	......	Gem Oil Co.	1	----	1
......	28	......	Globe Oil Co.	1	2	5
......	28	......	Spillacy & Woods	2	----	3
......	28	......	Mt. Diablo Oil Co.	1	1	2
31	28	28	Senator Oil Co.	3	1	4
......	28	......	Green & Whittier	1	----	1
......	28	......	Fresno and Hanford Oil Co.	----	----	1
......	28	......	Sterling Oil Co.	1	2	4
......	28	......	Peerless Oil Co.	1	4	6
32	28	28	Reed Crude Oil Co.	1	2	6
......	28	......	Kern Oil Co.	1	1	4
......	28	......	West Shore Oil Co.	1	4	6
33	28	28	Imperial Oil Co.	2	2	5
......	28	......	Thirty-three Oil Co.	2	15	17
34	28	28	Reed Crude Oil Co.	1	6	11
......	28	......	Sol. Jewett	----	1	1
2	28	28	C. F. Gardner	1	----	----
26	28	27	Wm. Dingee, Jr.	1	----	----
24	28	28	Santa Barbara and Kern County Oil Co.	1	----	----

PROSPECT WELLS ON THE BARKER RANCH.

7.3.8. *Barker Ranch Development Company* (J. Dalzell, president) has two wells in Sec. 5, T. 29 S., R. 29 E., M. D. M. In well No. 1, the formation penetrated is as follows: Gravel and drift to 23′; brown shale to 33′; yellow shale to 63′; clay to 93′; blue shale to 340′; then a hard stratum of blue sand to 506′. This well yields warm flowing, sulphureted water and gas. In well No. 2 the formation penetrated is as follows: Clay to 10′; light-colored clay and diatomaceous earth to 40′; limestone and shale to 41′; diatomaceous earth to 90′; hard shell (the term "shell" is used by the drillers to signify a thin stratum of hard rock) to 91′; blue clay to 199′; hard shell to 200′; blue clay to 215′; hard shell to 216′; blue clay to 320′; soft shale to 321′; blue clay to 460′; hard shell to 468′; blue sand to 509′; hard shell to 514′; blue sand to 542′; hard shell to 557′; blue clay and sand to 573′; shell to 574′; blue clay to 601′; shell to 609′; blue sand to 617′; shell to 622′; blue clay to 630′; shell to 631′; clay and sand to 640′; clay to 658′; clay and bowlders to 668′; cemented sand to 678′; black shale to 685′; sand and bowlders to 701′; hard shell to 704′; hard shale to 706′; bowlders to 707′; hard shell to 708′; clay to 711′; hard shell to 715′; sand and yellow clay to 743′; hard shell to 743½′; bowlders to 747′; sand to 765′; yellow clay to 778′; clay and sand to 802′; hard shell to 812′; blue clay and bowlders to 819′; shell to 825′; blue sand to 828′; dark-blue clay to 866′; blue clay to 872′; hard shell to 874′; blue clay to 876′; hard shell to 880′; yellow clay to 890′; shale to 896′; hard shell to 910′; soft blue shale to 916′; shale to 959′; blue shale to 969′. Drilling. No water.

7.3.9. *Beaver Oil Company* has a well in the S.E. ¼ of Sec. 36, T. 28 S., R. 28 E., M. D. M.

7.3.10. *Rio Bravo and White Range Oil Company* has a well near the west line of the N.W. ¼ of Sec. 30, T. 28 S., R. 29 E., M. D. M.

PROSPECT WELLS ON COTTONWOOD CREEK.

7.3.11. *Mount Adelaide Oil and Mining Company* (of Bakersfield; James P. Dougherty, president) has a 150′ well on the N.W. ¼ of Sec. 18, T. 29 S., R. 30 E., M. D. M.; also one 215′ well on the S.E. ¼ of Sec. 18, T. 29 S., R. 3 E., M. D. M.

PROSPECT WELLS ON POSO CREEK.

7.3.12. *Bachelors Oil Company* (of San Francisco) has a well near the center of Sec. 20, T. 27 S., R. 28 E., M. D. M.

7.3.13. *Cosmopolitan Oil Company* (of San Francisco; W. Gregg, president) has a well in the center of Sec. 32, T. 27 S., R. 29 E., M. D. M. Formation, blue clay and sand to a depth of 1033′. Drilling.

7.3.14. *Defiance Mineral Company* (of Bakersfield) has a well in the S.E. ¼ of Sec. 12, T. 27 S., R. 28 E., M. D. M.

7.3.15. *New Hope Oil Company* has a well on the S.E. ¼ of Sec. 29, T. 27 S., R. 27 E., M. D. M.

7.3.16. *Twenty-two Oil Company* has a well on the S. ½ of Sec. 22, T. 27 S., R. 27 E., M. D. M.

7.3.17. *Vishnu Oil Company* (of San Francisco; W. Gregg, president) has one well in Sec. 19, T. 27 S., R. 29 E., M. D. M. Formation, clay and sand with good water, which rose to within 100′ of the top of the casing. Drilling. This company has also a well in Sec. 30, T. 27 S., R. 29 E., M. D. M. Formation, blue clay, shale, and sand. Good water rose to within 110′ of the top of the casing. This company has also a well in the N.E. ¼ of Sec. 2, T. 28 S., R. 28 E., M. D. M.

PHOTO 29. Pacific Coast Oil Company's Wells, Pico Cañon, Los Angeles County.

PHOTO 30. Sunset Oil-Field, Kern County.

CHAPTER 4.

THE SUNSET OIL-DISTRICT.

7.4.1. The first locators of claims in the Sunset oil-district were the grantors of the Sunset Oil Company of Tulare. In January, 1890, the Sunset Oil Company leased their oil-claims in the Sunset district to Charles Barnard, who assigned a half interest in his lease to Messrs. Jewett & Blodget of Bakersfield, and eventually sold them his entire interest in the Sunset district.

7.4.2. Messrs. Jewett & Blodget sunk a group of thirteen wells, all within an area of about 400′ by 30′. These wells varied from about 80′ to 500′ in depth, except one well, which was 1300′ deep. These wells yielded, all told, about 15 bbls. a day, the gravity of the oil being about 12° B. A second group of wells was drilled by Messrs. Jewett & Blodget, about a mile southeast of their first wells. This group consisted of three wells from 820′ to 1350′ deep, and yielded about 15 bbls. of oil a day, with much water. The gravity of the oil was about 16° B.

7.4.3. Messrs. Jewett & Blodget also refined the asphaltum from the superficial deposits of the Sunset district. They used the heavy oil as flux. The refinery consisted of open kettles, and the refined product was shipped by team to Bakersfield, a distance of about 40 miles. The expense of transportation led to the suspension of the enterprise.

7.4.4. Messrs. Jewett & Blodget then sunk sixteen wells and three shafts in Sec. 13, T. 11 N., R. 24 W., S. B. M., and Sec. 18, T. 11 N., R. 23 W., S. B. M., and other wells were drilled as hereinafter recorded. (See Photo No. 30.) (See record of producing and prospect wells.) In August, 1900, it was said that there were eighteen producing wells in the Sunset district. The product of these wells is being refined by Messrs. Jewett & Blodget in their refinery in the Sunset district. (See Refineries.)

7.4.5. The Sunset oil-district is situated on the southwest side of the San Joaquin Valley about 40 miles from Bakersfield. (See Photo No. 30.) This district embraces T. 32 S., R. 23 and 24 E., M. D. M.; T. 12 N., R. 23 and 24 W., S. B. M.; T. 11 N., R. 22 and 23 W., S. B. M.; also that portion of T. 11 N., R. 24 W., S. B. M., lying east of the western boundary of Kern County; and includes the first two tiers of foothills of the Coast Ranges. The two tiers of foothills mentioned commence in the most northeasterly portion of the Temblor Mountains, and extend in a southeasterly direction until they sink in the mesa land between the foothills and the valley. (See Atlas, Figs. J, K, and M.)

7.4.6. The rocky strata throughout the foothills of this portion of the Coast Ranges are generally obscured by soil, which, except in dry seasons, is productive of fair grazing during the spring. There is no potable water in the Sunset oil-district, although there are numerous saline springs. To the south of the district, tier after tier of mountainous ridges rises toward the dominant ridge of the Tehachapai range, as this portion of the Coast Ranges is named on the Kern County map. The northeastern slope, and the greater portion of the summit slope of the Tehachapai range, are covered with alluvium. On the summits of these mountains there are not only grazing, but also agricultural lands. Potable water is found in springs and also by digging in the bottoms of ravines; and, although, as the writer is informed, several dry wells are often dug before water is obtained, the water-supply, except in dry seasons, appears to be sufficient for the requirements of the inhabitants.

7.4.7. The rocky formations which impinge on the southern portion of the Sunset oil-district constitute the mountainous ridges previously mentioned on the northeastern slope of the Tehachapai range. These ridges are, for the most part, formed by faults and minor folds in the stratified rocks supplemented by erosion. The strike of this formation, in a general way, is northwesterly. No fossils were found in this formation, but its lithological character resembles that of the San Emidio Cañon, where a small collection of fossils was obtained. Dr. J. G. Cooper found these to consist of two orders: (*a*) Fossils from thick sandstone strata, which are referred by him to the Tejon group of the Eocene age, formerly called Cretaceous B; (*b*) Miocene fossils, also from thick sandstone strata. As previously mentioned, the Miocene and Pliocene formations are grouped under the head of Neocene.

7.4.8. The rocky formations of the Sunset oil-district will now be enumerated in what appears to be the order of their relative stratigraphical superposition. (See Fig. 12.) The geological periods to which they respectively belong can only be inferred from the few poorly preserved fossils obtained in this locality, and from the physical resemblance of the rocks themselves to the rocks of other formations on the eastern slope of the Coast Ranges, which are richer in palæontological evidence. The oldest rocks exposed in the Sunset oil-district consist of sandstone, calcareo-silicious rocks and impure limestone, dark-colored shales, massive light-colored shales showing a hackly fracture, strata of sandstone with rounded concretions, calcareous sandstones, and fine calcareous conglomerate. The exposures of formation are scarce, and the few that exist show great geological disturbance. Within short distances, the strata frequently dip in opposite directions and at different angles of inclination; the prevailing dip, however, appears to be northeasterly. This formation yields springs of sulphureted brines, and in one place a small quantity of greenish oil accompanies the brine, but no calcareous tufa nor any solid bituminous deposit is formed. No fossils were found in these strata. The most characteristic features

FIG. 12

SECTION SHOWING APPROXIMATELY THE MAXIMUM THICKNESS OF LIGHTCOLORED SHALES EXPOSED IN THE SUNSET OIL DIST. KERN CO.

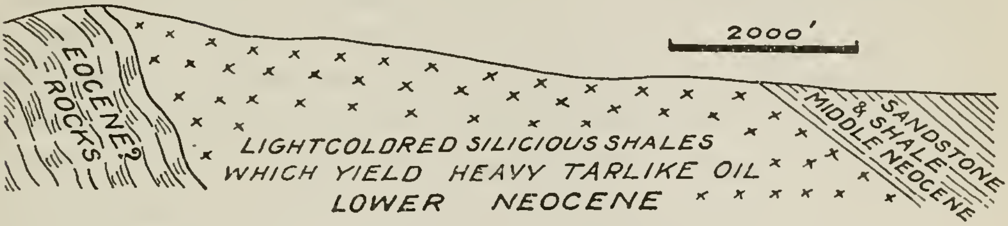


FIG. 13

SECTION OF TERTIARY STRATA IN KETTLEMAN HILLS. (MIDDLE NEOCENE.)

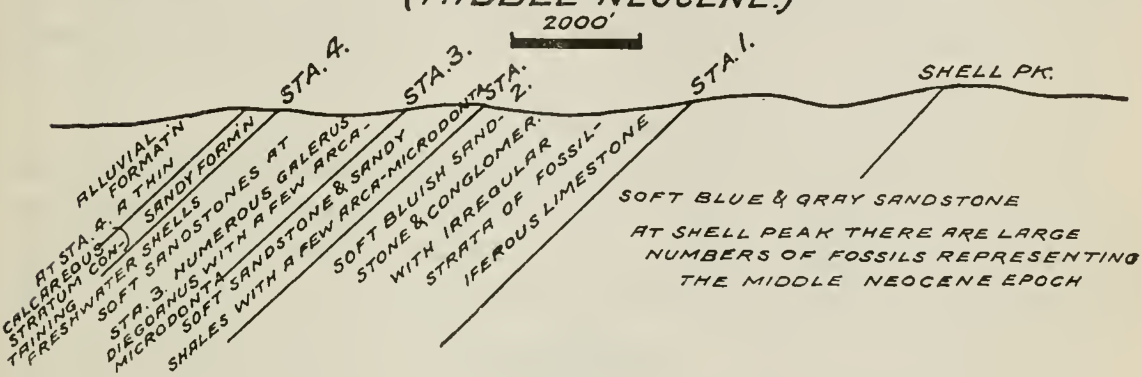
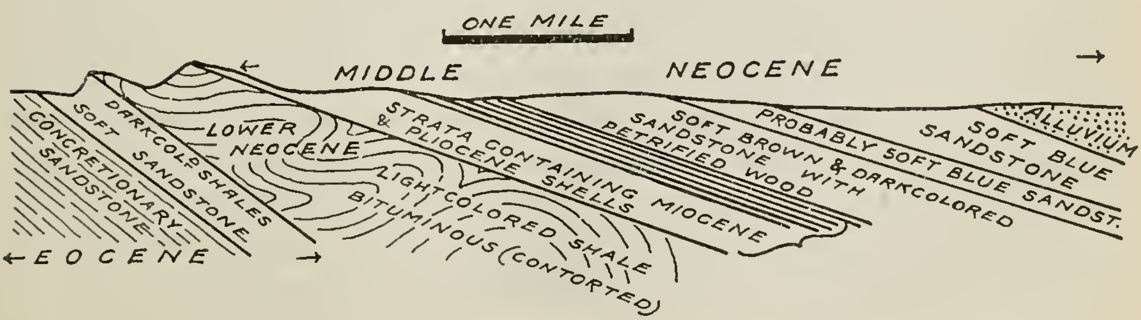


FIG. 14

SECTION THROUGH OIL CITY FIELD FRESNO COUNTY



of this formation are the dark-colored argillaceous shales, and the sandstone containing rounded concretions. The stratigraphical position and the physical character of this formation warrant the assumption that it belongs to the same geological horizon as do the Eocene shales and sandstones underlying the light-colored silicious shales in the oil-district 9 miles north of Coalinga in Fresno County. Overlying the formations, which we may tentatively class as Eocene, in the Sunset district, is a formation composed mainly of light-colored silicious shales, and constituting the first tier of foothills. (See Fig. 12.) These shales are for the most part of a brownish color when first mined, but they become almost white under the action of the atmosphere; indeed, the outcroppings of this rock are white or light-colored for several feet beneath the surface. In some places, the bleaching of these shales can be traced directly to the action of sulphureted vapor.

7.4.9. This light-colored silicious shale is by far the most characteristic rock of the bituminous formations; much of it is of low specific gravity and porous, sticking readily to the tongue, and is easily scratched. Some of it, however, especially in the lower portion of the formation, is indurated, apparently by the infiltration of silicious water. Occasionally pieces of this shale are found which show silicious induration only in the outer portions of the laminæ of which it is composed, and a cross-fracture reveals soft, light-colored shale within.

7.4.10. The chemical composition of these shales is as interesting as their physical appearance, the characteristic feature being the large amount of silica they contain. Two specimens from the Sunset oil-district were examined which showed as follows:

	Insoluble in Acid.	Silica Soluble in Sodium Carbonate.	Total Amount of Silica.
(*a*)	99 per cent	12 per cent	98 per cent
(*b*)	91 per cent	24 per cent	89 per cent

7.4.11. The light-colored shales are much less disturbed than the formation on which they rest. The prevailing direction of the dip of the light-colored shales in the Sunset oil-district is N. 30° E., and the angle of inclination is in some places as low as 20°, while in others it is as high as 80°. Although the southern limit of the light-colored shale in the district is tolerably well defined, it is not unlikely that in some places, where this shale has escaped erosion, it may extend a long way up the northeastern slope of the Coast Ranges. In one instance, a well was dug at an altitude of nearly 3000′, in which light-colored shales, similar in appearance to those found in the lower foothills, were penetrated.

7.4.12. Investigations in various parts of the Coast Ranges warrant the classification of these shales as Lower Neocene (Miocene); there is reason to believe that they rest non-conformably on the underlying rocks.

7.4.13. Numerous seepages of heavy petroleum exude from these shales, forming beds of asphaltum, which, in some places, before these deposits were mined by Messrs. Jewett & Blodget, extended over an area of several acres. This asphaltum, much of which remains, is principally black, pitch-like bitumen, varying from solid to viscous, and some of it is of a yellowish-brown color; it is of different degrees of purity, and existed not only in beds and mounds, but was found by excavation to extend beneath the superficial drift. In some of these beds the bones of animals and stone mortars and other Indian relics were found beneath four or five feet of asphaltum.

7.4.14. When this territory was visited by the writer in 1894, he found that Messrs. Jewett & Blodget had drilled and dug twelve wells from 80′ to 500′ in depth in the shale formation; these wells are all within an area of 300′ in length by 40′ in width. They yielded, all told, about 15 bbls. of oil in twenty-four hours. The specific gravity of the oil varied in the different wells from about 12° B. to a liquid asphaltum which required to be heated by steam before it could be pumped.

7.4.15. In several places springs of brine and sulphureted water issue from the light-colored shales.

7.4.16. Overlying the light-colored silicious shales is a formation composed largely of comparatively soft sandstone. In the Sunset district only a few rocks belonging to this formation are exposed; they contain Middle Neocene fossils. (See Bulletin No. 3.) At Lobos Creek, on the San Emidio ranch, this formation is seen resting on the light-colored silicious shale. Between Lobos Creek and Mud Creek, a small collection of fossils was made from this formation. These were classified by Dr. J. G. Cooper and found to represent the Middle Neocene age. (See Bulletin No. 3.)

7.4.17. Near Coalinga in Fresno County, as hereinafter mentioned, the writer found evidence of this formation resting non-conformably on the light-colored shales, and in some places it contained fragments of shale, apparently similar to the light-colored silicious shales previously mentioned. At the Sunset oil-wells and in the Coalinga district, oil-sands are found in lower beds of this formation.

7.4.18. In 1892–93, Messrs. Jewett & Blodget drilled three wells in Sec. 28, T. 11 N., R. 25 W., S. B. M. Although at the point where the wells are drilled the rocks are covered with alluvium, there is little doubt that these wells penetrate Middle Neocene formations. The record of one of the wells is as follows:

WELL NO. 1.

Sulphur and apparently calcareous tufa deposited by mineral water	45′
Very hard gray and blue sandstone	80′
(At a depth of 58′ there was a little oil and some mineral water.)	
Gray sandstone with soft streaks and more mineral water	160′
(At this depth the casing was reduced to 8⅝″.)	
Soft blue sandstone, with hard shells and more water	402′
(At this depth the casing was reduced to 6⅝″.)	
Blue sandstone	420′
(At this depth the water was shut off.)	
Coarse sandstone, with oil and water and much gas	440′
Light blue sand	445′
Sand, with water	820′

This well was cased from the depth of 420′ to that of 820′ with 5″ casing. Superintendent Youle states that this well was tested, and that about 100 bbls. of brine and 6 bbls. of oil were pumped from it daily for three months. It also furnished enough gas for a cook-stove.

7.4.19. Many of the wells being drilled in the Sunset district in August, 1900, appeared to penetrate strata immediately overlying the light-colored shales and belonging to the Middle Neocene formation; the character of this formation is further shown by the record of the Monarch well, which penetrated a series of clays and sandstones. (See record of Monarch well.) The oil obtained in this formation is of lower gravity than that obtained in the silicious shale formation. In the shale formation it is usually about 10° or 11° B., but in the Sunset district the oil from the Middle Neocene formations varies from 14° to 17° B.

7.4.20. Associated with the rocks of the Middle Neocene age are white silicious sandstones, which appear to have been hardened by infiltering water. There is also a soft gypseous rock, which rests nonconformably on the older formations. In the eastern portion of the Sunset oil-district, and about a mile eastward therefrom, this white gypseous rock attains a thickness of several feet and forms low hills on the mesa-land. It may also be seen resting upon the upturned edges of older strata at an altitude of nearly 2000′. A specimen of this white rock was examined in the laboratory of the State Mining Bureau, and was found to be composed of sulphate and a carbonate of lime and clayey matter. There are also deposits of calcareous tufa and breccia, apparently of later age than the Neocene rocks. A description of the Sunset district would be incomplete unless some mention were made of its deposits of sulphur and gypsum.

7.4.21. The deposits of sulphur in the Sunset district are found under the following conditions: As drift cemented with sulphur, as irregular masses of sulphur in the drift, as sulphur incrusting and filling fissures in the rocks, as sulphurous earth, or as sulphurous precipitate from the waters of mineral springs. The sulphurous earths are frequently black, contain bituminous matter, and have a strongly acid taste and fetid odor. The sulphur deposits appear to follow fissures in the rocks, the prevailing trend being N. 80° E. The sulphur is evidently formed by the decomposition of sulphureted hydrogen. In some places these sulphur deposits have been prospected by excavation to a depth of 10′ or 12′. These deposits are not worked.

7.4.22. The principal deposit of gypsum in the Sunset district is situated in its southeastern borders. The gypsum forms a stratum of rather soft, chalky-looking rock, and in some places it attains a thickness of several feet. It is mixed, containing much carbonate of lime and chalky clay.

CHAPTER 5.

WELLS IN SUNSET OIL-DISTRICT.

The following records were obtained in August, 1900:

PRODUCING WELLS.

7.5.1. *Monarch Oil Company* (of Arizona; E. Aigeltinger, president) has a well in the N.W. ¼ of Sec. 2, T. 11 N., R. 24 W., S. B. M. In July, 1900, this well was 500′ deep. It is a flowing well and is said to yield 75 bbls. of oil a day. The formation penetrated by this well is: Drift and water-sand to 260′; hard stratum to 266′; blue clay to 311′; brown sand and a little oil to 336′; oil-sand to 350′; hard stratum to 358′; blue clay to 388′; sand and heavy oil to 396′; blue clay to 488′, and oil-sand to 495′.

7.5.2. *Jewett & Blodget Oil Company* has sixteen wells in the S.E. ¼ of Sec. 13, T. 11 N., R. 24 W., S. B. M. These wells vary from 250′ to 400′ in depth. The formation penetrated is principally shale. It is said that these wells yield from 10 to 25 bbls. of oil a day. Gravity of oil, 11° B. This company also has a well 875′ deep in the S.W. ¼ of Sec. 18, T. 11 N., R. 23 W., S. B. M. The formation is principally shale. There are two strata of oil-sand.

PROSPECT WELLS.

7.5.3. *Acme Oil Company* (of Los Angeles; E. V. Van Norman, president) has a well in the S.W. ¼ of Sec. 12, T. 11 N., R. 24 W., S. B. M. In July, 1900, this well was 300′ deep. Formation, shale, with good showing of oil. Drilling.

7.5.4. *Bachelors Oil Company* (of San Francisco) has a well in Sec. 22, T. 11 N., R. 24 W., S. B. M. It is said that there is a good showing of oil in this well.

7.5.5. *Barrett Oil Company* (of San Francisco) has a well in the N.E. ¼ of Sec. 11, T. 11 N., R. 24 W., S. B. M. In July, 1900, this well was

1025′ deep. Formation, mostly shale and clay, with a good showing of oil. Gravity of oil, 14° B. Drilling.

7.5.6. *Golden Gate Oil Producing Company* (of Stockton, San Joaquin County; D. O. Castle, president) has a well 400′ deep in Sec. 13, T. 11 N., R. 24 W., S. B. M., but it was abandoned on account of water. This company also has a well in the S.E. ¼ of Sec. 2, T. 11 N., R. 24 W., S. B. M. Drilling.

7.5.7. *Lion Oil Company* (E. B. Weed of San Francisco, president) has a well in the S.E. ¼ of Sec. 12, T. 11 N., R. 24 W., S. B. M. Drilling.

7.5.8. *Manhattan Oil Company* (of Los Angeles; A. C. Jones, president) has a well in the S. W. ¼ of Sec. 11, T. 11 N., R. 24 W., S. B. M. Drilling.

7.5.9. *Navajo Oil Company* (of Los Angeles; R. R. Burns, president) has a well 200′ deep in the N.W. ¼ of Sec. 20, T. 11 N., R. 23 W., S. B. M. Formation, shale, with a good showing of oil. Drilling.

7.5.10. *Pittsburg Oil Company* (of Bakersfield; F. S. Benson, president) has a well in the N.W. ¼ of Sec. 1, T. 11 N., R. 24 W., S. B. M. In July, 1900, this well was 800′ deep. Formation, clay-shale and sand. Drilling.

7.5.11. *State Crude Oil Company* (of Los Angeles; G. W. Whiteford, president) has a well in the S.E. ¼ of Sec. 14, T. 11 N., R. 24 W., S. B. M. Formation, principally shale. Drilling.

7.5.12. *Sunset Bakersfield Crude Oil Company* (of San Francisco; H. F. Bulwer, president) has a well in the N.W. ¼ of Sec. 13, T. 11 N., R. 24 W., S. B. M. In July, 1900, this well was 800′ deep. Formation, blue shale. This well yields flowing sulphureted water. Abandoned. This company also has a well in the N.W. ¼ of Sec. 21, T. 11 N., R. 23 W., S. B. M. In July, 1900, this well was 325′ deep. Formation, black shale, with some oil. Gravity of oil, 11° B. Drilling.

7.5.13. *Sunset Czar Oil Company* (of Pasadena, Los Angeles County; B. W. Hahn, president) has a well in the N.W. ¼ of Sec. 19, T. 11 N., R. 23 W., S. B. M. Drilling.

7.5.14. *Sunset King Oil Company* (of Los Angeles; B. W. Hahn, president) has a well in the N.E. ¼ of Sec. 10, T. 11 N., R. 24 W., S. B. M. Formation, blue shale. Drilling.

7.5.15. *Sunset Petroleum and Refining Company* (of Los Angeles; J. W. Evans, secretary) has a well 100′ deep in the N.W. ¼ of Sec. 29, T. 11 N., R. 24 W., S. B. M. Good showing of oil. Drilling.

7.5.16. *Sunset Queen Oil Company* (of Los Angeles; L. Vickery, president) has a well in the N.W. ¼ of Sec. 14, T. 11 N., R. 24 W., S. B. M. Formation, shale. Drilling.

7.5.17. *Western Mineral Oil Company* (of Bakersfield; Gordon Blanding of San Francisco, president) has a well in the S.E. ¼ of Sec. 17, T. 11 N., R. 23 W., S. B. M. In July, 1900, this well was 800′ deep. Formation, black shale, with some gas. Drilling. This company has also a well in the N.W. ¼ of Sec. 27, T. 11 N., R. 23 W., S. B. M. In July, 1900, this well was 1400′ deep. Formation, shale, with a little oil of high specific gravity. Drilling.

CHAPTER 6.

THE McKITTRICK DISTRICT.

7.6.1. The railroad depot at McKittrick is about 25 miles northwest of the Sunset district. The road between the two places lies over the lowermost foothills of the Coast Ranges. Along this road there are very few rock-exposures, but they are sufficient to show that the rocks forming the lower foothills between Sunset and McKittrick belong to the Middle Neocene formation; while the white slopes of the upper foothills indicate the white outcropping shales of the Lower Neocene age. At the time this locality was visited by the writer, prospect wells were being drilled in the foothills between Sunset and McKittrick by the Bay City, the Pacific Consolidated, and the Hartford oil companies. (See record of prospect wells in McKittrick district.)

7.6.2. The McKittrick district, including the Temblor district, embraces the following townships: T. 29 S., R. 20 and 21 E.; T. 30 S., R. 21 and 22 E.; T. 31 S., R. 22 and 23 E.; and also that portion of T. 30 S., R. 20 E., lying east of the western boundary of Kern County—all in M. D. M. This area extends more than 20 miles along the western foothills of the Santa Maria Mountains, and has a width of about 10 miles. The foothills in which the oil-wells and asphaltum-beds at McKittrick are situated are, for the most part, covered with alluvial soil, which, except in dry seasons, sustains a scanty herbage during the spring, but in many places there is an abundant growth of greasewood and sagebrush.

7.6.3. The first portion of the territory, now known as the McKittrick district, to be developed was the lowermost bench of hills which rises from the mesa land to the north of the McKittrick railroad depot. (See Photo No. 31.) These lands were patented about thirty years ago by Garibaldi, Jo Queralo, and others, and the patents include the asphaltum-beds at what is now called McKittrick.

In 1866 the Buena Vista Petroleum Company erected a still about 3 miles northwest from where McKittrick now stands, at the spring now owned by Miller & Lux. This still had a capacity of 300 gallons. The oil was taken from pits and open cuts, and had a gravity of from 10° to 12° B.; but it is said that at a depth of 30′ oil was obtained having a gravity of 21° B. About 3000 gallons of refined oil were produced, but, owing to the expense of transportation and other difficulties, the enterprise was abandoned. Subsequently Blodget & Weil of Bakersfield sunk a 300′ well, and at this depth there is said to have been a good showing of oil. In 1887, J. S. Hambleton and others drilled a 565′ well, in which the oil rose to within 3′ of the top of the casing. Later the Buena Vista Petroleum Company erected a refinery of three kettles to refine the superficial deposits of asphaltum, but this enterprise was abandoned. In 1893, when McKittrick, then called Asphalto, was visited by the writer, several companies were holding oil-land there; and a railroad had been built to it from Bakersfield. The Standard Asphalt Company, which had leased and acquired a large tract of oil and asphaltum land, had erected an asphaltum refinery of twelve kettles, each of which was 12½′x 5′x 3′. This refinery was erected to refine the superficial deposits of asphaltum. The enterprise would have been a failure but for the discovery of veins of asphaltum about 1½ miles southeast of McKittrick. Until 1900 large quantities of asphaltum were obtained from these mines. The refinery first erected by the Standard Asphalt Company was burned down, but a new one was built about 1½ miles southeast of the old site. This refinery consisted of twelve kettles, having a capacity of about 60 tons. Here the asphaltum from the asphaltum mines was refined until January, 1899, when the company practically suspended operations, making only occasional runs. The new works were called Asphalto, and the site of the old works, McKittrick.

In 1893, the Buena Vista Oil Company had a 410′ well, from which 22 bbls. of oil a day had been pumped, and a 92′ well which yielded about 3 bbls. of oil a day. Oil was also obtained for the asphaltum refinery from several dug wells.

In 1898, Melton McWhorter erected a small refinery at McKittrick, where he manufactured paint, axle-grease, and other compounds from the crude oil. In February, 1899, McWhorter, Berry, Keller & Spencer leased a portion of the land operated by the Buena Vista Petroleum Company. These gentlemen then formed the El Dorado Oil Company and drilled several wells, which were unsuccessful; but in the autumn of 1899 they drilled a 600′ well, which is said to be productive.

In the spring of 1899, McWhorter, Berry, Keller & Spencer sublet 40 acres to J. B. Treadwell, who drilled a 450′ well. This well was completed in May, 1899, and proved very productive. Subsequently other companies drilled in this district, as hereinafter noted. It is said that in this district the oil-sand has been penetrated for 300′. In August, 1900, there were sixteen producing wells in the McKittrick district, and seven prospect wells were being drilled, not including the wells in the Temblor district; several other wells were about to be commenced.

7.6.4. The formations most extensively exposed in the McKittrick district are light-colored silicious shales similar to those seen in the Sunset district. The outcropping rocks, which represent the formations resting on the silicious shales, are very scanty; they consist mainly of porous silicious rock containing marine diatoms, bituminous sandstones, and clayey and sandy strata. In some places the diatomaceous rocks contain petroleum, and in connection with the bituminous sandstones previously mentioned, they doubtless constitute oil-sand in the oil-wells at McKittrick. The diatomaceous rocks also contain a large amount of salt. A good exposure of these saline rocks may be seen in the N.W. cor. of Sec. 33, T. 30 S., R. 22 E., M. D. M., where a small cañon extends in a southwesterly direction. During the summer, a crust composed principally of salt forms on the surface of the saline rocks. A short distance from the outcrop of the saline rocks, the sides of the cañon are formed of soft sandstone, the loose sandy surface of which is in some places strewn with quartzose pebbles, fragments of silicious rock, and a few marine shells. In 1894 the writer collected several of these shells, and two well-known forms, identified among them by Dr. J. G. Cooper (see Bulletin No. 3), showed that the formation overlying the light-colored silicious shales at McKittrick belongs to the Middle Neocene series. At McKittrick there are extensive superficial deposits of asphaltum, which have exuded near the contact of the silicious shales and the Middle Neocene formations. The dip of the exposed rocks at McKittrick is about N. 30° E., and in many places the rocks stand at a very high angle, 60° or more. The strike of the formation corresponds to that of the oil-line, which is about N. 60° W.

7.6.5. The formation penetrated by the productive wells in the McKittrick district is that portion of the Middle Neocene formation which immediately overlies the light-colored silicious shales. The oil-yielding strata are inclined at a very great angle, which makes the oil-line a narrow one. It is said that in July, 1900, about 9000 bbls. of oil were sold from the McKittrick field. The gravity of the oil in this field ranges from 15° to 20° B.

Following the strike of the formation in a northwest direction from the oil-wells south of the McKittrick railroad depot, the character of the débris covering the hills and occasional outcropping ledges of rock, evidence the proximity of the sandstone and diatomaceous rocks. The sandstones are frequently oil-soaked, and seepages of maltha may be seen in nearly every cañon. These features warrant the conclusion that the source of the oil and maltha is at or near the contact of the sandstone and the diatomaceous rocks.

7.6.6. About 1½ miles west of the McKittrick depot there is a cliff of light-colored sedimentary strata, some of which are bituminous and some interspersed with fragments of silicious shale resembling the silicious shale of the Lower Neocene. In 1894 the writer noted a vein of very pure asphaltum at the base of this cliff. To the south of the stratum forming this cliff porous silicious shales are seen, but as investigation is made in a southerly direction across the strike of the formation, the light-colored shales lose their porous character and appear to be indurated by silica. In a few places there are weather-worn masses of limestone. Still farther to the south the light-colored shale is covered with alluvial soil, which, except in dry seasons, produces excellent pasturage during the spring.

7.6.7. About half a mile by a trail to the southeast of the McKittrick depot, there is a spring of warm mineral water, which yields inflammable gas and a little oil. The gas smells strongly of sulphureted hydrogen.

The asphaltum deposits at Asphalto are found under two conditions: (1) as superficial deposits of impure asphaltum; and (2) as veins of asphaltum in the Middle Neocene formations. The superficial deposits of asphaltum have been formed by exudation of heavy oil; they originally covered a good many acres, and were from 1′ to 12′ thick. This asphaltum varies greatly in quality; some of it is brownish in color and resembles ironite. It is frequently dry and powdery, and more or less mixed with earth. The best asphaltum in these superficial beds lies near the surface; in some places it forms a stratum varying in thickness from a few inches to two feet or more. This stratum consists principally of a dull-black, compact asphaltum, but some of it possesses a pitch-like luster, and here and there it is rendered viscous by fluid petroleum. Beneath the upper stratum the asphaltum is frequently impure and rotten, and interbedded with drift. Attempts to mine and refine this asphaltum have proved unprofitable.

7.6.8. The principal asphaltum mines are 1½ miles southeast of McKittrick. In these mines the asphaltum occurs as irregular veins and intrusive masses in the Middle Neocene rocks. These veins are from a few inches to five feet or more in thickness. In one of the workings that the writer examined in 1894, the foot-wall is light-colored clay and the hanging-wall soft sandstone.

In a cut made by miners who were prospecting for petroleum in the N.E. ¼ of Sec. 34, T. 30 S., R. 22 E., M. D. M., several strata of impure asphaltum 1″ to 1′ in thickness were cut through. The asphaltum was found to be interbedded with thin strata of light-colored clay, sand, and pebbles. One of the uppermost strata, which is composed of dark-colored sand, is fossiliferous and contains fresh-water shells. These strata dip N. 80° E. at an angle of about 50°. In 1894 the writer submitted specimens of these fresh-water shells to Dr. J. G. Cooper, who found them to be living forms. (See Bulletin No. 3, p. 49.) These asphaltum mines were successfully worked for several years.

7.6.9. *The Temblor Oil-Field* is about 12 miles northwest of the railroad depot at McKittrick, and is considered a portion of the McKittrick district. In August, 1900, there were three productive wells in this field, and six prospect wells were being drilled. The gravity of the oil ranges from 18° to 20° B., and the rocks penetrated resemble the lower portion of the Middle Neocene formation hereinbefore described.

CHAPTER 7.

WELLS IN McKITTRICK DISTRICT.

PRODUCING WELLS.

7.7.1. *California Standard Oil Company* (of Oakland; J. M. Merrill, president) has a 450′ well and two 500′ wells in the S.W. ¼ of Sec. 20, T. 30 S., R. 22 E., M. D. M. Formation: Asphaltum, shale, clay, and sand. It is said that in June, 1900, the 450′ well yielded 150 bbls. of oil a day by pumping, and that one of the 500′ wells yielded 40 bbls. and the other 75 bbls. a day. Gravity of oil, 22° B. This company has also three wells in Sec. 28, T. 30 S., R. 22 E., M. D. M. It is said that in July, 1900, these wells were about 600′ deep, with a good showing of oil. Drilling.

7.7.2. *Climax Oil Company* (of San José) has two wells in the Temblor field in the N.E. ¼ of Sec. 36, T. 29 S., R. 20 E., M. D. M. Formation: Soft shale and sandstone. A flow of oil was struck at 285′. It is said that in July, 1900, these wells were producing 30 bbls. a day each. Gravity of oil, 15° B. This company has also a producing well in the N.E. ¼ of Sec. 29, T. 29 S., R. 20 E., M. D. M.

7.7.3. *El Dorado Oil Company* (of Bakersfield; C. J. Berry, president) has a producing well 450′ deep in the N.E. ¼ of Sec. 29, T. 30 S., R. 22 E., M. D. M. It is said that in June, 1900, this well yielded 50 bbls. of oil a day. Gravity of oil, 20° B. On this quarter-section, oil was struck by the El Dorado Company in three wells, which were unfinished in July, 1900.

7.7.4. *Giant Oil Company* (of San Francisco; W. J. Dingee, president) has two wells in the N.W. ¼ of Sec. 13, T. 30 S., R. 21 E., M. D. M. Formation: Shale, clay, and sandstone. Oil-sand was struck at a depth of 700′ and penetrated to a depth of 1050′.

7.7.5. *Kern River Oil Company* (of San Francisco; C. Reise, president) has three wells, each 800′ deep, in the N.E. ¼ of Sec. 13., T. 30 S., R. 21 E., M. D. M. One of these wells is a flowing well. In July, 1900, they were said to yield, all told, about 200 bbls. a day by pumping.

7.7.6. *San Francisco McKittrick Oil Company* has an 800′ well in the N.E. ¼ of Sec. 14, T. 30 S., R. 21 E., M. D. M. In July, 1900, it was said to yield 25 bbls. a day.

7.7.7. *Shamrock Oil Company* (of San Francisco; J. W. Wright, president) has three wells in the S.E. ¼ of Sec. 19, T. 30 S., R. 22 E., M. D. M. Formation: Clay, shale, and sandstone. These wells are each about 800′ deep. Oil-sand was struck at a depth of about 700′. In July, 1900, it was said that each of these wells would yield 50 bbls. of oil a day by pumping.

7.7.8. *J. B. Treadwell Oil Company* has six wells in the S.E. ¼ of Sec. 20, T. 30 S., R. 22 E., M. D. M. These wells range from 400′ to 500′ in depth. Formation: Sand and shale impregnated with asphaltum. It is said that in June, 1900, these wells were pumped and yielded, all told, about 450 bbls. a day. Gravity of oil, about 20° B.

THE TEMBLOR OIL-FIELD—PRODUCING WELLS.

This district is about 12 miles northwest of McKittrick Station.

7.7.9. *Climax Oil Company* (of San José; S. F. Lieb, president) has three wells in the N.E. ¼ of Sec. 36, T. 29 S., R. 20 E., M. D. M. In well No. 1 the following formation was penetrated: Soft limestone to 20′; yellow shale to 35′; blue shale to 100′; brown shale to 250′, and oil-sand to 322′. In well No. 2 a similar formation to that in well No. 1 was penetrated to a depth of 285′, and then oil-sand to a depth of 330′. Below this depth the sand contained sulphureted water. In well No. 3 the formation passed through to a depth of 280′ was similar to that penetrated for the first 290′ in well No. 1, then oil-sand to a depth of 340′. The casing in these wells is not perforated. Well No. 2 is a flowing well, and yields about 30 bbls. of oil a day. Wells Nos. 1 and 3 yield about 10 bbls. of oil a day. The gravity of these oils ranges from about 18° to 20° B.

McKITTRICK DISTRICT—PROSPECT WELLS.

7.7.10. *Bay City Oil Company* (of San Francisco; G. W. Turner, president) has a well in Sec. 22, T. 32 S., R. 22 E., M. D. M., about 12 miles from McKittrick. Drilling.

7.7.11. *El Modelo Oil Company* (of Fresno; C. L. Waters, president) has a well in Sec. 24, T. 30 S., R. 21 E., M. D. M. In July, 1900, this well was about 1000′ deep, with some showing of oil. Drilling.

7.7.12. *Hartford Oil Company* (of Los Angeles; J. S. Dillon, president) has a 650′ well in Sec. 12, T. 31 S., R. 21 E., M. D. M., about 6 miles south of McKittrick. Formation, principally shale.

7.7.13. *National Oil Company* (W. C. Beattie of Oakland, president) has a well in the N.E. ¼ of Sec. 29, T. 30 S., R. 22 E., M. D. M. Formation, shale and sandstone. Oil was struck at 1100′. Drilling.

7.7.14. *Pacific Consolidated Oil Company* (of Fresno) has a 700′ well in Sec. 2, T. 31 S., R. 21 E., M. D. M., about 15 miles from McKittrick. It is said that oil-sand has been struck in this well.

7.7.15. *Sloan Oil Company* (of Los Angeles) has a well in the S.E. ¼ of Sec. 20, T. 30 S., R. 22 E., M. D. M. In this well a stratum of oil-sand was struck at 680′, and a second stratum at 775′. Gravity of oil, 20° B. Drilling.

7.7.16. *Virginia Oil Company* (of San Francisco; J. W. Wright, president) has a well in Sec. 29, T. 30 S., R. 22 E., M. D. M. In July, 1900, this well was 800′ deep, with some showing of oil. Drilling.

TEMBLOR OIL-FIELD—PROSPECT WELLS.

7.7.17. *Diamond Oil Company* (of San José) has a well in the N.W. ¼ of Sec. 11, T. 29 S., R. 21 E., M. D. M. Drilling.

7.7.18. *Eureka Oil and Development Company* (of Bakersfield; A. J. Lightner, president) has a well in Sec. 13, T. 29 S., R. 20 E., M. D. M. Formation, sandstone and a little shale. Oil struck at 80′. Gravity, 10° B. This well is being drilled with a portable rig, run by a gasoline engine. It is furnished with a steel cable carrying a string of tools weighing 1750 lbs. The rig was designed by G. M. Bobs of Los Angeles.

7.7.19. *Gould & Center Oil Company* has a well near the center of Sec. 18, T. 29 S., R. 21 E., M. D. M. In July, 1900, this well was about 200′ deep, with a good showing of oil.

7.7.20. *J. Jameson* (of Bakersfield) has a well in Sec. 31, T. 29 S., R. 20 E., M. D. M. In August, 1900, this well was 100′ deep. Formation, shale. Drilling.

7.7.21. *Nevada Oil Company* (of Bakersfield; M. Wagy, president) has a well 1000′ deep near the center of Sec. 24, T. 29 S., R. 20 E., M. D. M. Drilling.

7.7.22. *Sunrise Oil and Development Company* (of San José; O. L. Baker, president) has a well in the S.W. ¼ of Sec. 11, T. 29 S., R. 21 E., M. D. M. Formation: Alluvium and gravel to 240′; blue shale to 300′; soft sandstone to 340′; brown shale to 410′; sandstone to 460′. Some gas. Drilling.

CHAPTER 8.

THE DEVIL'S DEN DISTRICT.

7.8.1. This district adjoins the McKittrick district on the northwest. It embraces T. 25 S., R. 17, 18, and 19 E.; T. 26 S., R. 17 and 18 E.; T. 27 S., R. 18 and 19 E.; T. 28 S., R. 19 and 20 E.—all in M. D. M.; and that portion of T. 27 S., R. 18 E., lying east of the western boundary of Kern County.

7.8.2. In this district, the same sequence of formation was noticed as that heretofore described as forming the foothills of the Coast Ranges on the west side of the San Joaquin Valley, viz: the Middle Neocene sandstones and shales, the silicious shales of the Lower Neocene, and rocks which in physical appearance resemble the Eocene formations noted at Coalinga, in Fresno County. In August, 1900, there were no productive wells in the Devil's Den district, but four companies were drilling prospect wells. (See prospect wells in Devil's Den district.)

PROSPECT WELLS.

Only such wells are mentioned as were drilled, or being drilled, in August, 1900.

7.8.3. *Devil's Den Development Company* (of Visalia; A. R. Orr, president) has a 100′ well in the N.W. ¼ of Sec. 22, T. 25 S., R. 19 E., M. D. M.

7.8.4. *Imperial Oil and Development Company* (of San Francisco; E. C. Calvin, president) has a well in Sec. 27, T. 26 S., R. 17 E., M. D. M., about 6 miles southeast of Annette P. O.

7.8.5. *Raven Pass Oil Company* (of Los Angeles; M. A. Newmark, president) has a well in Sec. 23, T. 26 S., R. 17 E., M. D. M. Formation, sandy shale. Well said to be 400′ deep, with traces of oil. In June, 1900, this well was unfinished.

7.8.6. *Spreckels* (*R.*) (of San Francisco) has a 600′ well in the N.W. ¼ of Sec. 30, T. 25 S., R. 18 E., M. D. M. Formation: Hard sandstone to 60′; blue shale to 160′; hard stratum to 165′; black carbonaceous material to 170′; gas to 460′; hard, dark-colored shale interstratified with soft shale to 500′; and hard sandstone to 560′. Drilling in dark-colored shale.

CHAPTER 9.

THE KREYENHAGEN DISTRICT.

7.9.1. The Kreyenhagen district adjoins the Devil's Den district on the north, and is partly in Fresno County and partly in Kings County. It embraces T. 21 S., R. 16, 17, and 18 E.; T. 22 S., R. 16, 17, and 18 E.; T. 23 S., R. 16, 17, and 18 E.; T. 24 S., R. 17 and 18 E.; and such portions of T. 22 S., R. 13, 14, and 15 E.; T. 23 S., R. 15 and 16 E.; T. 24 S., R. 16 E., as lie east of the western boundary of Fresno and Kings counties—all in M. D. M.

This district includes the Avenal oil-field, which extends as far south as the sixth standard line of the Mount Diablo meridian, and the Kettleman Hills, which rise between Tulare Lake and the main foothills of the Coast Ranges, being separated from the latter by the Kettleman Plains.

7.9.2. In the Avenal oil-field, the Avenal Land and Oil Company is operating on a ridge which rises to an altitude of more than 2000′. (See Avenal Land and Oil Company.) In August, 1900, this company was drilling at a point on this ridge where it is cut through by Tar Cañon. In this cañon there are seepages of heavy, tar-like oil, which in one place has formed a small quantity of asphaltum. The before-mentioned ridge is composed of shale and sandstone, principally sandstone, and some of the sandstone is highly impregnated with petroleum. These rocks dip about N. 10° E. at an angle of from 60° to 75°. They contain fossils of Miocene age. (See Bulletin No. 3, and Table II at the end of this volume.) Some of the strata are highly fossiliferous, but the fossils are in a poor state of preservation. The formation composing the ridge must be regarded as Lower Neocene, and probably underlies the light-colored shales which are here covered by the Middle Neocene formation. The formations on the south slope of this ridge show strata of soft sandstone and sandy shales. To the north and at the foot of this ridge, the formation is soft blue sandstone, and the dip of the rocks appears to be more easterly and at a somewhat lower angle than that of the rocks forming the ridge. In 1893 the writer obtained a collection of fossils from this sandstone, which shows it to belong to the Middle Neocene age. (See Bulletin No. 3, p. 54.)

7.9.3. The Kettleman Hills are immediately north of the ridge on which the wells of the Avenal Oil Company are situated. A reconnaissance of these hills shows that their more elevated portions are formed of soft blue sandstone, and that their summits rise to an altitude of about 1000′. The summits of these hills present a rounded, undulating appearance, while their sides are furrowed by narrow gulches and ravines deeply cut in the comparatively recent formations. Near the summits of these hills the blue sandstone is interbedded with a few calcareous strata containing fossils which represent the latter portion of the Middle Neocene age. (See Bulletin No. 3, p. 54.)

7.9.4. One of the uppermost strata on the western slope of these hills contains fresh-water shells, but the fossiliferous portion is of no great thickness. The fresh-water shells obtained from this locality were classified by Dr. J. G. Cooper, who found that they were mostly living forms, which in point of age ranged downward to the Pliocene. (See Bulletin No. 3, p. 55.) An idea of the formation of the western slope of the Kettleman Hills may be gathered from Fig. 13.

In August, 1900, several prospect wells were being drilled in the Kettleman Hills, but the writer could not learn that any oil had been struck. (See Kettleman Hills—Prospect Wells)

7.9.5. On the Kreyenhagen ranch there are oil-seepages in cañons which cut through rocks of similar appearance to those seen in Tar

Cañon in the Avenal district. These rocks are well exposed on the south fork of the Zapato Chino Creek, where it breaks through the first tier of the higher foothills. Some of these rocks contain Miocene fossils. (See Bulletin No. 3, p. 55.) It is evident that these rocks, like those of Tar Cañon, must be classed as belonging to the Lower Neocene formations. As seen on the Kreyenhagen ranch, they contain three distinct strata of oil-sand. The uppermost stratum of oil-sand has a heavy black oil; the middle ledge also has a heavy oil, and the lower ledge yields a peculiar green oil of high specific gravity.

7.9.6. In August, 1900, there had been or were being drilled in the Kreyenhagen district the following wells: In the Avenal field, two prospect wells; in the Kettleman Hills, seven prospect wells; on the Kreyenhagen ranch, two producing wells and five prospect wells.

PRODUCTIVE WELLS.

7.9.7. *Black Mountain Oil Company* (of Los Angeles; E. R. Schneider, president) has an 800′ well in the S.W. ¼ of the N.W. ¼ of Sec. 33, T. 22 S., R. 16 E., M. D. M. Formation: Dark-colored shale to 80′; white sand to 85′; dark shale to 400′; light-colored shale to 550′; shale and sand with oil to 570′; light-colored shale to 640′; oil-sand to 660′; shale to 700′; oil-sand to 720′. Operations were suspended in order to use the oil for drilling. This company has also a well in the same section about 600′ from well No. 1. Formation resembles that in No. 1. Drilling.

7.9.8. *Kreyenhagen Oil Company* (of Los Angeles; J. H. Henderson, president) has two wells in the S.E. ¼ of Sec. 32, T. 22 S., R. 16 E., M. D. M. In one of these wells the formation is as follows: Dark-colored shale to 400′ (a water stratum was struck at a depth of 125′, and another at 400′); dark-colored shale to 650′; oil-sand to 660′. This is said to be a 15-bbl. well, and yields a light-green oil; gravity, 38° B. Work was suspended on this well that it might be a source of fuel for the other wells. The Kreyenhagen Oil Company has another well 1350′ deep. The formation is shale, with streaks of sand showing traces of oil at 1000′ and 1100′ and water at 1200′. Drilling.

PROSPECT WELLS.

7.9.9. *Avenal Land and Oil Company* (of San Francisco; A. B. Williamson, president) has two wells in Tar Cañon, in the E. ½ of the E. ½ of Sec. 18, T. 23 S., R. 17 E., M. D. M. In one of these wells the formation is: Adobe to 20′; oil-sand with water to 70′; blue water-sand to 140′; clay to 235′; shale to 521′; oil-sand to 555′; shale to 590′; sand showing traces of oil to 635′; shale to 802′; blue clay to 900′; sand with traces of oil to 984′. Drilling. The other well is a prospect well not yet completed.

7.9.10. *Baby King Oil Company* (of Hanford; Mr. Griswell, president) has one 1125′ well in the N.E. ¼ of Sec. 11, T. 23 S., R. 16 E., M. D. M. Oil of 30° B. specific gravity was struck at 400′; and at 1100′ oil of 18° B. specific gravity; a short distance below this depth flowing water was encountered, and the well abandoned.

7.9.11. *Consolidated Oil and Development Company* (of Hanford) has two wells in the N.E. ¼ of Sec. 10, T. 23 S., R. 16 E., M. D. M. One of these wells is 1100′ in depth. A good showing of oil was obtained at 1050′. The oil obtained from this well is of an amber color, and has a specific gravity of 20° B. Drilling.

7.9.12. *Kings County Oil Company* (of San Francisco; T. E. Lamb, president) has a 500′ well in the S.W. ¼ of the S.W. ¼ of T. 23 S., R. 16 E., M. D. M. Formation: Black shale, blue sandstone, and brown sandstone containing oil. This well was abandoned on account of water. This company also has a well in the S.W. ¼ of the N.E. ¼ of Sec. 3, T. 23 S., R. 16 E., M. D. M. Formation: Clay and soil to 12′; white shale to 29′; black shale to 65′; black sand to 67′; black shale to 90′; hard gravel to 120′; black shale to 275′; gravel to 285′; black shale to 410′; blue sand-rock to 450′; water-sand to 490′; blue sand-rock to 540′; sand to 556′; clayey sandstone to 600′; black shale to 660′; clayey sandstones to 696′; hard shale to 720′; hard rock, sandstone predominating, to 900′. Heavy oil was struck at a depth of 240′. This company has also a well 140′ deep.

7.9.13. *St. Lawrence Oil Company* (of Hanford, Kings County) has a well in the S.E. ¼ of the N.E. ¼ of Sec. 12. It is said that oil was struck at the bottom of the well.

KETTLEMAN HILLS—PROSPECT WELLS.

7.9.14. *Esperanza Oil Company* (of Hanford; D. L. Barney, president) has two wells, one 1100′ deep, abandoned on account of water, and one 840′ deep, operations suspended. These wells are in the S.W. ¼ of Sec. 14, T. 22 S., R. 17 E., M. D. M.

7.9.15. *Florence Oil Company* (of San Francisco; D. Donan, president) has two 720′ wells in the N.W. ¼ of Sec. 15, T. 22 S., R. 17 E., M. D. M. In one of these wells much gas was struck. Operations suspended. In August, 1900, this company was drilling a well for water.

7.9.16. *Gibbs Oil Company* (of Hanford; E. M. Gibbs, president) has a 500′ well in the N.W. ¼ of Sec. 28, T. 21 S., R. 17 E., M. D. M. Drilling.

7.9.17. *Iowa Oil Company* (of Hanford; Louis Decker, president) has a 260′ well in the S.W. ¼ of Sec. 4, T. 22 S., R. 17 E., M. D. M.

7.9.18. *Oceanic Oil Company* (of Hanford; B. M. McCray, president) has a 950′ well in the N.W. ¼ of Sec. 1, T. 32 S., R. 17 E., M. D. M. Operations suspended.

7.9.19. *Stanislaus Oil Company* (of Modesto; J. Hewel, president) has a 600′ well in the N.W. ¼ of Sec. 4, T. 22 S., R. 17 E., M. D. M.

7.9.20. *Stockton Oil Company* (of Stockton, San Joaquin County) has a 670′ well in the N.W. ¼ of Sec. 30, T. 22 S., R. 18 E., M. D. M. Operations suspended.

CHAPTER 10.

THE COALINGA DISTRICT.

7.10.1. This district adjoins the Kreyenhagen district on the north. It embraces T. 21 S., R. 14 and 15 E.; T. 20 S., R. 13, 14, and 15 E.; T. 19 S., R. 13, 14, and 15 E., all in M. D. M.; also such portions of T. 21 S., R. 12 and 13 E.; T. 20 S., R. 12 E.; and T. 19 S., R. 12 E., M. D. M., as lie east of the western boundary of Fresno County. Except in one instance, all the development and prospect work in this district is north of the south branch of Los Gatos Creek, locally known as Alcalde Creek. In the Coalinga district oil-mining has been carried on in two fields: In the Oil City field, which lies to the north of the north fork of Los Gatos Creek, and in the Alcalde field, which lies between Alcalde Creek and the north fork of Los Gatos Creek.

7.10.2. The most important of these fields is the Oil City, about 9 miles north of Coalinga railroad depot on the S. P. R. R. (See Photo No. 32.) In this field the exposed formations range from the upper portion of the Middle Neocene to that of the Eocene or Tejon (Cretaceous B, according to the old nomenclature). A general idea as to the relation of these two formations may be gathered by an inspection of Fig. L (see atlas), which shows a ground plan of a portion of the territory, and of Fig. 14, which is a cross-section drawn through the Oil City field in a direction of S. 50° E. As therein shown, the lowermost formation consists of hard sandstone containing numerous concretions. This sandstone is overlain by dark-colored shales and sandstone containing Eocene fossils. Some of the strata of sandstone interbedded with the dark-colored shales yield an oil of low specific gravity, and have proved very productive. The shales and concretionary sandstone on which they rest are of Eocene (Tejon) age. Resting non-conformably on the Eocene rocks is a light-colored silicious shale, hereinbefore mentioned as belonging to the Lower Neocene series. Seepages of heavy, tar-like oil issue from this shale, and in some places form beds of asphaltum. In some of the wells in this vicinity an oil of 18° B., apparently from oil-sand in this formation, has been obtained. The only fossils found in the shales at Coalinga were *Pecten peckhami* (a Lower Neocene fossil), a few fish

PHOTO 31. McKittrick Oil-Field, Kern County.

PHOTO 32. Oil City, Fresno County

bones, and marine diatoms. The light-colored shale is very much contorted, and the exposed rocks for the most part stand at a greater angle than do the underlying or overlying rocks. Resting non-conformably on the light-colored shales (see Bulletin No. 3) is a series of sandstones and shales, sandstone predominating. This series contains numerous fossils, and represents the Middle Neocene formation. In most places it dips to the east of south at an angle of less than 25°. In this formation, immediately overlying the silicious shales, are strata of oil-sand, beds of gypsum which at one time were mined, and diatomaceous rocks impregnated with petroleum, the last named resembling the diatomaceous rocks seen at McKittrick, in Kern County. These rocks contain Miocene and Pliocene fossils. Higher up in the series are sandy formations containing beds of *Ostrea titan*, *Liropecten*, and *Tamiosoma*. Still higher up are dark-colored sands containing petrified wood. The upper portion of the Middle Neocene formations in this locality is characterized by a soft bluish sandstone and fine conglomerate containing fossils of Middle Neocene age. The soft bluish sandstone dips east of north at an angle of 10° to 15°.

7.10.3. The first well in the Oil City field was drilled about 1890. It was 163′ deep, penetrated dark-colored shale and soft sandstone, and yielded a little green oil and much gas. A windmill pump was attached to this well, and 20 bbls. of oil were pumped from it in two days. The third day it yielded 7 bbls.

In 1891–92 four wells were drilled by Messrs. Rowland & Lacy of Los Angeles. In one of these (a 4″ well), which was drilled to a depth of 400′, the formation penetrated is soft dark-colored shale and soft sandstone. This well was tested by pumping, and yielded about 9 bbls. of oil daily. The other wells were never pumped.

When the locality of which Oil City is now the center was visited by the writer in 1893, he found five wells—one a 4″ well in which an oil of low specific gravity stood within 32′ of the surface, and in which inflammable gas bubbled freely through the oil (see table of oil analyses, Part 2, Chapter 3); one a 4″ well, plugged; one a 7″ well, plugged; one a 10″ well, plugged; one a 14″ well, from which oil and water flowed and from which inflammable gas was rising. The last named well was burning fiercely, and a small stream of mineral water and oil flowed from the top of the casing.

In 1895, the Producers and Consumers Oil Company of Selma was organized by J. A. McClurg and others. They sunk a 695′ well and a 700′ well on Sec. 20, T. 19 S., R. 15 E., M. D. M., a short distance southeast of the wells of Rowland & Lacy. The two wells sunk by McClurg & Co. yielded 15 bbls. and 20 bbls. of oil a day respectively. The gravity of the oil was 34° B.

In 1896, Chanselor & Canfield commenced drilling in Sec. 17, T. 19 S.,

R. 15 E., M. D. M. They drilled two or three wells which were small producers. In this year (1896) Chanselor & Canfield leased the territory of the Producers and Consumers Oil Company in the N.W. ¼ of Sec. 20, T. 19 S., R. 15 E., M. D. M. They then drilled a well about 300′ east of the old wells, and struck oil-sand at a depth of 890′. This was a flowing well and yielded about 300 bbls. of oil a day.

In 1897, the Home Oil Company, of Selma, was organized by G. W. Terrill and others. This company drilled in the N.E. ¼ of Sec. 20, T. 19 S., R. 15 E., M. D. M. The wells drilled ranged from 900′ to 1700′ in depth, and were farther down the dip of the formation than other wells drilled in the Oil City field at that time. The third well drilled by this company is the Blue Goose, which is 1400′ deep; this well was completed in 1898, and is a flowing well, which is said to have produced from 500 to 1000 bbls. of oil a day. In August, 1900, it was stated that this well flowed at the rate of 250 bbls. in twenty-four hours.

In 1899, many other companies commenced operations in the Oil City field, but without success.

In 1900, the exploitations were carried on farther to the east. In the Middle Neocene formations overlying the silicious light-colored shales, some of these wells have proved very successful.

7.10.4. During the early development of the Oil City field, much inconvenience was experienced through lack of water. In 1899, J. A. McClurg sunk two 275′ wells in the valley land about 6 miles southwest of Oil City. The formation is: Drift to 200′; water gravel to 212′; tough clay to 275′. The water rose about 5′ in the casing. These wells yield an immense supply. Two 4″ steam pumps are being used to pump the water into the receiving tank. A duplex Dow pump, having a capacity of more than 15,000 gallons in twelve hours, forces the water through 6 miles of 3″ pipe to an elevation of 275′ above the top of the wells. The oil-field consumes about 15,000 bbls. of water every twenty-four hours. This is potable water, and rather hard.

7.10.5. The output of petroleum from the Oil City field during 1899 was 439,372 bbls. The oil is conveyed by pipe-line from Oil City to Ora Station on the S. P. R. R., a distance of 8½ miles. (See Pipe-lines.)

THE ALCALDE FIELD.

7.10.6. This field is about 3 miles southwest of Coalinga, and extends from the old coal mines, which are about 4 miles a little west of north from Coalinga, to Alcalde Creek. The petroleum claims on which prospect wells have been drilled are situated in the first two tiers of foothills which run in a southeasterly direction from the old coal mines. These foothills are for the most part formed of sandstone containing fossils of the Middle Neocene age. (See Bulletin No. 3, pp. 58–59.) It is conceded that these Neocene rocks lie non-conformably on the Eocene, although the dip of the two formations is about the same. No white shale is seen between the Eocene and Middle Neocene formations in this locality, except a slight outcrop near the San Joaquin coal mine. In 1893 the writer obtained a small collection of fossils from the San Joaquin and California coal mines, which demonstrates that the formations of these mines are of the Eocene age (Cretaceous B, according to the old nomenclature). (See Bulletin No. 3, pp. 57–58.)

The outcropping rocks belonging to the Middle Neocene formations are principally sandstones with a little shale and conglomerate, the prevailing dip being about N. 70° E. Several brine and sulphur springs issue from this formation, and at one point there is a spring of tar-like oil. In 1893 the writer visited the San Joaquin coal mine (one of the coal mines in this locality) and saw a small quantity of oil of medium gravity bailed from one of the workings. There are no productive wells in the Alcalde district, but in August, 1900, ten prospect wells had been, or were being, drilled.

OIL CITY FIELD—PRODUCING WELLS.

Only such wells are mentioned as were producing in August, 1900.

7.10.7. *Coalinga Oil Company* (of Coalinga; C. A. Canfield, president) has fifteen wells in the N.W. ¼ of Sec. 20, and four wells on the S. ½ of Sec. 17, T. 19 S., R. 15 E., M. D. M. The wells on Sec. 20 range from 300′ to 1450′ in depth, and produce from 1 to 200 bbls. of oil a day. The formation is blue shale until oil-sand is struck at the bottom of the well. The oil-sand ranges from 2′ to 80′ in thickness. The wells on Sec. 17 range from 300′ to 600′ in depth, and it is said that they appear to be near the edge of oil-sand. They are small producers. The oil obtained from the wells on Secs. 17 and 20 has a gravity of about 33.3° B.

7.10.8. *Home Oil Company* (of San Francisco; R. A. Clark, president) has five wells, varying in depth from 1100′ to 1680′. The formation is dark-colored shale and oil-sand. These wells yield from 20 to 250 bbls. of oil a day. Specific gravity of oil, 33.3° B. No. 3 of this group is the original Blue Goose well, which has proved such a bonanza. In August, 1900, this company was drilling two new wells, which were then 500′ and 1200′ deep, respectively.

7.10.9. *Independence Oil Company* (of Fresno) has three wells, varying in depth from 800′ to 1000′, in the S.W. ¼ of the N.E. ¼ of Sec. 28, T. 19 S., R. 15 E., M. D. M. Formation, shale and sandstone. These wells are said to yield more than 5 bbls. a day each. Gravity of oil, 22° B. This is a brown oil.

7.10.10. *Oil City Petroleum Company* (J. T. G. Hart, president) has a 450′ well in the W. ½ of the N.W. ¼ of Sec. 28, T. 19 S., R. 15 E., M. D. M., and three wells in the S.E. ¼ of the same section. These wells range from 800′ to 950′ in depth. They yield about 40 bbls. of oil a day. Specific gravity of oil, about 22° B. The formation is sandstone and shale.

7.10.11. *Phœnix Oil Company* (of Hanford; P. McRae, president) has a 330′ well and a 560′ well in the S.E. ¼ of Sec. 20, T. 19 S., R. 15 E., M. D. M. The formation in the deeper of these wells is as follows: Pink shale to 300′; sand with water to 330′; dark-colored shale to 420′; sand, with sulphur, water, and oil, to 440′; dark-colored shale to 500′; white clay-shale to 520′; oil-sand to 535′; shale to 540′; white shale to 560′; oil-sand to 575′. It is said that this well yields 50 bbls. of oil a day. Specific gravity, 18° B. In the shallower well the oil-sand was struck at a less depth, but the well yields only 25 bbls. of oil a day. Specific gravity of the oil is 14° B.

7.10.12. *Twenty-eight Oil Company* (of Hanford) has a 1000′ well in the N.E. ¼ of Sec. 28, T. 19 S., R. 15 E., M. D. M. It is said that this well yields about 50 bbls. of oil a day. Gravity of oil, 22° B. This is a brown oil. Formation, shale and soft sandstone.

OIL CITY FIELD—PROSPECT WELLS.

7.10.13. *Ætna Oil Company* (of San Francisco) has a 900′ well in the N.E. ¼ of Sec. 31, T. 19 S., R. 15 E., M. D. M. Formation, mostly shale. Abandoned.

7.10.14. *Blue Goose Oil Company* (of San Francisco; W. H. Gray, manager) has a 1600′ well in the E. ½ of the N.E. ¼ of Sec. 20, T. 19 S., R. 15 E., M. D. M. Formation, dark-colored shale. Drilling.

7.10.15. *Bonanza King Oil Company* (of San Francisco; Mr. Hotaling, president) has a 1300′ well in the S.W. ¼ of Sec. 10, T. 19 S., R. 15 E., M. D. M. Formation, shale and water-sand.

7.10.16. *California Oil and Gas Company* (of Coalinga; W. Graham, president) has a well in the S.E. ¼ of Sec. 19, T. 19 S., R. 15 E., M. D. M. Formation, principally shale. This company has also a well in the S.W. ¼ of Sec. 20. Abandoned.

7.10.17. *Caribou Oil Company* (of Hanford; C. C. Spinks, president) has a well in the S.W. ¼ of Sec. 22, T. 19 S., R. 15 E., M. D. M. Formation, dark-colored shale and oil-sand.

7.10.18. *Carmelita Oil Company* has commenced drilling in the W. ½ of the E. ½ of Sec. 3, T. 20 S., R. 15 E., M. D. M.

7.10.19. *Confidence Oil Company* (of Fresno; F. Clarey of Coalinga, manager) has a 900′ well in the S.E. ¼ of Sec. 25, T. 19 S., R. 4 E., M. D. M. Formation, dark-colored shale. Drilling tools lost in the well. Abandoned. This company has also a 300′ well in the N.W. ¼ of Sec. 31, T. 19 S., R. 15 E., M. D. M.

7.10.20. *Crescent Oil Company* has a 900′ well in the S.E. ¼ of Sec. 20, T. 19 S., R. 15 E., M. D. M. Formation, light-colored shale. Abandoned.

7.10.21. *Elk Oil Company* (of Hanford; E. E. Bush, president) has a 500′ well in the N.E. ¼ of Sec. 22, T. 19 S., R. 15 E., M. D. M. Formation, shale and much water.

7.10.22. *Great Western Oil Company* (G. W. McNear, president) has an 1150′ well in the S.W. ¼ of Sec. 26, T. 19 S., R. 15 E., M. D. M. Formation, shale and sandstone, with much water.

7.10.23. *Independent Oil Company* has a 1580′ well on the N.E. ¼ of Sec. 17, T. 19 S., R. 15 E., M. D. M. Formation, dark-colored shale and sandstone, flowing water, and a little oil. Abandoned.

7.10.24. *Investment Oil Company* (of San Francisco; E. B. Pond, president) has an 1800′ well in the S.E. ½ of Sec. 16, T. 19 S., R. 15 E., M. D. M. Formation, dark-colored shale. Drilling.

7.10.25. *Minnesota Oil Company* (of Fresno, Cal., and Duluth, Minn.; J. A. McClurg, president) has a 600′ well in the N.E. ¼ of Sec. 23, T. 19 S., R. 15 E., M. D. M. Formation, sandstone and blue shale. Drilling.

7.10.26. *Montjack Oil Company* (of Hanford; E. E. Bush, president) has a 500′ well in the N.W. ¼ of Sec. 22, T. 19 S., R. 15 E., M. D. M. Tools lost. Not completed.

7.10.27. *Mutual Oil Company* has an 1800′ well in the S.E. ¼ of Sec. 20, T. 19 S., R. 15 E., M. D. M. Abandoned.

7.10.28. *New York Oil Company* (of Coalinga; L. L. Cory, president) has a 2080′ well in the S.W. ¼ of Sec. 20, T. 19 S., R. 15 E., M. D. M. Formation, shale.

7.10.29. *Old Keystone Oil Company* (of Santa Paula, Ventura County; Lyman Stewart, president) has an 1150′ well on the S.E. ¼ of Sec. 8, T. 19 S., R. 15 E., M. D. M. Formation, dark-colored shale, with small quantity of oil. Abandoned. This company has also a 1200′ well on Sec. 4, T. 19 S., R. 15 E., M. D. M. Drilling.

7.10.30. *Rock Oil Company* has a 700′ well in the S.W. ¼ of Sec. 28, T. 19 S., R. 15 E., M. D. M. Formation, shale and sandstone. Drilling.

7.10.31. *Santa Clara Oil Company* has a 900′ well in a fraction on the west side of Sec. 30, T. 19 S., R. 15 E., M. D. M. Abandoned on account of water.

7.10.32. *The Selma Oil Company* (J. A. McClurg, president) has an 1888′ well in the S.E. ¼ of Sec. 20, T. 19 S., R. 15 E., M. D. M. Formation: Sandstone to 340′, then dark-colored shale to within 70′ of the bottom of the well, at which depth oil-sand was struck. Abandoned.

7.10.33. *Wisconsin Oil Company* (of Superior, Wisconsin; J. M. Smith, president) has a 400′ well in the N.E. ¼ of Sec. 32, T. 19 S., R. 15 E., M. D. M. Formation, principally sandstone. Drilling.

ALCALDE OIL FIELD—PROSPECT WELLS.

The following records were obtained in August, 1900:

7.10.34. *Badger State Oil Company* (of Duluth, Minn.; P. G. Hart of Fresno, president) has a 700′ well near the center of Sec. 1, T. 21 S., R. 14 E., M. D. M. The formation is similar to that noted at the Sunnyside wells. This well was abandoned on account of water and running sand.

7.10.35. *Hawkeye State Oil Company* (of Los Angeles) has two wells in Sec. 6. One of these is 500′ deep, and is being drilled still deeper. It is said that oil-sand has been struck in one of the wells; the other well is abandoned.

7.10.36. *May Brothers* (of Coalinga, Fresno County) have a 970′ well in the S.E. ¼ of Sec. 14, T. 20 S., R. 14 E., M. D. M. The formation is blue shale. At 900′ a small quantity of light oil was struck in a thin stratum of oil-sand. Abandoned.

7.10.37. *Rommel & Westlake Oil Company* (of Los Angeles) has a well in the N.E. ¼ of Sec. 2, T. 21 S., R. 14 E., M. D. M. Work suspended.

7.10.38. *Star Oil Company* (of San Francisco; G. W. Terrill, president) has a 650′ well in the N.W. ¼ of Sec. 34, T. 19 S., R. 15 E., M. D. M. Formation, principally blue shale.

7.10.39. *Sunnyside Oil Company* (of West Virginia; J. A. McClurg of Coalinga, president) has a 654′ well in the S.E. ¼ of Sec. 35, T. 20 S., R. 14 E., M. D. M. Formation: Sandstone to 40′; dark-colored shale, with oil, to 75′; oil-sand to 110′ (this oil had a specific gravity of 25° B.); then a stratum of hard sandstone, and a thick stratum of running sand with good water to 654′. This company has also a 256′ well and a 312′ well in the N.W. ¼ of Sec. 1, T. 21 S., R. 14 E., M. D. M. In these wells a formation similar to that noted in the well in Sec. 35 was penetrated, but the oil-sand was struck at a depth of 256′ and 312′, respectively. The oil-sand was penetrated for about 20′. It is said that these wells would produce about 3 bbls. of green oil a day, which has a specific gravity of 24° B.

7.10.40. *Wright Association* (of Downey, Los Angeles County; W. W. Wright, president) has a 900′ well in the N.W. ¼ of Sec. 26, T. 20 S., R. 14 E., M. D. M. This well is about 200′ north of the Whittier & Green well. It was abandoned on account of water.

WARTHAM CREEK FIELD.

7.10.41. *Venus Oil Company* (of San Francisco; J. Greenbaum, president) has an 850′ well in the N.W. ¼ of Sec. 5, T. 22 S., R. 14 W., M. D. M. Formation, slaty shale, with traces of oil of high specific gravity. Drilling.

7.10.42. *Wale Oil Company* (of Los Angeles) has a 700′ well in Sec. 4, T. 22 S., R. 14 E., M. D. M. Some oil was struck, but the well was abandoned on account of water and quicksand.

PART 8.

MONTEREY, SAN LUIS OBISPO, AND SAN BENITO COUNTIES.

CHAPTER 1.

MONTEREY COUNTY.

THE OIL-YIELDING FORMATIONS.

By H. W. Fairbanks, Ph.D.

8.1.1. The geological conditions of Monterey County with reference to oil are in many respects quite similar to those of San Luis Obispo County, which adjoins it on the south. (See San Luis Obispo County.) The same formations that are found in the latter county extend northwesterly into Monterey. In recent months much attention has been given to the oil-producing shales of this county, particularly in that region lying along the western side of the Salinas Valley, and in the southeastern portion occupied by the Cholame Valley. The following notes will deal particularly with the western portion of the county.

In the western part of the county the oil-yielding formations are confined to the strip of territory lying between the summit of the Santa Lucia range and the Salinas River. These formations probably extend under the Salinas Valley in the direction of Cholame, but are separated from that valley by a low ridge of older rocks. At the southern edge of the county the flinty organic shales of the oil-producing formation form low hills, through which the San Antonio River flows to join the Salinas. As we continue northward between the San Antonio and the Salinas rivers we find a broad zone of low hills called the San Antonio Hills. These hills, as well as the region occupied by the San Antonio Valley, are formed of the same oil-producing shales. North and northwest of Jolon these rocks rise to form the more rugged mountains grouped about Santa Lucia Peak. A broad reach of mountainous country formed of the shales extends northerly to the valley of the Arroyo Seco and thence over a low divide to the headwaters of the Carmelo River. In the latter region the shales form a long trough inclosed between the Santa Lucia range and the Soledad Hills. The shales continue almost unbroken down the valley of the Carmelo River to the ocean. The writer is not aware that any oil has been found in this region.

Although the oil-producing rocks are thus seen to be very extensive in Monterey County, indications of the presence of oil are not as prominent as farther south. There are, however, a number of promising localities. At the point where the San Antonio River cuts through the hills to join the Salinas, there is an extensive bed of oil-sand or bituminous rock. This may be traced for about a mile, and is fully 200′ thick in places. The oil, as it issued from the shales, has here been preserved in a bed of sandstone at the base of the San Pablo formation. The extent of the latter formation and the presence of porous sandstones at its base condition, in large measure, the extent and value of the oil-deposits of this section, as is the case in San Luis Obispo County. Farther north, along the eastern slope of the San Antonio Hills, in the vicinity of San Lucas, other indications are reported, and it is these that form the basis of the drilling now going on in the latter region. Seepages are also reported from one of the southern branches of the Arroyo Seco.

Six miles west of Bradley a well is now being drilled with the expectation of testing a portion of the oil-sands first described. Near San Lucas, one well has been drilled with negative results.

In selecting locations for wells in this region, the greatest care should be exercised in studying the peculiarities of the formations present. It should be recognized that the oil-sands are not a part of the flinty shales, the oil-producing formation, but that they lie at the base of a younger formation overlying the former. Faulting and folding have affected this younger formation, and these conditions must be taken into account. Wells drilled in the flinty shales are doomed to be dry.

THE PARKFIELD DISTRICT.

By W. L. Watts.

8.1.2. The Parkfield district embraces T. 23 S., R. 13 E., and that portion of T. 22 S., R. 14 E., M. D. M., which lies west of the Fresno County line. In this district the greatest interest has been centered in the Little Cholame Valley. On the east side of this valley the main ridge of the Coast Ranges rises to an elevation of nearly 4000′. The axial rocks of this ridge are granite. In some places the granite is overlain by metamorphic sedimentary formations, and in others by unaltered Tertiary rocks. In the Parkfield district the Tertiary system is well represented. In Stone's Cañon are coal-bearing rocks, presumably of Eocene age. At several places in the Little Cholame Valley, silicious shales, characteristic of the Lower Neocene series, are found; they are also met with higher up on the mountain range, where they rest on the granite. In by far the greater portion of Cholame Valley the exposed rocks are shales and sandstones belonging to the Middle Neocene series. At several places in the Little Cholame Valley there are seepages of petroleum issuing from rocks belonging to the Middle Neocene series, and strata of oil-sand are exposed. At one point on the Big Sandy Creek oil of low specific gravity issues from a narrow strip of sedimentary rocks. Toward the north, these unaltered sedimentary formations are in contact with a bed of metamorphic sedimentary rocks and serpentine, and toward the south with granite; the latter is for the most part covered with sedimentary formations, probably of Neocene age. The granitic rocks form the axis of a fold which extends through the upper portion of the Big Sandy and Cholame creeks. In most places where the granitic rocks crop out, they are much decomposed and might easily be mistaken for sandstone. In September, 1900, the following companies were operating in the Parkfield district:

8.1.3. *Cholame Valley Oil and Development Company* (Captain Frank Barrett of Palo Alto, manager) has four wells in Sec. 31, T. 22 S., R. 14 E., and Sec. 5, T. 23 S., R. 14 E., M. D. M. One well was drilled 950′ through shale, rotten sand, and granite; a small amount of oil (gravity, 20° B.) was struck at a depth of 130′. The three other wells in like formation had a depth of 800′, 200′, and 200′, respectively. Abandoned.

8.1.4. *Parkfield Oil Company* (Captain Frank Barrett of Palo Alto, manager) has a well about 100′ deep in Sec. 16, T. 23 S., R. 14 E., M. D. M. Abandoned.

8.1.5. *Waverly Oil Company* (Charles King of Hanford, president) has a well in Sec. 32, T. 22 S., R. 14 E., M. D. M. At 350′ sand and a little gas were encountered; at 700′ and 800′ from 18″ to 2′ of lime "shells" were penetrated; below that depth the formation is black shale. This well is 1100′ distant from the croppings of light-gray sand, and 1700′ east of a granite ledge which has a strike of west of north.

THE SAN ARDO DISTRICT.

8.1.6. This district includes that portion of the drainage basin of the Salinas River and its tributaries which lies between the 5th and 6th standard lines south of Mount Diablo. In September, 1900, the following companies were operating in this district:

8.1.7. *Tomboy Oil and Improvement Company* (of San Francisco) has one well in Sec. 19, T. 22 S., R. 10 E., M. D. M.

8.1.8. *San Antonio Oil Company* (Seth Mann of San Francisco, president). In October, 1900, this company was drilling on lands in Secs. 20, 29, and 30, T. 22 S., R. 10 E., M. D. M., on the west side of the Salinas River about 2 miles southwest of the town of San Ardo.

8.1.9. *San Ardo Consolidated Oil Company* (G. W. Fletcher of San Francisco, president). The territory of this company is in San Ardo district, in Sec. 12, T. 22 S., R. 9 E., M. D. M., and Sec. 7, T. 22 S., R. 10 E., M. D. M. One well; formation, soil to 50′; water-sand to 100′; sandy shale to 200′; coarse gray sand, gravel and bowlders, and sandy shale interbedded with oil-sand to 450′; hard shells and shale to 500′; oil was struck between the depths of 560′ and 630′; below that depth the formation is oil-sand and shale to 846′.

CHAPTER 2.

SAN LUIS OBISPO COUNTY.

THE OIL-YIELDING FORMATIONS.

By H. W. Fairbanks, Ph.D.

8.2.1. That portion of the Coast Ranges embraced within the boundary of San Luis Obispo County is characterized particularly by extensive deposits of bituminous rock. There are also to be found numerous springs of a thick, tar-like oil. Under some circumstances the oil from these springs has impregnated sandstones forming bituminous rock; under others it has accumulated in great quantities on the surface, as in the valley of Tar Spring Creek. The source of the oil is to be found in a formation which once covered nearly the whole of the area of the county, but which has now been in a great measure removed by erosion. This oil-producing formation belongs to the lower part of the Middle Tertiary period, and is known as the Monterey formation. It is composed of sandstones, limestones, clays, and hard silicious shales. Investigation has shown that the limestones and silicious shales are the source of the oil and other bituminous products. The rocks are in a great part of organic origin, having been formed of the skeletons of fish and microscopic sea organisms. In some places the oil-producing rocks are nearly a mile in thickness.

Through a long-continued process of distillation brought about through the influences of pressure and heat, the organic matter has been driven off and in places preserved. Conditions for its preservation are in part furnished by porous rocks, such as sandstones and sandy shales. The oil-producing formation is at present found forming the main portion of the San Luis range, extending from Point Buchon southeasterly past Arroyo Grande and toward the Sisquoc. That portion of the Santa Lucia range lying east of Cuesta Pass is also formed of the same shales. Another belt runs northwesterly past Santa Margarita and down the Salinas Valley. These rocks swing around the northern edge of the low granite mountains lying east of the Salinas River, and undoubtedly underlie the Estrella region. Going south toward La Panza, upon the northeastern side of the San José Mountains, extensive outcrops of these rocks appear. They dip easterly under the valley of the San Juan, and there is every reason to suppose that these oil-producing shales underlie much of the Carissa Plains and the Temblor range, separating these plains from the San Joaquin Valley. They thus appear to connect with the oil-producing regions of Kern County. It must be borne clearly in mind in exploiting for oil that this oil-producing formation, whose extent has just been described, is not necessarily the best one in which to drill wells. Although the thick oil is distinctly seen issuing from this formation in springs in the San Luis and Santa Lucia ranges, yet it can only be found gathered in commercial quantities in those rocks which are of a nature sufficiently porous to permit of its absorption. On Tar Spring Creek, as well as on the Huasna River, heavy beds of sandstone are associated with the oil-producing shales as a part of the same formation, and it would seem that conditions might be favorable in this region for oil-wells in the oil-producing formation; but in other parts of the county oil can be found only where another and younger formation occurs overlying the oil-shales. It is to this younger formation that we owe the presence of the great deposits of bituminous rock in the vicinity of Edna, where this formation consists essentially of porous sandstones. The formation is termed the San Pablo, and belongs to the upper division of the Middle Tertiary. The San Pablo formation forms an elongated basin-like syncline reaching from a point on the Marie ranch about 1 mile northwest of Sycamore Springs southeasterly to Arroyo Grande Creek. The base of this formation, resting directly upon the oil-producing shales, is almost everywhere filled with an oil now so thickened that it constitutes the bituminous rock of commerce. Upon the Marie ranch along the ocean cliffs southeast of Mallagh Landing, and in the vicinity of Edna, the outcrops of bituminous rocks are particularly prominent. In the past years, quite a number of wells have been drilled in San Luis Obispo County, but the most of these have been so poorly located that, as yet, we cannot assert that this field has been fairly prospected. That vast quantities of oil have been formed here is certain; that it is forming to-day through chemical action and heat is equally certain, but as to whether it will be found in quantity in a thin condition, we have as yet no definite evidence. It may be that in this region the oil has a greater proportion of permanent base than in other sections. More investigations, however, are required to settle the matter.

In drilling wells, it is very important to pay attention to the geological conditions. Those locations must be selected where the geological structure indicates that the proper rocks will be penetrated by the drill. Much useless work has been done in this section because of the lack of precaution in this regard. It is certain that the supply of bituminous rock in the southern part of the county is very great, and further exploitation may show oil thin enough to pump. Indications are certainly favorable. In the northeastern part of the county there is a vast field underlain by the oil-producing rocks which is worthy of practical investigation. It is as yet too little known for one to say anything about the depth at which these rocks would be encountered.

RECORD OF WELLS.

By Geo. A. Tweedy, C.E.

8.2.2. In this county there is as great a showing of bituminized formations as in any other county in the State. There are extensive beds of bituminous rock which have yielded a large amount of paving material, and some attempts have been made to mine and refine the asphaltum which occurs as superficial deposits. During the last twelve years, several prospect wells have been drilled for oil, and in September, 1900, the following companies were operating in San Luis Obispo County:

8.2.3. *Huasna Development Company* (of Alcatraz Landing, Santa Barbara County) has two wells in the Huasna district about 15 miles east of Arroyo Grande. One of these wells is in T. 32 S., R. 15 E., M. D. M., and is said to be 841′ deep. Abandoned. The other is in Sec. 23, T. 32 S., R. 15 E., M. D. M. In October, 1900, this well was said to be 210′ deep. Drilling.

8.2.4. *San Luis Obispo Petroleum Company* has one well on the Tar Spring ranch in T. 32 S., R. 14 E., M. D. M. This well is said to be 900′ deep. Abandoned.

8.2.5. *Union Oil Company* has three wells near Arroyo Grande. In these wells only traces of oil were obtained. This company is drilling a fourth well in the same locality.

CHAPTER 3.

SAN BENITO COUNTY.

8.3.1. In San Benito County there are oil-yielding formations in the Big Panoche, Little Panoche, and the Hollister districts.

BIG PANOCHE DISTRICT.

8.3.2. This district includes the drainage basin of the Big Panoche Creek and its tributaries. By far the greater portion of the district lies within the confines of San Benito County. The companies that have drilled or are drilling in the Big Panoche district are as follows:

8.3.3. *Ashurst Oil Company* (Jacob Simon of Stockton, president). This company began operations in October, 1900, in Sec. 31, T. 16 S., R. 11 E., M. D. M., on the lands of Robert Ashurst, 2 miles south of the Union Oil Company's lands.

8.3.4. *Dewey Oil Company* (W. Crawford of Hanford, president). A 16′ shaft sunk by this company on Sec. 8, T. 17 S., R. 11 E., M. D. M. struck a strong seepage of oil.

8.3.5. *Dos Palos Oil Company* (M. Christian of Dos Palos, president) has a well in Sec. 8, T. 15 S., R. 11 E., M. D. M. Drilled, with hydraulic rig, 400′ through shale and sandstone. A small quantity of oil was struck.

8.3.6. *Esmeralda Oil and Development Company* (H. S. Field of San Francisco, president) has a well in Sec. 13, T. 15 S., R. 10 E., M. D. M. Hand-drilled 32′, through shale; struck sand stratum with a little oil. This company was also preparing to drill in Sec. 26, T. 17 S., R. 11 E., M. D. M.

8.3.7. *Fresno Alpha Oil Company* (Gen. J. M. Gleaves of San Francisco, president) has a well in T. 16 S., R. 12 E., M. D. M., on Silver Creek. This well was drilled to a depth of 325′, and struck a strong flow of gas. Between the depths of 95′ and 268′, a 35′ and a 33′ stratum of oil-sand were struck; at 300′ a heavy flow of water was encountered. This company has made a preliminary survey for a railroad line to Mendota.

8.3.8. *Hamiltonian Oil Company* (N. C. Briggs of Hollister, president) has sunk a shaft 14′ deep in Sec. 24, T. 17 S., R. 11 E., M. D. M A 2′ stratum of oil-sand was struck. Still prospecting.

8.3.9. *Ingomar Oil Company* (M. H. de Young of San Francisco, president) has a well in Sec. 8, T. 15 S., R. 11 E., M. D. M. Hand-drilled 17′ through shale and sand.

8.3.10. *McCoy Oil Company* (R. Irwin of Fresno, president) has sunk several shafts from 6′ to 16′ deep in Sec. 9, T. 17 S., R. 11 E., M. D. M. Some oil struck.

8.3.11. *Olympia Oil Company* (John Hammerschmidt of San Francisco, president) has sunk a shaft 46′ deep in Sec. 10, T. 15 S., R. 11 E., M. D. M.

8.3.12. *San Benito Oil Company.* During the summer of 1900, this company prospected in Secs. 24 and 36, T. 16 S., R. 10 E.; Sec. 1, T. 17 S., R. 10 E.; Sec. 7, T. 17 S., R. 11 E., M. D. M. (lands of J. C. Barg); and in Sec. 6, T. 17 S., R. 11 E., M. D. M. (lands of Thomas Flint, Jr., and Mark Ashurst), 65 miles southeast of Hollister.

8.3.13. *San Carlos Oil Company* has a well in Sec. 8, T. 17 S., R. 11 E., M. D. M. Seven years ago a 105′ well was drilled by hand, and some oil struck. No work has been done since, owing to litigation.

8.3.14. *Santa Maria Oil Company* (Charles T. Behan of San Francisco, president) has sunk a 40′ shaft in Sec. 21, T. 17 S., R. 11 E., M. D. M. Formation, principally sandstone. Some oil was struck.

8.3.15. *Silver Creek Oil Company* (George W. Schmidt of Fresno, president) has a well in Sec. 33, T. 15 S., R. 12 E., M. D. M., on Silver Creek 15 miles south of Panoche store. Drilled 800′ through sand and shale.

8.3.16. *Union Oil Company* (Lyman Stewart of Santa Paula, president) has drilled five wells, varying in depth from 700′ to 1200′ in Sec. 24, T. 16 S., R. 10 E., and Sec. 19, T. 16 S., R. 11 E., M. D. M. Three of these wells produced 30 to 40 bbls. per day; oil, 34° B. These three wells were capped. The two others were abandoned and the casings drawn.

THE LITTLE PANOCHE DISTRICT.

8.3.17. This district includes the drainage basin of the Little Panoche Creek and its tributaries. The greater portion of the district is in Fresno County. In October, 1900, the following companies were operating or had been operating in this district:

8.3.18. *Big Panoche Oil Company* has a well 700′ deep in Sec. 23, T. 13 S., R. 11 E., M. D. M. Casings drawn and well abandoned.

8.3.19. *Old Glory Oil Company* (in Merced County?). One well drilled 530′ and abandoned.

8.3.20. *Pacific Oil and Development Company* (of Los Baños) has a well in T. 13 S., R. 9 E., M. D. M. Drilled 400′. At a depth of 280′ some oil was struck.

8.3.21. *Panichito Oil Company* (D. M. Lloyd of Oakland, president) has a well in Sec. 20, T. 14 S., R. 11 E., M. D. M. Drilled 350′ through shale and sandstone. Some oil was struck.

8.3.22. *World Oil Company* (J. T. Riley of San José, president) has drilled one well in Sec. 31, T. 14 S., R. 10 E., M. D. M., 500′ through shale and sand, encountering a body of salt water.

THE HOLLISTER DISTRICT.

8.3.23. This district includes the drainage basin of the San Benito River and its tributaries. In October, 1900, the following companies were operating or had been operating in this district:

8.3.24. *Hollister Crude Oil Company* (Ltd.) (C. J. Tallon of San Francisco, president; E. J. Bean, resident superintendent). This company has sunk a 68′ shaft on lands leased from R. W. Chappel in San Justo grant, Lot 14, 4 miles southeast of Hollister. The formation is black shale, with a strong odor of oil. In October, 1900, a derrick had been erected preparatory to drilling.

8.3.25. *Nonpareil Consolidated Oil Company* (of San Francisco; E. C. Newell, manager) has a 1030′ well in Sec. 32, T. 18 S., R. 10 E., M. D. M., on the Alvarez ranch near Bitterwater Creek. Formation, blue shale and some hard shells, with traces of oil. Drilling. This company has also three test wells, 68′, 89′, and 97′ deep, respectively. The owners state that oil was struck in all the test wells.

8.3.26. *San Benito County Oil Company* (R. P. Lathrop of Hollister, president; E. J. Bean, superintendent). This company is operating on 170 acres of land leased from John Kehl, 5 miles southeast of Hollister, in Sec. 24, T. 13 S., R. 5 E., M. D. M. In the middle of October, 1900, one well had been drilled to a depth of 425′. Formation: Black shale to 220′; oil-sand to 267′; blue shale to 285′ (at this depth gas and warm salt water were struck); blue shale to 425′.

PART 9.

ALAMEDA, SANTA CLARA, SAN MATEO, AND CONTRA COSTA COUNTIES.

CHAPTER 1.

ALAMEDA COUNTY.

9.1.1. Oil-yielding formations crop out in many places in Alameda County, and as early as 1875 attracted the attention of the oil-prospector. Since that date, several comparatively shallow wells have been sunk, principally in the vicinity of Livermore.

9.1.2. *The Alameda Oil Company* (of San Francisco) has a well in Sec. 22, T. 2 S., R. 2 E., M. D. M., at a point about 4 miles north of Livermore. In July, 1900, this well was 1175′ deep. The formation is principally sandstone. The well yields much gas and salt water, with some traces of oil.

CHAPTER 2.

SANTA CLARA COUNTY.

9.2.1. The existence of petroleum-yielding formations in Santa Clara County has been known for many years, notably at Moody Gulch and at the Sargent ranch near the western boundary of the county. At the first-mentioned locality an oil-field was developed by Mr. R. C. McPherson, the first well being drilled in 1878–79. This field has been a productive one until the present time. It is now owned by the Golden Gate Oil and Development Company. On the Sargent ranch there are extensive superficial deposits of asphaltum, and tar-springs ooze not only from sedimentary formations, but also from serpentine. In 1890 a well was sunk on the Sargent ranch, but only a small quantity of tar-like oil was obtained. A large portion of the Sargent ranch and adjacent territory is leased by the Watsonville Oil Company, as hereinafter noted.

9.2.2. The geological formations seen by the writer on the territory of the Watsonville Oil Company consist of:

(1) Silicious shales, which resemble the silicious shales of the Lower Neocene series. These shales are inclined at a great angle, and yield a heavy, tar-like oil, which forms superficial beds of asphaltum.

(2) A formation, consisting principally of sandstone, which appears to rest non-conformably on the silicious shales; in places the sandstone is bituminous.

A small portion of the territory owned by the Watsonville Oil Company is in Santa Cruz County.

9.2.3. Output of petroleum in Santa Clara County for three years ending 1899:

	Bbls.	Value.
1897	4,000	$10,000 00
1898	3,000	6,000 00
1899	1,500	3,000 00
Total for three years	8,500	$19,000 00

PRODUCTIVE OIL-WELLS.

Only those wells are mentioned which were producing in July, 1900.

9.2.4. *Golden Gate Oil and Development Company* (of San Francisco; Frank A. Garbutt, president). This company succeeded A. McPherson. The wells, numbering some fourteen, are situated in Moody Gulch, 2 miles west of Alma, in Secs. 8 and 17, T. 9 S., R. 1 W., M. D. M. The company began operations in March, 1900, re-opening two of the old wells, one at an elevation of 1225′, the other at 1050′. The upper well, which was down 700′, was deepened to 1150′, through black shale for the greater depth, and through a white pebbled sand near the bottom. A small amount of oil (about 1 bbl. per day) was struck at 900′. The lower well was sunk 900′ by the former operators, and the present company had derrick, engine, and boiler on the ground in July to continue drilling. A third well, which was drilled to a depth of about 1200′ by former operators, contains oil that stands about 15′ below the collar of the well. The oil has a gravity of 39° B. The formation has a strike of west of north, and dips to the west. Steam power is used, with wood for fuel. Until 1900 these wells were the only productive wells in Santa Clara County; in that year they produced 1500 bbls of oil.

9.2.5. *Watsonville Oil Company* (of Watsonville; F. A. Kilburn, president) has under lease 7235 acres, including 3269 acres of the J. P. Sargent tract, 1200 acres of the Santa Clara Land and Lumber Company tract, and 1845 acres of the Casserly tract. The Sargent lands, on which the Watsonville Oil Company operates, occupy Sec. 31 and a portion of Sec. 32, T. 11 S., R. 4 E.; Secs. 5 and 6, T. 12 S., R. 4 E.; Sec. 1 and a portion of Sec. 2, T. 12 S., R. 3 E.; and Secs. 35 and 36, T. 11 S., R. 3 E—all in M. D. M. There is also included in these lands two strips adjoining the Sargent lands on the north, containing respectively 433 and

488 acres. The Santa Clara tract and the Casserly tract lie to the north and northwest. The operations include seven wells. Well No. 7 was started in September, 1900, and in the middle of that month was down about 300′. Wells Nos. 5 and 6 were sunk 670′ and 980′. In the spring and summer of 1900, No. 5 was producing about 5 bbls. a day, the oil finding a market at Gilroy and Hollister, where it is used for fuel; it is also used for fuel by the company operating the wells. In July last, it was decided to abandon well No. 6, for only traces of oil had been found in it, but when the casing was drawn, oil began to flow into the well. Well No. 7 was then commenced within 300′ of Nos. 5 and 6. The wells of the Watsonville Oil Company are 2 miles distant from a shipping point on the S. P. R. R.

PROSPECT WELLS.

Information obtained by L. H. Eddy.

Only those wells are mentioned which had been drilled, or were being drilled, in August, 1900.

9.2.6. *Alma Oil Company* (of San José; M. G. Rhodes, president) has a well 4 miles south of Alma, in T. 9 S., R. 1 W. The company owns 20 acres on Los Gatos Creek. Drilling was commenced in July, 1900. The well is situated at an elevation of 1425′, on a yellow sandstone belt which has a course of east of north. It is within half a mile of the Santa Cruz narrow-gauge branch of the S. P. R. R., 2½ miles from Wrights, and 60 miles from San Francisco. Steam power is used. There is a plentiful supply of wood and water.

9.2.7. *Gilroy Oil and Development Company* (of Gilroy, recently incorporated). This company has bonded 1000 acres of land on Uvas and Arthur creeks, in Solis district, 4½ miles west of Gilroy. The surface formation is sandstone. There are oil-seepages within 200 yards of the well.

9.2.8. *Kreyenhagen Land and Oil Company* (of Los Angeles; John A. Hendrickson, president) has leased from the Watsonville Oil Company 250 acres in Sec. 32, T. 11 S., R. 4 E., M. D. M. In September, 1900, this company was preparing to drill.

9.2.9. *Main Estate* (oil-wells on). The following records of wells drilled on the Main Estate, 7½ miles south of San José, were given the writer by R. C. McPherson, of Santa Clara County:

Well No. 1: Coarse gravel to 30′; sand and clay to 50′; slate to 83′; brown shale and gas to 134′ (gas burned at top of well); sand, with oil, to 160′; hard shale (gas) to 170′; soft shale and a little sand, with oil, to 180′; hard, dark shale, with oil, to 212′; granitic rock and shale to 260′; black shale and oil to 285′; hard shells to 290′; shale, with oil, to 300′; shelly formation, with some oil, to 215′; dark shale to 340′; lime rock to 390′; brown shale to 400′; sandy shale to 410′; slate and iron pyrites to 415′; hard gray sand and gas to 422′; shale to 462′; slate and streaks of hard, shelly rock to 498′; shale to 504′; cavey formation to 508′; sandy shale, with strong flow of gas, to 513′; slate to 541′; soap rock to 565′; slate to 580′; sand rock to 590′; sand and shale, with more gas, to 620′; slate to 629′; very soft slate to 666′; hard streaks of slate to 680′; bottom of well in slate to 754′. The well was cased with 10″, 8″, and 6″ casing. Drilled in 1892.

Well No. 2: Gravel to 25′; sand to 35′; clay and little streak of sand to 28′; sand to 109′; clay to 119′; brown shale, with heavy oil, to 136′; brown shale and gas to 153′; sand to 156′; brown shale to 162′; shale mixed with green rock to 170′; dark sand, with showing of oil, to 190′; hard shale (brown) to 200′. This well is 30′ west of well No. 1. Drilled in 1894.

Well No. 3: Sand and gravel to 30′; green clay and thin stratum of brown shale to 112′; coarse gravel and sand, with gas and heavy oil, to 141′; streaks of clay mixed with sand rock to 180′; shale to 184′; brown sand rock to 200′; brown shale to 228′; marl filled with sea-shells to 336′; brown shale to 345′; mud streak to 406′; soft brown shale to 437′; very dark shell rock and salt water to 478′; gray sand, with strong flow of gas, to 490′ (at this depth the gas raised water over derrick); gray sand and more gas to 505′; dark slate rock filled with sea-shells to 520′; sand rock, with asphaltum, to 525′; hard shale to 557′; mud streak to 565′; brown shale, full of oil, to 570′; brown shale, with more oil and gas, to 574′. Drilling was still in progress, the formation being shale, with oil and gas, when record was obtained. Drilled in 1896–97.

CHAPTER 3.

SAN MATEO COUNTY.

9.3.1. Oil-yielding formations have been traced through many portions of San Mateo County, and there are numerous seepages of petroleum; there are also deposits of asphaltum on the Savage ranch about 2 miles southeast of Spanishtown. The only productive wells yet obtained in San Mateo County are wells less than 500′ deep drilled on the Purissima and Tunitas creeks. Since 1890, several wells have been drilled on land adjacent to Purissima Creek about 4 miles southeast of Spanishtown, the deepest being only 350′. The formation is sandstone and dark-colored shale. It is said that none of these wells yielded more than 2 bbls. of oil a day, and that the specific gravity of the oil was 42° B.

About 10 miles southeast of Spanishtown on Tunitas Creek, two or more wells were drilled several years ago. The formation resembled that penetrated by the wells on Purissima Creek. The deepest of these wells is 560′. It is said that none of these wells yielded more than 2 bbls. of oil a day, and that the gravity of the oil was 48° B. A few fossils were obtained from one of the wells on Tunitas Creek. They were identified by Dr. J. G. Cooper, and proved to be of Eocene age.

9.3.2. *The Paraffin Oil Company* (of San Mateo; G. D. Roberts of Los Angeles, president). In July, 1900, this company was drilling a well on land adjacent to the Purissima Creek at a point 400′ higher than, and 1100′ east of, an old well drilled several years ago. At the date mentioned, this well was said to be 600′ deep. Oil of 51° B. had been struck at 450′, and it was thought that the well would produce 3 bbls. a day. The oil had been cased off, and the well was being deepened. The formation is sandstone and shale. There was some gas. Oil for fuel was obtained from the oil-well previously referred to.

9.3.3. *Wells near Half Moon Bay.* About three years ago E. J. Bean drilled for oil on land now owned by Joseph Fernandez, situated 1½ miles south of Half Moon Bay, near Clam Rock, about 800′ from the beach. Well No. 1, 700′ deep, caved in, and was abandoned. Well No. 2, 10′ from No. 1, 900′ deep; 700′ of casing; tools lost in the well, and the well abandoned. Well No. 3, 10′ from No. 2, 1300′ deep; abandoned on account of lack of funds.

About 1½ miles south of the Bean wells, a well was drilled many years ago, of which no reliable data can now be obtained. More than twenty years ago, oil was prospected for on the ranch of R. D. Savage, about 1½ miles easterly from Half Moon Bay. About 1896, George Owens drilled a well in the gulch to the east of Savage's house. It is stated that at a depth of 30′, a 20′ stratum of oil-sand was struck which yielded a heavy black oil. The oil has since risen to within 2′ of the surface. This well was drilled to a depth of 1200′, at which depth granite was struck and the well abandoned. It is said that a stratum of dry oil-sand was struck before reaching the granite. About a year ago, Mr. Sidney Smith drilled a well 600′ east of the Owens well. At a depth of 30′ a stratum yielding a heavy black oil similar to that of the Owens well was penetrated to a depth of 60′, but the well was abandoned. In this well, also, the oil has risen to within 2′ of the surface. These wells are less than 3 miles from the ocean, and about 600′ above sea-level.

9.3.4. In May, 1898, Mr. McNee and others drilled three wells about 300′ from Draffin's Beach, about 9 miles from Half Moon Bay. It is said that in one at a depth of 200′, and in each of the others at less than 100′, granite was encountered, and the wells abandoned. The formation is as follows: Well No. 1: Soil to 3′; yellow clay to 21′; blue clay to 40′; water-sand and pebbles to 60′; blue sand to 84′; blue clay to 90′; oil-sand to 114′ (end of casing); granite to 150′; blue quartz to 158′; granite to 178′; quartz to 196′; granite to 200′. Well No. 2: Soil to 15′;

clay to 20′; yellow sand to 45′; gray sand to 50′; coarse pebbles, with water, to 58′; blue sand and coarse gravel, with a little oil, to 62′; gray sand, with oil, to 67′; clay and sand, traces of oil, to 71′; blue clay, with traces of oil, to 75′; green sand to 77′; granite to 80′.

CHAPTER 4.

CONTRA COSTA COUNTY.

9.4.1. The existence of petroleum in Contra Costa County has been known as long ago as 1864. At that date J. W. Cruikshank (now of Paso Robles) drilled several experimental wells about 1½ miles south of the Empire coal mine. One of these wells was drilled to a depth of 300′. Mr. Cruikshank states that in one well he struck a green oil of high specific gravity, and pumped about 15 bbls.

In 1865 the Adams Petroleum Company was organized; several shallow wells were drilled, and some oil was obtained. It is said that the drilling machinery used was inadequate, and the enterprise was abandoned. The Adams Petroleum Company operated on land which is now a part of the Coates estate.

9.4.2. *American Oil and Refinery Company* (of San Francisco; W. E. Holbrook, president) has a well on the Minor ranch, about 1½ miles from Orinda Park postoffice. It is said that this well is 1300′ deep. The formation penetrated is shown by the following record: Alluvium to 15′; gray sandstone to 90′; tough clay to 215′; fine-grained, bluish sandstone to 900′. Salt water flows from this well, and when the water is stirred inflammable gas rises to the surface. Tools were lost in the well and it was abandoned. The company then selected another well-site near the first well, and in October, 1900, a new drilling plant had been set up. In the creek-bed near the new well-site, sandstone and shale are exposed and there are seepages of petroleum.

9.4.3. *Contra Costa Oil and Petroleum Company* (of San Francisco; L. R. Mead, president) has bonded a portion of the Coates estate, and has selected a well-site about 1½ miles south of the Empire coal mine. In October, 1900, this company had erected a derrick and had machinery on the ground ready to drill. The land on which the derrick of this company stands was the scene of one of the earliest attempts at oil-mining in California, and some oil was found, as before recorded.

9.4.4. *Grand Pacific Oil Company* (A. G. Deardorf, president) has bonded the ranch of Josephus Hodges, about a mile east of Lafayette. In October, 1900, this company had selected a well-site and had a drilling plant on the ground.

9.4.5. *McCamley Ranch* (near San Ramon). It is said that shallow prospect wells have been sunk on this ranch, with satisfactory results.

9.4.6. *Mount Diablo Oil Company* (of San Francisco; G. W. Terrill, president) has secured control of the Old Tar ranch, situated about 2 miles easterly from San Pablo. Oil was found on this ranch many years ago, and several shallow wells have been drilled on it. In 1899, Mr. J. W. Laymance of Oakland drilled a 170′ well. He states that much seepage oil was found. In October, 1900, a drilling plant was on the ground.

9.4.7. *Point Richmond Oil Company* (of San Francisco; H. B. Russ, president) has two 100′ wells on the Mulford ranch, 3 miles northeast of San Pablo. There is a seepage of heavy oil near these wells.

9.4.8. *San Pablo Oil Company* (E. L. Doheny of Los Angeles, president) has a well about a mile northeast of San Pablo on the ranch of T. W. Mulford. The well is about 500′ above sea-level. It is said that the company has drilled 670′, and that traces of oil have been found. Inflammable gas escapes from the well.

9.4.9. *Sobrante Oil and Investment Company* (C. Harris, president) has secured land upon the Castro tract. The well-site chosen is about 1¼ miles northeasterly from the Mount Diablo Company's wells, and is about 160′ above sea-level. It is said that there are indications of oil in the vicinity.

9.4.10. *Tide Water Oil Development Company* (C. D. Howry, president) has a well about 1 mile south of the well-site of the Contra Costa Oil and Petroleum Company. The well is on the Coates estate. In October, 1900, this well was about 300′ deep. Water was struck at 250′.

PART 10.

MENDOCINO, COLUSA, HUMBOLDT, AND NAPA COUNTIES.

CHAPTER 1.

MENDOCINO COUNTY.

10.1.1. In Mendocino County petroleum-yielding formations have been discovered in several places, the best known being Point Arena, where ledges of oil-sand are exposed.

As described by Mr. Goodyear in the VIIth Report of the California State Mining Bureau, several prospect wells had been drilled at Point Arena prior to 1887, but no valuable quantity of oil was obtained.

During the past two years other prospect wells have been drilled at Point Arena. The following history of these enterprises is contributed by Mr. H. Howe of that place:

10.1.2. The Watson Oil Company of Napa Junction, California, drilled a 700′ well on the Curley ranch, about 1½ miles northwest of Point Arena. The formation is sandstone and soft rock. At 700′ a stratum of asphaltum was struck. This company then drilled a second well on the Porter O'Neill ranch, a short distance west of the first well. This well was between 600′ and 700′ deep; it is abandoned.

10.1.3. The interests of the Watson Oil Company were purchased by the White Lumber Company of San Francisco, and others, who drilled two 400′ wells on the land of the White Lumber Company. These wells are about 100 yards northwest of the chutes where the lumber company load their vessels. The records of these wells are similar to the records of the wells of the Watson Oil Company. Asphaltum was struck; it could not be penetrated, and the wells were abandoned.

CHAPTER 2.

COLUSA COUNTY.

10.2.1. As mentioned in Bulletin No. 3, published by the California State Mining Bureau, the existence of petroleum in Colusa County has been known for many years. At an early day in the history of the county, some prospecting was done on the McMichael and the Stoval ranches, near the Mountain House, on the Lake County road. Formations which yield inflammable gas are exposed at the Peterson ranch, near Sites; and at the Elgin mine, near Sulphur Creek; and at several other places in Colusa County.

10.2.2. In the winter of 1896, the writer made a reconnaissance of a portion of Bear Creek, where some of the springs of petroleum were said to exist. In T. 14 N., R. 5 W., M. D. M., about a mile east of Sulphur Creek P. O., on land owned by T. Sheerer and M. A. Long & Sons, of the village of Williams, Colusa County, petroleum was found oozing from the rocks. The general character of the formation exposed along Bear Creek is shale and sandstone, with thin strata of impure limestone.

10.2.3. A few fossils were obtained, which indicated that these rocks were deposited during the Cretaceous period. In many places, the stratified rocks show metamorphic action.

The summits of the adjacent hills, especially to the west of Bear Creek, consist of serpentine, and on the flanks of the hills the stratified rocks are much obscured by blocks of serpentine and earth. The structure of the stratified rocks is that of compressed anticlinal folds.

The first oil-seepage inspected is near the S.E. corner of Sec. 21, in the bed of a little creek emptying into Bear Creek.

10.2.4. At the point named a small quantity of greenish petroleum and mineral water issues from a deposit of calcareous tufa which covers the stratified rocks.

The dip of the last-mentioned rocks, as observed in the bed of Bear Creek, is N. 50° E., and the angle of inclination is about 70°.

On the hill-side east of Bear Creek, near the mouth of Sulphur Creek, there is a coarse sandstone containing numerous fossils (*Aucella*), but they are much decomposed.

At several places in the bed of Bear Creek, and for a distance of about half a mile below the mouth of Sulphur Creek, strata of shale and sandstone are exposed. They dip N. 50° E. and N. 60° E., at an angle of from 50° to 80°.

10.2.5. A short distance south of the S.E. corner of the S.W. $\frac{1}{4}$ of the N.W. $\frac{1}{4}$ of Sec. 27, T. 14 N., R. 5 W., M. D. M., Bear Creek crosses an anticlinal axis. The dip of the formation is S. 25° W. and N. 25° E. at an angle of about 70°. At and near the axis there is a slight showing of oil in the creek.

Farther down Bear Creek, the formation is shale; it is much crushed, and small quantities of oil are said to exude from it in hot weather. Near the N.E. corner of the S.W. ¼ of Sec. 27, Bear Creek has cut through a thick stratum of sandstone. This stratum is the source of several springs of sulphureted water, on the surface of which a small quantity of oil was floating.

10.2.6. It is said that many years ago a 6″ well was sunk to a depth of 200′ in this sandstone, and that it yielded more than 1 bbl. of oil a day. In December, 1896, this well was full of sulphureted water, on the surface of which there was a slight showing of oil.

The above-mentioned sandstone stratum is much fractured, and, except where it is broken by a fault, the dip is about S. 30° E., at an angle of 75°. Near the well, the sandstone contains numerous specimens of *Aucella*.

Another seepage of oil was observed in the creek-bed, in the N.E. ¼ of Sec. 34. At this point, the formation is sandstone, and the angle of the dip decreases about 35°. It is said that a small amount of coal is found in this sandstone.

A short distance farther southward, the sandstone dips to the northeast, at an angle of about 85°. Farther down Bear Creek, the exposed rocks are for the most part serpentine. As this creek enters Section 35, it has a general course of about S. 80° E., and the rocks are obscured by earth and drift.

10.2.7. Still farther down Bear Creek, near the S.E. corner of Sec. 35, strata of sandstone and impure limestone dip N. 23° E. at an angle of about 70°, and gas bubbles up in the creek at several places. Near the S.E. corner of Sec. 35, there are seepages of petroleum, and some work, consisting of open cuts, pits, and tunnels, has been done by Mr. J. P. Rathburn of the village of Williams. Most of these workings are in the serpentine drift which covers the stratified rocks. From one of these openings a small quantity of petroleum and mineral water was running into a trough. Samples of petroleum were obtained from this trough, and from the surface of the water which had collected in the workings. The petroleum in the trough had been exposed to the weather for a long time, and had thrown down a flocculent precipitate, resembling the sludge, or b. s., found in petroleum from other localities. No signs of asphaltum were seen on Bear Creek.

Samples of this petroleum and precipitate were examined by the writer in the laboratory of the State Mining Bureau. The results of this examination are given in Chapter 5, Part 12, of this Bulletin. When the flocculent precipitate above mentioned was heated, it separated into water, oil, and earthy or organic matter.

In September, 1900, the following companies were drilling in Colusa County:

10.2.8. *Herron Oil Company* (of Los Angeles) has one well in the S.E. ¼ of Sec. 35, T. 14 N., R. 5 W., M. D. M. Formation: Serpentine (loose rocks) to 100′; shale to 800′. Some oil was obtained, apparently seepage, from the serpentine. Drilling.

10.2.9. *Gorrell & Smith Oil Company* has a 543′ well in the S.E. ¼ of Sec. 7, T. 13 N., R. 3 W., M. D. M.

CHAPTER 3.

HUMBOLDT COUNTY.

By F. M. Anderson, C.E.

10.3.1. The existence of oil in Humboldt County has been known from an early date. A full account of the attempts made here in 1865–67 will be found in the VIIth Report of the State Mineralogist, pages 195–202. According to the author, Mr. Adolph H. Weber, no less than twenty-five wells were sunk at that date, but the total amount of oil produced by any of them did not exceed 100 bbls., which was the quantity taken from the Union well on the north fork of the Mattole River. Smaller quantities were taken from other wells, but all of them had to be pumped. The abandonment of these prospects at that date is said to be largely due to the views held at the Land Office regarding location of these lands.

The oil-bearing formation is stated by Mr. Weber to be a close-grained, light-gray sandstone, overlain by bluish clay-shales.

A feebler effort was made in 1892–93, but little or no success was attained, for reasons that will appear later.

A third and more promising effort to obtain oil in paying quantities has been more recently made and is now in active progress. During the spring and summer of 1900 no less than six companies began operations in southwestern Humboldt County in search of oil. At the date of this report (September, 1900) only three companies were actually drilling, and only one had reached any considerable depth.

10.3.2. *The Mackintosh Well*, situated on the Cook ranch (Sec. 29, T. 1 S., R. 2 W.), is being drilled by Mr. A. Mackintosh under a term lease. It is on a low ridge separating the two branches of McNutt Gulch, near the site of the old Muldrow well of 1865. The present well has reached a depth of more than 1200′, passing mainly through blue and yellow clay-shales and sandstone, which are at intervals more or less bituminous, but not yet sufficiently so to be profitably productive. The present capacity of the well does not probably exceed 2 bbls. per day, but it is expected that with greater depth more productive strata will be reached. Oil was struck at a depth of 300′ and again at 1100′, from which depth the greater portion is believed to come. The oil is of good quality, having a specific gravity of 0.860 and from 33° to 34° B.

10.3.3. *The Craig Well*, situated on the lower north fork of the Mattole River, near the site of the old Union well (Sec. 30, T. 1 S., R. 1. W.), is being drilled under a contract by Mr. Allen Craig, as directed under the management of Major Bulyer and others. The present depth is about 300′. The formation is mainly sandstone.

10.3.4. *The Humboldt Oil Company*, consisting of Dr. E. L. Dow, A. F. Coffin, and others, has drilled to a depth of nearly 200′ on a tributary of the Mattole known as Buckeye Creek (Sec. 6, T. 2 S., R. 1 W.). The formation is mainly sandstone and shale, no bituminous strata having yet been reached.

10.3.5. *Other companies* actually making preparations for drilling are as follows: T. L. Reed & Co. have two derricks in progress of erection, with proper equipments (Secs. 14 and 24, T. 1 S., R. 2 W.); the Wild Goose Company (Kroeger, Coffin, Dow, and others) is erecting a derrick at Joel's Flat, near the site of a former somewhat productive well (Sec. 15, T. 1 S., R. 2 W.); and the Mattole Paraffin Company, including the firm of Baker & Hamilton, is erecting a derrick, with equipments, on the upper north fork of the Mattole (Sec. 2, T. 3 S., R. 1 W.). All of these and still other companies have secured leases or other titles to large and desirable tracts of land in the Mattole Valley for the purpose of thorough prospecting.

10.3.6. *Extent of Oil Lands.*—The true extent of the territory in Humboldt County that might be classed as oil-lands is very vaguely known. At present, the chief district is that of the Mattole Valley. Promising indications have been recognized along the Bear River, at Oil Creek, Ferndale, Scotia, and Eureka. In fact, much of the southwestern portion of the county is known to be underlain by more or less bituminous strata.

This belt extends along the southern coast of the county for a distance of 60 miles or more, and with an average width of 12 or 15 miles. The belt consists chiefly or entirely of Neocene strata, the upper portions of which include the Wild Cat series of Prof. A. C. Lawson, which is usually fossiliferous. The lower portions consist of yellow or blue sandstones and shales, with some interstratified beds of chert and limestone. No recognizable fossils have yet been found by which their age can be certainly determined, but their general aspect, situation, and bituminous character lead to the belief that they are not older than the Miocene. The oil-bearing members of the series are moderately fine-grained sandstones, often loose and porous in texture, but also occasionally pretty hard. Where fresh and bituminous samples of the rock are to be seen it is dark in color, but bleaches in the weather to a light-gray or yellowish sandstone. It often contains lenses or strata of pebbly sandstone or conglomerate. No satisfactory section of the series has yet been made.

10 3.7. *Structural Features of the District.*—The geological structure of this belt is not very simple. A great deal of faulting has broken the country into numerous blocks that have on the whole something of a systematic arrangement. Most of the topographical features of the country trend northwesterly. The more conspicuous fault-lines have a similar course, though they are often sinuous and not easily followed for a great distance. Transverse faulting is common, though less pronounced. Most of the faulting appears to be normal. The inclination of these fault-blocks is not regular; in many of them the strata dip toward the southwest, or westerly, and in some cases they dip in other directions. It is stated by local observers that everything dips southwesterly or in the opposite direction. There are several prominent lines or zones of faulting, some of which deserve to be mentioned.

10.3.8. The Mattole Valley, which contains the field most prospected for oil at the present, is evidently a structural valley, developed by normal faulting. To one unfamiliar with the structural features of the county its existence is a surprise. It is surrounded on all sides by hills that attain a general elevation of nearly 2500′, among which it has been sunk to a general level of 200′ to 800′. Even along the coast it is shut off from the sea by a comparatively high and narrow line of hills. The river passes from the valley to the ocean through a narrow gorge in this breastwork of ridges. Two chief lines of faulting run somewhat parallel in a southeasterly direction from the coast and determine the trend and, in part, the borders of the valley. One of these lines follows the northern border, and is in evidence along the southern face of the hills 3 miles north of Petrolia. The other line lies nearly as far south of the town and is perhaps followed by the upper portion of Squaw Creek Valley. Fault-lines intermediate between these two are easily found. In some places sharp folds in the strata are to be seen which have left the beds in a steeply inclined position. The structural conditions of the country, which are always important in an oil-district, ought especially to be studied here, and it is to the interest of the county as well as to prospecting companies to secure a clear statement of these facts by a competent expert early in the history of prospecting for oil.

10.3.9. *Evidences of Petroleum.*—There are many proofs of the presence of oil in this district, chief among which are the oil-springs and seepages and vents of the hydrocarbon gases everywhere known. These "indications" fall into line in their distribution, forming two or three well-marked zones traversing the country in a southwesterly direction.

This fact has led to the general recognition of as many distinct "oil-belts" in the vicinity of the Mattole and Bear rivers. A cursory examination of the country makes it apparent that these lines agree with the principal fault-lines already described. Connected with nearly all the springs of oil or gas there are more or less clearly recognizable evidences of faulting. This is expressed either in the presence of escarpments, often somewhat reduced by erosion, or in the highly tilted and broken strata which in some cases are even brecciated. This is true at the "Osborne Spring," where brecciated sandstone forms a portion of the very steep slope of the hill that marks the position of a transverse fault. The brecciated appearance of the rock here has led some to suppose that the oil-bearing strata were pebbly sandstone. Similar facts are observed along Bear River, at the Morrison ranch, and elsewhere, the "Guptell Spring" being apparently situated on a line of faulting. Some of these springs afford a few gallons of oil per week for a portion of the year, but most of them are small seepages. Gas springs are fairly common, particularly along Bear River, and at other points farther north. At Briceland, near the head of Mattole Valley, some 25 miles southeast of Petrolia, natural gas from a well drilled for oil is used for light and fuel. Gas, and petroleum, too, have been struck in the deep borings for water in the town of Eureka. Other places still farther north are reported to afford indications, but they are not well known. It is stated that at the present time over 12,000 acres of land in southern Humboldt County are filed on as "mineral locations."

10.3.10. *Character of the Oil.*—As to the character of the oil found in the seepages and in the wells, it may be said that it has generally been pronounced to be of superior quality. It is claimed that the oil from the "Osborne Spring," which is of unusual quality, has often been used for lighting in ordinary lamps. It is a dichroic oil, showing considerable fluorescence, appearing of a reddish amber color in transmitted light, while in reflected light it is a dark olive-green. It has a density of 30° B. and a specific gravity of 0.875.

Most of the seepage oils are similar, but are usually darker and thicker, with a greater specific gravity. Oil from the Mackintosh well is considerably darker in color, being translucent only in thin films, with a density of 33° to 34° B., and with a gravity of 0.860. Upon exposure to air it becomes still darker in color and loses much of its fluidity by the volatilization of some of its lighter ingredients. The oils of this district differ from those of other sections of California in the fact that they contain a smaller percentage of asphalt bases and a relatively larger percentage of paraffin.

10.3.11. *Promise of the District.*—From what has already been said, the apparent promise of this district may be inferred. The presence of oil cannot of course be doubted, but it yet remains to be demonstrated whether it can be found in paying quantities. No attempt has yet been made to ascertain the facts available to scientific search in answer to this question. As usual, prospecting has been carried on without any study of the field by a geologist competent to give it direction. Among the things which such an investigator would deem desirable to know and which his science would enable him to discover are two of paramount importance: (1) What is the character, richness, and extent of the oil-bearing strata? (2) What are the structural peculiarities of the country? And considering the present stage of development of this district, the question might be subjoined: If oil exists in paying quantities, why has it not been reached by the drill?

No satisfactory answer to these questions can be made in this report, but a few impressions may be worth recording. Concerning the first question, it is commonly believed that the oil-bearing strata are mainly of close-grained sandstone, often quite hard, and existing in comparatively thin beds. No attempt has been made to determine their real extent or to learn their aggregate thickness. Alternating beds of sandstone and shale is the rule in parts of the series. The whole series of strata ought to be better known. Close-grained rock is not the most favorable for containing oil.

One often hears in this district the fear expressed that the country is "too much broken." Faulting is indeed common, but it is less frequent than is generally believed. It follows chiefly a few prominent zones trending southeasterly through the country. Most of the seepages of oil and gaseous emissions are along these lines of faulting. Most, if not all, of the wells thus far sunk are comparatively near the seepages, and consequently along the lines of faulting. For several reasons such a location for a well is not the most favorable, although the seepages seem to indicate the presence of oil at such points. It ought to be remembered, however, that if the vents opened by faulting or otherwise are of long duration the oils from their vicinity may have been largely drained off, and are therefore no longer available. A better location would be at a point somewhat removed from such faulting, other things being equal. It is possible, if not probable, that paying quantities of oil have not yet been reached only because wells have so far been sunk in exhausted portions of the field. Similar observations have been recorded for other districts of California in former years. In the VIIth Report of the State Mineralogist, page 41, Mr. W. A. Goodyear remarks: "It was believed in the early days of our petroleum excitement that where oil was found upon the surface, or seen issuing from the ground, such points were the proper places to sink for the reservoirs; but experience has taught us the fallacy of early convictions, as the present producing wells have demonstrated. In passing over our oil-belt it is noticeable that nearly all the earlier workings, afterward abandoned, were in close proximity to the exudations, or in ravines." Such statements, if true, ought not to be ignored in any district. Something like a recognition of such principles is contained in the common belief that a "much-broken" country is not favorable for oil in large quantities. On the whole, it may be truthfully said that the best success in reaching oil in this district in commercial quantities will be attained by the employment of some one able to interpret the indications and the structure of the country correctly, for the purpose of making a detailed report upon it.

CHAPTER 4.

NAPA COUNTY.

PETROLEUM.

10.4.1. *Mount Shasta Oil and Development Company* (J. E. Finnell, president) has an oil-spring in the N.E. ¼ of Sec. 32, T. 10 N., R. 3 W., M. D. M., on the western slope of the Blue Mountain range, about 6 miles northeast of Monticello, on property owned by Mrs. Harris. Elevation, about 1000′. The spring occurs in a fissure in blue sandstone resting on dark-colored shale. Gas issues from an orifice in the sandstone about 2′ from the mouth of the oil-spring. The flow of oil is intermittent, and is accompanied with water. The spring produces about 4 gals. of oil in twenty-four hours. The oil is said to be an excellent lubricant. An analysis by Mr. Krutzman, chemist to the Pacific Refining and Roofing Company, gives the following:

Analysis of Oil from Berryessa Valley, Napa County.

Specific gravity of crude oil	0.9642.	Viscosity,	4.87
Light lubricating oil	24%	"	2.91
Heavy lubricating oil	22%	"	28.80
Gas oil	32%		
Residue	18%		
	96%		

Asphalt in residue, 3.66%; sulphur, no trace.

The Harris Cañon, in which the oil-spring is located, runs nearly east and west from its mouth to the site of the spring. The formation consists of alternate strata of shale and grayish sandstone. The strike is northwest and southeast, and the angle of the dip varies from 55° to 80°.

It is said that at the quicksilver mine at Knoxville, 22 miles north, a seepage of similar oil occurred between the 300′ and 400′ levels, and that the oil was used for lubricating the machinery at the mine.

PART 11.

PIPE-LINES AND REFINERIES.

CHAPTER 1.

PIPE-LINES.

11.1.1. It has long been known that tables which supply information concerning the transmission of water through pipe-lines are not applicable to the conveyance of oil by pipe-lines. Since the publication of Bulletin No. 11 the writer has received numerous inquiries concerning this subject. The data he has obtained on this important question are therefore placed in one chapter, in the hope that some idea as to the conveyance of California oil by pipe-line may be gathered therefrom.

11.1.2. *Central Oil Company.*—The oil from the wells of this company is conveyed by pipe-line to Los Nietos, on the Santa Fé Railroad, a distance of about $4\frac{3}{4}$ miles. It is a 4″ pipe-line, and has a head of 700′. Along its course there are no undulations which exceed 25′ in variation of altitude. At a temperature of about 65° F. this pipe-line discharges at the rate of about 60 bbls. an hour. The gravity of the oil is about 21° B.

11.1.3. *Oil City (Fresno County) Pipe-Line.*—This line conveys the oil from the Oil City wells to Ora Station on the S. P. R. R. This is a 3″ line. It is $8\frac{1}{2}$ miles in length; the difference in elevation between the head and point of discharge is 600′. The gravity of the oil is 33° B. An experiment of ten hours' duration showed that the oil could be discharged at the rate of 125 bbls. an hour, the temperature of the oil being about 60° F. In hot weather the discharge is less and irregular, owing to the gas generating in the pipe-line, which collects at the high points and retards the flow. When the pipe-line was first laid it was above ground, and the retardation of the flow in the summer time amounted to 25 bbls. an hour. Subsequently the pipe-line was covered with earth, and the retardation of the flow was made less.

11.1.4. *Puente Oil Company.*—The pipe-line of this company extends from their wells in the Puente Hills to their refinery at Chino, a distance of 15 miles. It is a 5″ pipe-line, and the head is about 700′.

The gravity of the oil averages 33° B. The discharge is about 1 bbl. a minute at a temperature of 60° F. Along this line there are several undulations, some of which show a variation in altitude of more than 100′.

11.1.5. *Pacific Coast Oil Company.*—The pipe-line of this company conveys the oil from their wells in Pico Cañon, Los Angeles County, to the seashore at Ventura, in Ventura County, a distance of 44 miles. For 20 miles from the wells, the line is 2″ pipe, and from that point to Ventura, a distance of 24 miles, it is 3″ pipe. The head is about 1900′. The greatest undulation is about 200′, and for nearly the entire distance the grade is uniform and nearly level. This pipe discharges by gravity at the rate of 25 bbls. an hour at a temperature of 65° F. The gravity of the oil is about 41.5° B. The Pacific Coast Oil Company has also a pipe-line extending from their wells in Pico Cañon to the railroad at Newhall. This line is about 7 miles long, and is of 2″ pipe. It has a head of about 600′, and at a temperature of about 65° F. it will discharge by gravity at the rate of about 30 bbls. an hour.

11.1.6. *Sunset Oil Company* (of Ventura County).—The pipe-line of this company conveys the oil from their wells in Hopper Cañon to Buckhorn Station on the Santa Barbara branch of the S. P. R. R., Ventura County. This is a 2″ pipe-line, and about 5 miles long. It has been laid with no regard to hydraulic grade. It has a head of about 500′, and along its course there are no undulations in which the difference of altitude is more than 50′. The oil is about 12° B., and is mixed with about equal volumes of water. The water and oil pass through the pipe-line in a rotating column, the oil forming a core in the center of the column. In summer time the discharge from the end of this pipe at Buckhorn is about 250 bbls. in twelve hours; in winter time, 250 bbls. in eighteen hours.

11.1.7. *Union Oil Company* (of Santa Paula).—The oil from the various oil-fields owned and controlled by this company is conducted by pipe-lines to a trunk line in the Santa Clara Valley by which the oil is conveyed to the seashore at the mouth of the Sespe River. It is a 4″ line, and is about 25 miles in length, although the distance between Santa Paula and Ventura is less than 20 miles in an air line. The feeders are usually 2″ and 3″ pipe. The total length of pipe-line belonging to the Union Oil Company's pipe-line system in Ventura County is said to be 100 miles. No particulars could be obtained about the rate of discharge. The facts relating to the following interesting experiment were kindly furnished by Mr. Lyman Stewart, president of the Union Oil Company: Several years ago, oil from the Astarte wells in the Sisar Cañon, Ventura County, was conveyed by a 2″ pipe-line to a tank in the Santa Paula Cañon, a distance of 3 miles, with a fall of 300′. The oil had a gravity of about 13° B., and at a temperature of 60° F. the discharge by gravity was at the rate of 20 bbls. in twenty-four hours. As an experiment the oil in the pipe-line was placed under a pressure of 800 lbs. to the square inch, but the discharge was only increased to 24 bbls. in twenty-four hours. When the pressure was increased it burst the pipe-line.

11.1.8. *Union Oil Company's Pipe-Line at Los Angeles.*—The pipe-line of the Union Oil Company extends from First and Lake Shore streets, in the Los Angeles oil-field, to Palmetto and San Mateo streets, on the S. P. R. R., a distance of about 4 miles. It is a 4″ line, and the course followed is undulating. The gravity of the oil is 14° B. It is forced through the pipe-line under a pressure of 600 lbs. Some trouble is experienced from the sand which the oil contains accumulating in low places in the pipe-line. In summer the discharge from this line is about 800 bbls. in twenty-four hours; in winter, about one third less.

The pipe-line of the Union Oil Company in Orange County extends from the Fullerton oil-field to Bixby, a distance of 26 miles. This is a 4″ line and has a head of 450′. The gravity of the oil which runs through this line averages 21° B., and at a temperature of about 65° F. the rate of discharge is about 2000 bbls. in twenty-four hours.

11.1.9. *Alcatraz Refinery Pipe-Line.*—This line conveys a solution of asphaltum dissolved in distillate from the mines of bituminous sandstone at Sisquoc to the company's refinery at Alcatraz Landing, Santa Barbara County. The length of the pipe-line is about 37 miles; diameter of the pipe, 3″. The difference in elevation between Sisquoc and Alcatraz Landing is 1900′. Along the pipe-line there are several undulations, one of which shows a difference in elevation of about 1000′. The gravity of the solution is about 25° B.

The following interesting data concerning the rate of discharge from a pipe-line in the Eastern States were furnished the writer by Mr. Lyman Stewart of the Union Oil Company: There was a 4″ pipe-line running from Duke Center, Pennsylvania, to Olean, in New York, a distance of about 13 miles. The course is undulating, and the line ran over hills about 900′ higher than the pumping station. Oil having a gravity of 47° B. was transmitted through this pipe-line under a pressure of about 1150 lbs., the discharge being at the rate of 15,000 bbls. of oil in twenty-four hours.

11.1.10. *The Modelo Oil Company's Pipe-Line.*—It extends between the Modelo oil-wells and the railroad at Piru, Ventura County. This is a 2″ pipe-line and is about 3 miles in length; the difference in elevation between the head and the point of discharge is about 800′. The gravity of the oil is 28° B.

11.1.11. Some information concerning the discharge of oil through pipe-lines can be gathered from the following tables:

DISCHARGE OF OIL BY GRAVITY.

Pipe-Lines.	Length of Pipe-Line	Diameter of Pipe	Spec. Gravity of Oil.	Head.	Temperature	Rate of Discharge in 24 Hours.	Remarks.
	Miles.	*Inches.*		*Feet.*		*Bbls.*	
Central Oil Co.'s pipe-line. Between Central Oil Wells and Los Nietos, Los Angeles County.	4.65	4	21° B.	700	65° F.	1440	No great undulations.
Union Oil Co.'s pipe-line. Between Astarte Wells and Santa Paula, Ventura Co.	3.00	2	13° B.	300	60° F.	20	No great undulations.
Union Oil Co.'s pipe-line. In Orange County, between Fullerton oil-field and Bixby.	26.00	4	21° B.	450	65° F.	2000	No great undulations.
Sunset Oil Co.'s pipe-line. Bet. Sunset Wells and Buckhorn R. R. Station, Ventura Co.	5.00	2	12° B.	500	75° F. in summer, 60° F. in winter.	500 350	No great undulations. Oil mixed with about equal volume of water.
Pipe-line between Oil City and Ora Siding on the S. P. R. R., Fresno County	8.50	3	33° B.	600	60° F.	3000	No great undulations.
Puente Oil Co.'s pipe-line. Bet. Puente Wells, Los Angeles County, and Chino, San Bernardino County.	15.00	5	33° B.	700	60° F.	1440	Several undulations, some of which differ in elevation more than 100′.
Pacific Coast Oil Co.'s pipe-line. Between Pico Cañon and Ventura, Ventura County.	44.00	(*a*)	41.5° B.	1900	65° F.	700	Grade fairly uniform. Undulations differ 200′.
Pacific Coast Oil Co.'s pipe-line. Between Pico Cañon and Newhall, Los Angeles County.	7.00	2	41.5° B.	600	65° F.	600	....
Alcatraz Refining Co.'s pipe-line. Conveying asphaltum solution between Sisquoc mines and Alcatraz Landing, Santa Barbara County.	37.00	3	25° B.	1900	65° F.	....	Along pipe-line several undulations show variation in elevation of 1000′.

(*a*) For 1 to 20 miles the diameter of pipe-line is 2″; for remaining distance it is 3″.

DISCHARGE OF OIL UNDER PRESSURE.

Name of Company.	Length of Pipe-Line.	Diameter of Pipe.	Spec. Gravity of Oil.	Head.	Approximate Temperature.	Pressure.	Rate of Discharge in 24 Hours.	Remarks.
	Miles.	*In.*		*Feet.*		*Lbs.*	*Bbls.*	
Union Oil Co., pipe-line at Los Angeles	4.00	4	14° B	200	70° F.	600	800	Course undulating.
Union Oil Co., Astarte wells, Ventura County	3.00	2	13° B	300	60° F.	800	27	No great undulation.
Discharge of Eastern Oil Under Pressure.								
Pipe-line running from Duke Center, Pa., to Olean, N. Y.	13.00	4	47° B	900	60° F.	1150	1500	----------

CHAPTER 2.

PETROLEUM REFINERIES.*

11.2.1. *American Oil and Asphalt Company* (of Los Angeles) has a refinery at Date and Alhambra streets. Plant consists of two 300-bbl. and three 125-bbl. stills; tankage for crude oil, 2300 bbls. Product: stove distillate, 32° B.; distillate for spraying trees, 28° B.; fuel distillate, 22° B.; asphaltum. Fifteen men are employed.

11.2.2. *Asphaltum and Oil Refinery Company* (of Los Angeles; E. D. Roberts, president) has a refinery at Ninth Street and Santa Fé Railroad track. Plant consists of two 150-bbl. stills, one 55-bbl. still, and one 25-bbl. still. Product: gasoline, gasoline-engine distillate, illuminating, neutral, and fuel oils.

11.2.3. *The Franklin Refining Company* (of Los Angeles; E. H. Dunham, president) has a refinery at 1504 Newton Street. Plant: one 300-bbl. still, four 100-bbl. stills, and three 50-bbl. stills. Product: gasoline, 60° to 64° B.; gas-engine distillate, 43° to 52° B.; gas distillate, 32° to 34° B.; neutral oils, 26° to 28° B.; lubricating oil, 18° to 22° B.; green oil, 15.5° to 16.5° B.; asphaltum. Amount of crude oil handled in 1899 was 20,000 bbls.

11.2.4. *Jewett & Blodget Refinery* is situated at Hazelton, Sunset oil-district, about 40 miles west of Bakersfield. Plant consists of one still, capacity 100 bbls. in twenty-four hours. The Baku process is used. Product: distillate, lubricating oil, and asphaltum. The crude oil yields gas distillate, 20%; lubricating oil, 12%; heavy distillate, 13%;

*For asphaltum refineries, see general report of California State Mining Bureau.

asphaltum, 55%. The product is shipped to Gosford on the McKittrick branch of the S. P. R. R. Gosford is about 8 miles from Bakersfield.

11.2.5. *Paraffin Paint Company* (of San Francisco) has a refinery at Emeryville, Alameda County. Plant consists of three 60-bbl. stills and a tankage of about 360 bbls. Six men are employed. The oils refined by this company are all of high specific gravity, none of them being above 19° B. The product is distillates ranging from 15° B. to 16° B., and asphaltum. The asphaltum constitutes about 22%, by volume, of the crude oil.

11.2.6. *Pacific Coast Oil Company* (of San Francisco) has a refinery at Alameda Point, Alameda County. Plant consists of 13 stills which have a total capacity of 2215 bbls., and the following tankage: For crude oil, 54,000 bbls.; for refined products, 12,000 bbls.; bleachers and agitators, 4000 bbls. Thirty-two men are employed. The petroleum refined by this company is obtained principally from the wells of the Pacific Coast Oil Company near Newhall. The product is gasoline, illuminating and lubricating oils, and other distillates and asphaltum.

11.2.7. *Puente Oil Company's Refinery* is connected by pipe-line with the Puente oil-wells, distance about 15 miles. Plant consists of three 400-bbl. stills, and 95,000 bbls. crude-oil tankage. Manufactured product consists of gasoline, 67° B.; water-white illuminating oil, 45° B.; residuum fuel oil, 18° B. The residuum is about 60% of the crude oil. Output of Puente refinery for 1899: gasoline, 105,000 gals.; painters' benzine, 50,000 gals.; water-white oil, 450,000 gals.; gas-engine distillate, 900,000 gals.; total, 1,505,000 gals., or about 35,833 bbls. The amount of crude oil was 120,000 bbls.

11.2.8. *Southern Refining Company.*—Refinery at First Street and Alhambra Avenue, Los Angeles. Plant, two 25-bbl. stills. Product: gas-engine distillate, 49° B.; stove distillate, 35° B.; gas distillate, 22° B.; neutral oils, 22° B.; lubricating stock, 16° B.; asphaltum.

11.2.9. *Sunset Oil Refining Company* (J. A. Tubbs, Pittsburg, Pa., president).—Works situated at Obispo, Terminal Island, Los Angeles County. Plant consists of eight stills; total capacity, 1200 bbls. a day. Tankage for crude oil, 25,000 bbls. Product: gasoline, illuminating oil, lubricating oil, and intermediate products. The president of this company informed the writer that a special process was employed at his works which had not previously been used in California. Work was commenced at this refinery in May, 1900, when two stills were in operation, thirty-five men being employed.

11.2.10. *Union Oil Company's Refinery* is at Oleum, Contra Costa County. The stills at these works have a total capacity of 900 bbls. of crude oil. Tankage for refined product, 20,000 bbls.; tankage for crude oil, 70,000 bbls. Product: benzine, 52° to 63° B.; illuminating oil, 43° B.; gas-engine distillate, 39° B.; gas distillate, 28° B.; lubricating oil, 15° to 28° B.; asphaltum.

PART 12.

SUMMARY OF OIL-YIELDING FORMATIONS, CHARACTER OF CALIFORNIA PETROLEUM, AND HISTORICAL SKETCH OF OIL-MINING IN CALIFORNIA.

CHAPTER 1.

GEOGRAPHICAL AND GEOLOGICAL RANGE OF OIL-YIELDING FORMATIONS IN CALIFORNIA.

12.1.1. It is now in order to summarize and compare the leading geographical and geological facts thus far ascertained concerning the occurrence of petroleum in California, and to review the character of the oil-yielding formations and their relation one to another.

Nearly all the oil-fields which at this writing contribute to the petroleum product of California are situated below the 17th township line south of Mount Diablo. (See Fig. M.) The productive oil-fields in the portion of the State referred to are distributed as follows: In the foothills of the Sierras near the eastern extremity of the San Joaquin Valley; on the eastern slope of one of the Coast Ranges which form the western boundary of the San Joaquin Valley; and in other localities of the Coast Ranges which traverse Santa Barbara, Ventura, Los Angeles, and Orange counties.

12.1.2. It must not be supposed that the oil-yielding formations are confined to the localities enumerated, for they constitute a large portion of the mountains composing the Coast Range system. Moreover, in many places they form the bedrock beneath the alluvium of the valley land. It does not necessarily follow that wherever these oil-yielding formations are found they contain oil in valuable quantities, any more than the coal-measures always contain valuable beds of coal; but it is a reasonable conclusion that there are in California numerous areas through which these formations extend wherein new oil-fields will be discovered. This conclusion applies not only to the portions of California described in this Bulletin, but also to a large portion of the State which lies between the foothills of the Sierras and the Pacific Ocean.

THE OIL-YIELDING FORMATIONS OBSERVED BETWEEN THE SESPE AND PIRU CREEKS, VENTURA COUNTY, COMPARED WITH THE OIL-YIELDING FORMATIONS OF OTHER DISTRICTS.

12.1.3. The relative position in point of vertical geologic range of the formations wherein remunerative oil-wells have been obtained in Ventura and Los Angeles counties, is demonstrated by an investigation of the country between Piru and Sespe creeks in Ventura County, where a sequence of formations ranging from the uppermost beds of the Middle Neocene to the lowermost beds of the Eocene are exposed. At Piru Creek, beds of conglomerate occur which contain Neocene fossils, Pliocene forms being the more numerous. (See Table III.) This formation is more than a thousand feet thick, and in one place it was found to be impregnated with petroleum. The conglomerate rests on a clay-shale, likewise containing Neocene fossils. (See Table III.) The lower portion of the shale is interbedded with sandstone strata, and passes into a mass of sandstone, which, in Hopper Cañon (see Fig. 10), shows a thickness of 1100′. In most instances when the lower portion of the Middle Neocene is exposed, strata of sandstone are found more or less impregnated with petroleum. At the mouth of Hopper Cañon, the Middle Neocene shale and sandstone show an aggregate thickness of about 3000′. (See Fig. 9.) The Middle Neocene rocks form a very important series, for, as described in the foregoing pages, by far the greater portion of the oil mined in California is obtained from sandy strata in the lower portion of this group.

12.1.4. Thus, the old-yielding rocks at Elsmere Cañon near Newhall are evidently of Middle Neocene age (see Table III); and, as before described, the outcropping rocks on the south side of the valley of the Santa Clara River indicate that the oil-yielding formations which extend from Newhall to Bardsdale belong to the Middle Neocene series, although the gravity of the oil is less than that of the oil usually obtained from Middle Neocene beds.

12.1.5. In the Puente Hills the Middle Neocene rocks are well represented, and the principal oil-yielding formations are sandstone strata interbedding the lower portion of the Neocene shales. At Summerland, in Santa Barbara County, the character of the oil-yielding formations and their relation to the whitish shales of Lower Neocene age, which are exposed near Carpinteria and in the low ridge of hills immediately east of Summerland, warrant the conclusion that the oil-measures in Summerland are of Middle Neocene age.

12.1.6. On the eastern side of the San Joaquin Valley, we find the oil-field of the Kern River district wherein the oil-measures must be referred to the Middle Neocene series.* On the western side of the San Joaquin Valley, the most productive oil-measures in the Sunset district, the oil-measures of the McKittrick district, and those in the

*See fossils collected in this district, as described in Bulletin No. 3, pp. 39 and 40.

southern portion of the Oil City field in Fresno County, are of Middle Neocene age.* In the San Joaquin Valley, the Middle Neocene formation consists of sandstones and shales, the sandstones predominating, while in Ventura, Los Angeles, and Orange counties, the formations of corresponding age consist of conglomerate and a thick body of shale, the lower portion of which is interstratified with sandstone, passing into a massive body of sandstone at the bottom of the Middle Neocene series.

12.1.7. The oil obtained in the Middle Neocene formation varies greatly in quality, the specific gravity ranging from 12° B. to 30° B. In most districts, however, in which the oil-yielding formations have been identified as of Middle Neocene age, the gravity of the oil ranges between 14° B. and 22° B.

12.1.8. In the territory between Sespe and Piru creeks, the formation immediately underlying the Middle Neocene series is a very characteristic one. It consists of silicious shale. This shale is well exposed in Hopper Cañon and at the Modelo oil-wells, and shows a thickness of about 1500′. When freshly broken, this shale usually smells of petroleum, and in most instances it gives a calcareous reaction with acid. The upper portion of this mass of shale is interbedded with sandstone. There is no marked stratigraphical division between these shales, which rest conformably on a whitish sandstone, and the overlying rocks. Nevertheless, since silicious shale is so characteristic of the Lower Neocene in other portions of California, the writer has tentatively referred the silicious shale of the territory under discussion to that horizon. In Los Angeles County a similar shale is exposed at a few points in the central portion of the Puente Hills, and it is not improbable that the whitish silicious shale seen in the Santiago Cañon in Orange County belongs to this horizon. As previously mentioned, the silicious shale rests on a whitish sandstone formation, which, as is shown in Fig. G, constitutes a large portion of the higher mountains between the Piru and Sespe creeks. This sandstone is evidently several thousand feet in thickness, and contains some fossils which are referred by Dr. J. C. Merriam to the Lower Neocene epoch. (See Table II.)

12.1.9. The silicious shale previously referred to as being in the Puente Hills and in the Santiago Cañon, rests on a thick-bedded sandstone. In the Santiago Cañon this sandstone contains fossils representing the Lower Neocene epoch. On the western side of the San Joaquin Valley the Middle Neocene beds rest non-conformably on a whitish silicious shale, and this rests either on Eocene strata, as at Oil City, or on sandstone or shale of Lower Neocene age, as is the case at the Avenál field in the Kreyenhagen district.† In most instances the oil from these

*See fossils collected in this district, as described in Bulletin No. 3, pp. 38, 43, 49, 54, 55, 56, 58, 59, 63, 64, 65.

†See Bulletin No. 3, p. 53: Fossils collected in Tar Cañon, now called the Avenal field. Recently the writer obtained specimens of *Turritella ocoyana* from this locality. See also same Bulletin, p. 55: Specimens collected in Zapato Chino Creek, Kreyenhagen.

formations has a gravity of more than 25° B. As before stated, the whitish sandstone extends westward from Piru Creek, in Ventura County, to the Sespe oil-district, the distance between the two places being about 8 miles.

12.1.10. At the Sespe oil-district, the whitish sandstone rests probably non-conformably on a shale formation, although the non-conformability is not very apparent. The shale formation is whitish and grayish at the top, passing into a dark-colored shale, which is interbedded with numerous thin strata, or nodular masses, of hard bituminous limestone. These shales rest on a drab-colored sandstone of no great thickness and contain Eocene fossils.* The drab-colored sandstone rests on a brown sandstone, locally known as the Sespe brownstone.

12.1.11. In the Devil's Gate mining district the brownstone rests on whitish sandstone, and the latter on a buff-colored sandstone. The Sespe brownstone, the white sandstone, and the buff-colored sandstone all contain typical Eocene fossils.† All these sandstones are more or less interbedded with shale. The principal oil-yielding formations in the Sespe district are the lowermost portions of the drab-colored shales, the drab sandstone, and the uppermost portion of the Sespe brownstone. These formations have been extensively exploited by the Union Oil Company.

12.1.12. It is probable that the oil-yielding formations in the northern portion of the Oil City field in Fresno County,‡ and those on the Tunitas and Purissima§ creeks in San Mateo County, belong to the same geological horizon as do the oil-yielding rocks of the Sespe district. In the Devil's Gate district there are numerous seepages of petroleum in the hard, buff-colored Eocene sandstones, and productive oil-wells have been obtained. Between the Piru and Sespe districts no marked non-conformability was observed by the writer, the variations of dip being referable rather to local geological disturbance than to non-conformability. Still, it by no means follows that the formations actually rest conformably one on another.

12.1.13. It is conceded that in California the Lower Neocene formations rest non-conformably on the Eocene, and observations in Orange and Los Angeles counties lead to the conclusion that the Middle Neocene shales overlap the underlying formations. There are also some reasons for believing that in Los Angeles County the conglomerate rests non-conformably on the Middle Neocene shales. Since the Eocene period,

*See Bulletin No. 11, pp. 82, 83, 84, 85: Fossils collected at Tar Creek ranch and on a divide between Tar and Maple creeks.

†See Bulletin No. 11, p. 84: Fossils collected at mouth of Stony Corral Creek and Redstone Peak.

‡See Bulletin No. 3, p. 62: Fossils collected at oil-claims 9 miles north of Coalinga, Fresno County.

§Two shells were brought up by the sand pump from a well on Purissima Creek and they were identified by Dr. J. G. Cooper as being of Eocene age.

there have been not only epochs of unusual geologic disturbance, but also disturbances of a secular nature which have produced oscillations of the land surface during the deposition of the Tertiary and Quaternary formations. Similar disturbances continue to this day. It appears that in many instances these disturbances were of local character.

CHAPTER 2.

NEOCENE AND MORE RECENT FORMATIONS IN PORTIONS OF ORANGE AND LOS ANGELES COUNTIES.

12.2.1. As mentioned in a previous chapter, the rocks containing petroleum deposits in Los Angeles and Orange counties are members of a geological series represented by formations which may be studied to advantage in the foothills of the Santa Ana Mountains, between the Santiago Cañon and the cañon of the Santa Ana River. (See Figs. 1, B, and 7.) This series may be correlated with the Lower and Middle Neocene formations observed between the Piru and Sespe creeks in Ventura County, and previously described. In the order of its downward vertical range it consists of conglomerate, shales, and sandstones, the sandstones being for the most part of a whitish color. The whitish sandstones rest on Eocene and Cretaceous formations, and in the portion of the Santa Ana Mountains herein referred to, the Cretaceous formations rest on crystalline rocks. The areas over which these Neocene formations extend are shown in Figs. A, B, and G. The writer made a brief reconnaissance of the portion of the Santa Ana Mountains consisting of eruptive crystalline rocks and the Cretaceous and Eocene formations.

12.2.2. The area occupied by these rocks is marked "Unexplored" in Fig. 1. The fossils obtained from the Cretaceous and Eocene rocks are classified in Table I. They are from localities adjacent to those shown in Figs. 1 and B. It is probable that in the extremity of the Santa Ana Mountains, the formations immediately overlying the crystalline rocks are Cretaceous, and there is reason to believe that there are Eocene formations between the Cretaceous rocks and the whitish sandstone.

12.2.3. Some Lower Neocene (Miocene) fossils were obtained in sandstone in the higher portions of the Santa Ana Mountains, in the S.E. cor. of Sec. 12, T. 4 S., R. 6 W., S. B. M., but the greatest body of this sandstone is found in the foothills. A cross-section of this sandstone is shown in Fig. 7, where it is about 7000′ in thickness.

12.2.4. At the bottom of the whitish sandstone formation there are a few strata of conglomerate, and the pebbles forming this conglomerate are principally quartzose. Whitish sandstone similar to that seen between the Santiago Cañon and the Santa Ana River, forms a large portion of the Puente Hills, and also a large portion of the ridge which traverses Elysian Park at Los Angeles. A similar sandstone forms the central mass on the San Joaquin Hills, and crops out on the shore-line near the southeast corner of Orange County. On the north side of the valley of the Santa Clara River, in Ventura County, a similar whitish sandstone, as previously described, is found resting on Eocene formations. At the Santiago Cañon and in the San Joaquin Hills in Orange County, and at Piru Creek in Ventura County, these sandstones were found to contain Lower Neocene (Miocene) fossils. Near Piru Creek, they yield petroleum in valuable quantities. (See Table II, at end of this Bulletin.)

12.2.5. Resting on this whitish sandstone, near the mouth of the Santiago Cañon, is a very interesting series of shales, the lower portion of which is white or whitish, and the upper portion gray or brown. The whitest of the shales resembles infusorial earth. The upper portion is brown clay-shale, and is, for the most part, thin-bedded. It is interbedded with thin strata of sandstone. At the first glance, it appears improbable that the white shale belongs to the same formation as the overlying brown clay-shale; yet the writer could discover no non-conformability between the white shale and the dark-colored shale overlying it. An inspection of this shale formation in the eastern portion of Orange County showed a gradual transition from the white shale into the dark-colored shale overlying it. Similar whitish shales are found at several other places in Orange County, and it seems reasonable tentatively to correlate them with the silicious shales found resting on the whitish sandstone formation in the Puente Hills and in Ventura County, as previously described, and with the silicious shales which form a large portion of Point San Pedro in Los Angeles County. North of the San Joaquin Hills in Orange County, the white shale forms the bedrock throughout a large area in the valley lands, and shales of this series, grayish to brownish in color, form low cliffs along the shore-line to the east of Newport Bay. At Point San Pedro there are silicious shales which were deposited during a period of volcanic activity, for not only does eruptive rock occur there as dikes penetrating the shale, but also the shale is found interstratified with volcanic material. The clay-shales overlying the whitish shale in Orange County must be correlated with the Middle Neocene shales observed in Ventura County, in the Puente Hills, and in the City of Los Angeles. These clay-shales are the prevailing formation exposed in the southeast end of Orange County, where they form purple-colored cliffs along the shore-line. As described in previous chapters, this formation has been identified in other localities, and fossils obtained therefrom are classified by Dr. Merriam as representing the Middle Neocene epoch. (See Table III.) These shales were classed as Pliocene in previous reports, on account of the number of living forms found among the fossils they contain. It is not surprising that a more extensive examination of this formation and of the collection of fossils from larger areas, led to the conclusion that these shales are somewhat older than they were at first supposed to be. As previously stated, the principal oil-yielding formations in the Puente Hills are situated in the lower portion of this shale formation, and probably in the upper portion of the underlying sandstone. In Newport in Orange County, shales resembling the Middle Neocene shales contain a large amount of heavy petroleum.

12.2.6. The question as to whether these shales rest conformably or non-conformably on the underlying sandstone, is an important one. The structural evidence on this point in sight at the Santiago Cañon is not very conclusive, owing to the fact that there has been much local disturbance, but such evidence as is in sight favors the conclusion that the shale rests non-conformably on, or at least overlaps, the underlying sandstone; in other words, that at least a portion of the shale was deposited when the land surface was sinking, and that the ocean, from which the sediments forming the shale were deposited, was overflowing, not only the whitish sandstone, but also the formation underlying it. In this connection, the most important evidence observed by the writer is, that, as noted between the Santiago Cañon and the Santa Ana River, there is a discrepancy between the direction of the angle of the dip of the whitish sandstone and the overlying shales, that the shale is found resting on different material in different places, and that in some places it rests on formations underlying the whitish sandstone. At Point San Pedro in Los Angeles County, silicious shales rest on eruptive and metamorphic rocks, and near the Aliso Cañon in the San Joaquin Hills, an outlier of the shales rests on rocks underlying the whitish sandstone. In the Puente Hills south of Pomona, these shales are found in close proximity to granitic rocks, and there does not appear to be any whitish sandstone intervening between the shale and the metamorphic and granitic rocks.

12.2.7. Resting on the shale is a conglomerate composed principally of granitic pebbles containing much black mica. From this conglomerate a few fossils of Middle Neocene age were obtained.* In the Puente Hills the conglomerate is much less disturbed and dips more to the west than does the underlying shale; but whether these differences are due to non-conformability or to local disturbance, coupled with the difference

*It will be noted that a conglomerate similar to that seen in Los Angeles and Orange counties is found resting on the Middle Neocene shales in Ventura County.

in the relative tensile strength of the shale and the conglomerate, it is not easy to determine. One thing, however, is certain, the difference in the character of the sediments forming the shale, and of those forming the conglomerate, indicates that these sediments were deposited under very different conditions. The change from homogeneous bodies of shale to shale interbedded with sandstone, and from that to conglomerate, tells of a gradual rise in the land surface. The massive granitic rocks which are the probable source of the pebbles forming the conglomerate are ten miles or more distant from the conglomerate at the mouth of the Santiago Cañon. This fact indicates an interval between the end of the period when the shale was deposited and the beginning of the period when the conglomerate was deposited. It is probable that the pebbles forming this conglomerate came from a land surface composed largely of granitic drift.

12.2.8. At San Juan Capistrano, in Orange County, a sandy formation was found containing fossils representing the Upper Neocene (Pliocene) epoch. (See Table IV.) In that locality the rock-exposures are insufficient to determine the relation of the Upper Neocene formations to the underlying shales. At the San Pedro Peninsula, a sandy formation containing numerous Quaternary fossils is found resting non-conformably on shales, presumably of Neocene age (see Table V), and there are diatomaceous deposits which probably belong to the same geological horizon.

12.2.9. On the low cliffs which form the shore-line of the inner bay at Newport, Orange County, there are diatomaceous shales and sandy strata, the latter being impregnated with petroleum. These formations contain numerous Quaternary fossils, and rest non-conformably on shales resembling the Middle Neocene shales previously described. As may be inferred from the foregoing pages, the hill ranges in the portion of Los Angeles and Orange counties described in this Bulletin, owe their existence mainly to the structure of the rocky formations; but their outline has been modified both by atmospheric erosion and by wave-cutting, as is evidenced by the terraces on the San Pedro Peninsula and at other places. (See Photo No. 12.)

12.2.10. Since even the recent sedimentary beds in Los Angeles County are more or less tilted, it is probable that the process by which the rocks have been folded continues in operation until the present day. A study of the western end of the San Joaquin Hills and of Point San Pedro leads to the conclusion that there have been volcanic outbursts since the deposition of the Neocene shales. Moreover, there is evidence that the bed-rocks beneath the alluvium of the valley are traversed by fissures. Thus, about a mile northwest of the village of Whittier, and at Howard Station, about 10 miles south of Los Angeles, there are deposits of sulphurous earth or decomposed rocks more or less impregnated with sulphur.

These deposits have doubtless been formed by sulphurous gases arising from fissures in the bedrock.

12.2.11. Beneath the alluvium of the valley the bedrock may be of any of the formations which have been described. There is reason to believe that throughout large areas the bedrock is of Quaternary age, for Quaternary fossils have been brought up from a depth of several hundred feet, and in one instance, from a depth of more than 1000′ in wells sunk in the valley land. (See record of well at Bell Station; also record of Green Meadow ranch well, described in Bulletin No. 11.) In some instances, natural gas has been struck in wells penetrating what appear to be Quaternary formations beneath the alluvium of the valley land. (See Marius Meyer well, also the Rosecrans gas-well.)

CHAPTER 3.

RECAPITULATION.

12.3.1. A recapitulation of the occurrence of petroleum in California, as described in this and previous bulletins, will give the reader a clearer conception as to the distribution of this mineral.

Petroleum, in the form of natural gas, oil, and asphaltum, is found at various places in the Coast Ranges and in the foothills of the Sierras in Kern County. Natural gas is also found in the Central Valley of California, and at some places in the foothills of the Sierras. The geological formations yielding petroleum in California range from the Lower Cretaceous to the Quaternary. Some idea as to geographical and geological distribution of these formations may be gathered from a brief enumeration of the localities where oil-mining has been carried on, and where, in some instances, valuable oil-fields have been developed. In the Puente Hills in Orange and Los Angeles counties and at the City of Los Angeles, the oil-yielding formations, as previously stated, belong to the Middle Neocene series. On the south side of the valley of the Santa Clara River in Ventura and Los Angeles counties, the principal oil-yielding formations may be tentatively classed as of Middle Neocene age, but the writer has not yet made a detailed examination of those districts.

12.3.2. On the north side of the valley of the Santa Clara River in Ventura County there are four oil-yielding horizons:

1. In the lower portion of the Middle Neocene series.
2. In the upper portion of the Lower Neocene series.
3. In the upper portion of the Eocene series.
4. In the lower portion of the Eocene series.

In the oil-fields north of Santa Paula in Ventura County the geological structure is so complex that there is some doubt as to the age of the rocks which really furnish the oil, but in the Ex-Mission field the oil-yielding formations probably belong to the upper portion of the Lower Neocene.

12.3.3. At Summerland in Santa Barbara County the character of the oil-yielding formations leads to the conclusion that they belong to the Middle Neocene series. The writer has been unable to procure any fossils from these formations. In the foothills bordering the San Joaquin Valley the oil-yielding formations range from the Eocene to the lower portion of the Middle Neocene. In the foothills of the Sierras east of Bakersfield the oil-yielding formations may be referred to the Middle Neocene. In the foothills of the Coast Ranges west of Bakersfield in Kern County petroleum is found in formations ranging from the Eocene to the Middle Neocene. In these oil-fields the most productive formations are in the lower portion of the Middle Neocene series, and valuable quantities of heavy oil are found in the upper portion of the Lower Neocene. At McKittrick the oil-bearing strata are of Middle Neocene age; at the Avenal and Kreyenhagen districts the oil-yielding strata are of Lower Neocene age. At Oil City, near Coalinga, remunerative oil-yielding strata are found in the lower portion of the Middle Neocene, the upper portion of the Lower Neocene, and the upper portion of the Eocene formations.

12.3.4. In the Panoche Valley in San Benito County, both the Middle and Lower Neocene formations are represented, but the writer has not made a detailed examination of that county. At the Cholame Valley in Monterey County there are oil-yielding formations of Middle Neocene age. At Moody Gulch in Santa Clara County, the age of the oil-yielding rocks has never been determined.

12.3.5. At the Tunitas and Purissima creeks in San Mateo County, oil is obtained from wells which penetrate rocks of Eocene age.

12.3.6. North of San Francisco, petroleum-yielding formations crop out along the coast at Bolinas Bay and at Point Arena; at these places the exposed rocks probably belong to the Upper Neocene series.

The Humboldt County oil-fields are less known than any in the State, but reconnaissances that have been made of these northern oil-territories warrant us in tentatively referring a large portion of the oil-yielding formations of Humboldt County to the Lower and Upper Neocene series. On Bear Creek and Sulphur Creek* in Colusa County gas and oil are found in rocks of Cretaceous age. Oil-yielding formations have also been discovered in Napa, Contra Costa, and Alameda counties. At Calleguas at the west end of the Simi Valley in Ventura County, a straw-colored oil has been found in volcanic tuff; and in the Placeritos Cañon

*See Bulletin No. 3, p. 6. See also chapter on the oil-yielding formations of Colusa County in this Bulletin.

in Los Angeles County, a light-colored oil is obtained from crystalline rocks. It is reported that oil-yielding formations have been discovered in the foothills of the Sierras in Shasta County, and near Yuma on the Colorado River.

12.3.7. At Stockton, in San Joaquin County, at the City of Sacramento, and near Tulare Lake, in Tulare County,* natural gas is obtained in remunerative quantities from wells penetrating strata of Quaternary age. At Marysville Buttes,† and near Sites,‡ in the Sacramento Valley, natural gas is found in rocks of Eocene age. There are several places in the Sacramento and San Joaquin valleys where wells are yielding sufficient natural gas to be of local value.

12.3.8. It is reasonable to suppose that the oil-fields described in this Bulletin have their counterparts in many other places in California not yet explored, for the geological formations, including the oil-measures thus far developed, form a large portion of the Coast Ranges between San Diego and Humboldt counties. From the description of the oil-yielding formations, the geological positions of which have been determined, it appears that the productive oil strata are sandstones underlying bodies of shale or clay, or interstratified with them. It may be argued that these conditions indicate natural distillation as the chief cause of the accumulation of petroleum in the oil-measures.

12.3.9. It is reasonable to infer that the petroleum, having been elaborated in the shale, may have been driven out of it by natural distillation or by pressure into inclosing or interstratified beds of sandstone. Concerning the origin of sufficient heat to produce natural distillation, it is enough to mention chemical action and the stress to which the rocks have been subjected. It is generally conceded that the principal source of petroleum is animal and vegetable organisms which have been buried in rock-forming sediments. There doubtless have been different epochs in which such organisms were particularly abundant. Thus, in California, the early Neocene appears to have been such an epoch, for during this epoch the silicious shales which form such a landmark in the geology of our Coast Ranges, were deposited, and in many places these shales are found to be made up largely of the silicious skeletons of animal and vegetable organisms, mainly microscopic. It must also be remembered that a very small percentage of petroleum originally distributed through a great thickness of strata might be driven into different zones by natural distillation; and that, at certain temperature and pressure, it would pass readily through sandstone. The upward course of the petroleum might be impeded by strata of shale, and, when the temperature decreased, the petroleum might condense in any rocks suffi-

* See Bulletin No. 3, p. 68: Quaternary fossils from gas wells in the Central Valley.
† See Bulletin No. 3, pp. 9 and 10: Description of Marysville Buttes of California.
‡ See Bulletin No. 3, pp. 6 and 7: Inflammable gas, near Sites, Colusa County.

ciently porous to afford it storage. If the shale were only partially impervious to the petroleum, the former would be more or less permeated by the latter, and fractures in the shale would give the petroleum access to overlying formations. A modification of such processes, by gas or hydrostatic pressure, would be quite sufficient to bring about a redistribution of the petroleum and the formation of secondary deposits of that mineral.

12.3.10. The following table shows the geological horizon of the oil-yielding formations in the districts which the writer has investigated:

TABLE SHOWING GEOLOGIC RANGE OF OIL-YIELDING FORMATIONS IN CALIFORNIA AS FAR AS THEY HAVE BEEN DETERMINED.

System.	Epoch.	California Equivalent.	Localities where Oil-yielding Formations are Found.
Cretaceous	Lower	Knoxville beds	Bear Creek and Sulphur Creek, Colusa County.
	Upper.		
Tertiary	Upper Eocene	Tejon	Coalinga District, Fresno County; Tunitas and Purissima creeks, San Mateo County; Sespe and Devil's Gate districts, Ventura County; Santa Ynez Mountains, Santa Barbara County.
	Lower Neocene (Miocene)	Monterey	Kreyenhagen district, Kings County; Oil City, Fresno County; Sunset oil-district, Kern County; Modelo oil-wells, Ventura County; Sulphur Mountains; Ex-Mission district, Ventura County.
	Middle Neocene* (Transition between Miocene and Pliocene)	San Pablo	Coalinga district, Fresno County; McKittrick, Sunset, and Kern River districts, Kern County; Piru, Ventura County; Los Angeles City and Elsmere Cañon, Los Angeles County; and the Puente Hills, in Los Angeles and Orange counties. Also, a large part of the oil-yielding formations of San Luis Obispo, Monterey, and San Benito counties; Summerland, Santa Barbara County (?); the oil-fields on the south side of the valley of the Santa Clara River, Los Angeles and Ventura counties (?).

* In Bulletins Nos. 3 and 11 this formation was classed as Pliocene, on account of the number of living forms found among its fossils.

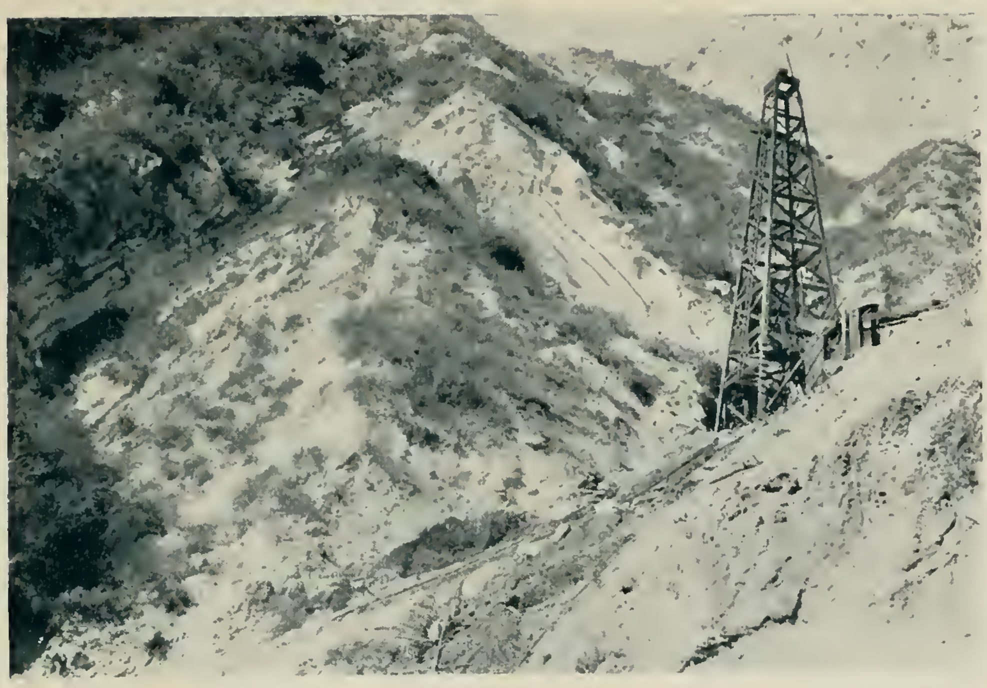


PHOTO 33. Fold in Modelo Cañon, Ventura County.

PHOTO 34. Inclined Fold, Temescal Ranch, Ventura County.

CHAPTER 4.

GEOLOGICAL STRUCTURE PERTAINING TO THE OCCURRENCE OF PETROLEUM IN CALIFORNIA.

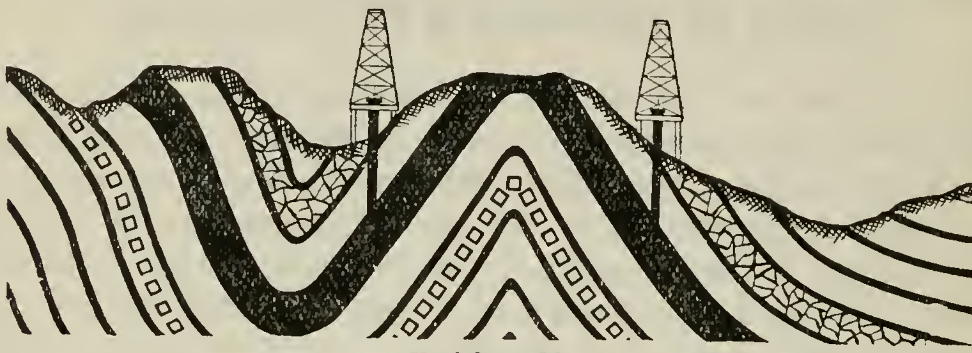
12.4.1. There are two phases of geological research upon which a right understanding of our petroleum deposits depends: (1) An investigation as to the area over which the petroleum-yielding formations extend; and (2) an investigation as to the probable course, length, and width of the oil-lines, or the lines along which remunerative wells can be obtained. With a good topographical map, the former can be successfully carried on without the expenditure of much time and labor; the latter, upon which alone a correct estimation as to the value of our petroleum deposits can be based, requires a careful study of the structural geology pertaining to the subject.

12.4.2. To those who explore the hills and mountains of the Coast Ranges there are few things more interesting than the curiously folded condition of the rocky strata. In California the student of structural geology has not to search very far before he finds natural illustrations of the types of folds he has seen in his text-books. In some parts of the world such folds are many miles in breadth, but in the Coast Ranges the conspicuous folds are generally narrow ones. These small and conspicuous folds usually constitute portions of larger folds, which, although they are more important than the small folds in the formation of hills and mountains, are not so easily detected unless a large area is carefully mapped out and studied. The small folds are, however, of great importance in determining the course and the width of oil-lines. It is in order, therefore, to speak of the more common types of folds and structural forms which are familiar to all students of geology, and to say a few words about their relation to petroleum mining.

12.4.3. *First*—The upright fold, as shown in Fig. 15. The strata forming the sides or limbs of this fold slope away at equal angles of inclination from the axis of the fold. Now, provided the structure is not complicated by faults, it is obvious that wells sunk on opposite sides of this fold, and at points equidistant from its axis, would strike the stratum of oil-sand at the same depth.

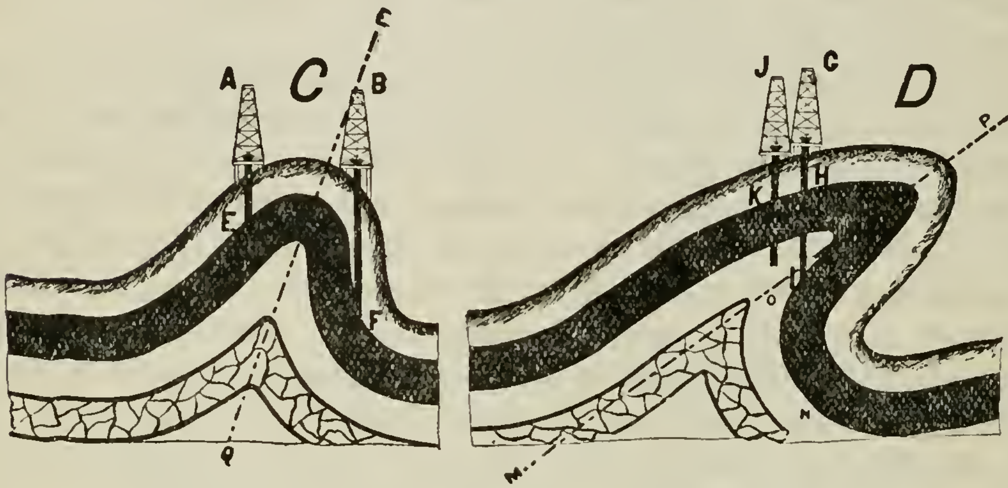
Second—The inclined fold, as shown at C, Fig. 16. In this fold the strata forming one side or limb of the fold slope away from the axis at a greater angle than do the strata forming the other side or limb of the fold. If wells were sunk on opposite sides of this fold at points equidistant from its axis, such as at points A and B, Figs. 16 and 17, it is evident that a well sunk at point A would strike the oil-sand at a much less depth than would a well sunk at point B.

Third—The overturned fold, as shown at D, Fig. 16. In this case a well sunk at point C would penetrate the oil-sand on both sides of the fold. When erosion has worn away the crown of an overturned fold, as shown at D, Fig. 17, a geological problem presents itself, which in many



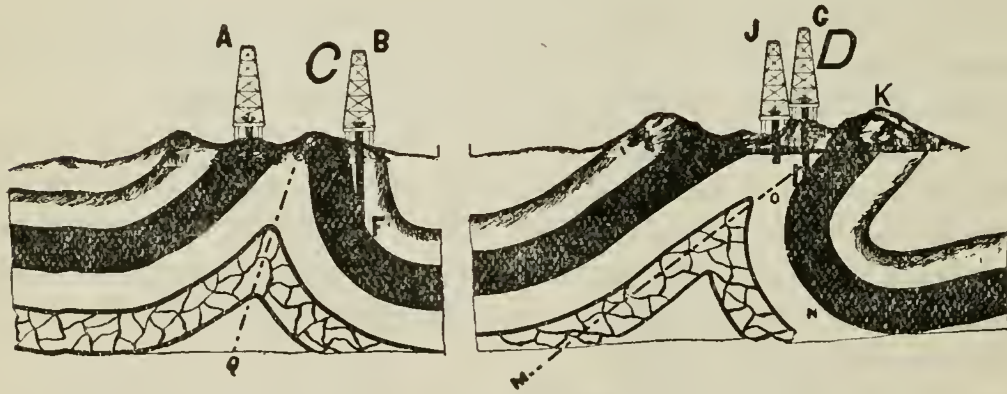
Upright Fold.

Fig. 15.



Inclined Fold. Overturned Fold.

Fig. 16.



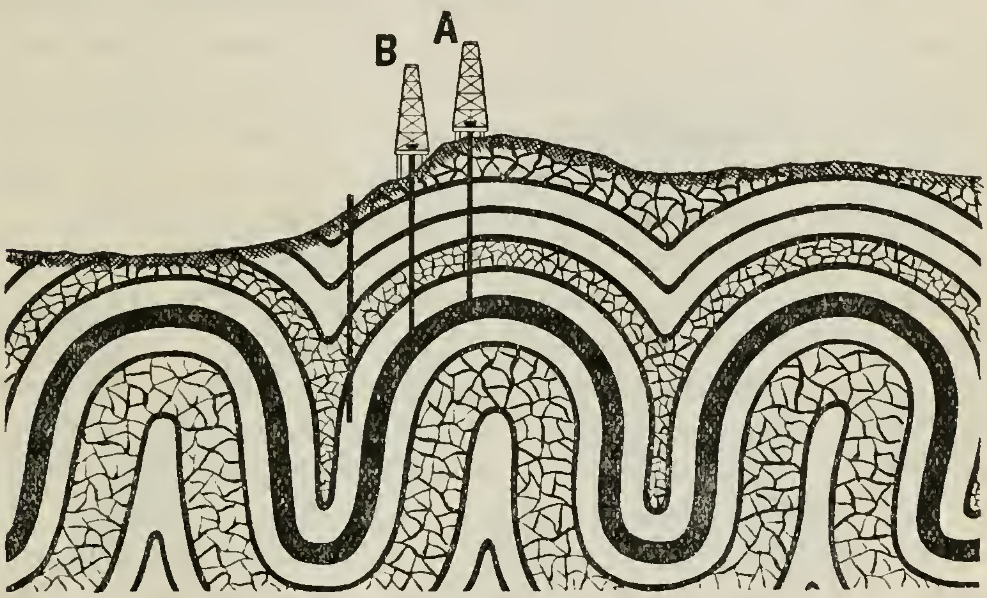
Wells on Inclined Fold. Wells on Overturned Fold.

Fig. 17.

instances requires the investigation of a wide area in order to obtain a satisfactory solution.

12.4.4. Illustration D, Fig. 17, shows mistakes which are quite likely to be made by drilling on an overturned fold. If an outcrop of oil-sand had been discovered at point K, the dip at the outcrop would coincide with OM, the axis of the fold. Unless the structure of the formation were known, it would naturally be supposed that the dip of the oil-sand stratum was fully shown by the exposed rocks at point K. If well G were drilled, the oil-sand would be struck at point I, and the oil-sand stratum would be penetrated lengthwise between I and N. This would lead to the erroneous conclusion that a very thick stratum of oil-sand had been penetrated. If well J were drilled with the intention of striking the oil-sand at O, it is obvious that the oil-sand would be missed altogether. This illustrates the advisability of exhausting all the evidence in sight concerning the structural geology of a locality before wells are located.

12.4.5. It is quite probable that in many instances the dip of strata greatly increases at short distances from anticlinal axes. Moreover, as the axis of a syncline is approached, the strata may be pushed over so that they dip backward toward the axis of the anticline, giving the fold



Fan-shaped Fold.

FIG. 18.

a fan-shaped structure, as shown on the right in Fig. 18. If oil-yielding formations were folded in this manner, it is obvious that, although the oil-sand might be struck at a reasonable depth near the axis of the anticline, as in the case of wells A and B, Fig. 18, a very short distance farther down the slope of the fold the oil-sand might plunge to so great a depth that it could not be profitably reached by the drill.

12.4.6. Photos 33, 34, and 35 illustrate the plication met with in the Coast Ranges. Photo 33 looks like an upright fold, especially at the point photographed. Investigation showed that the strata forming the side of the fold on which the derrick is situated dip at a less angle than do the strata on the opposite side of the fold. The fold is, therefore, slightly inclined. Photo 34 is a good representation of an inclined fold. Photo 35 illustrates the contortions to which rocky strata are subjected, and of which the overturned fold is a type. (See also Photos 1 and 20.)

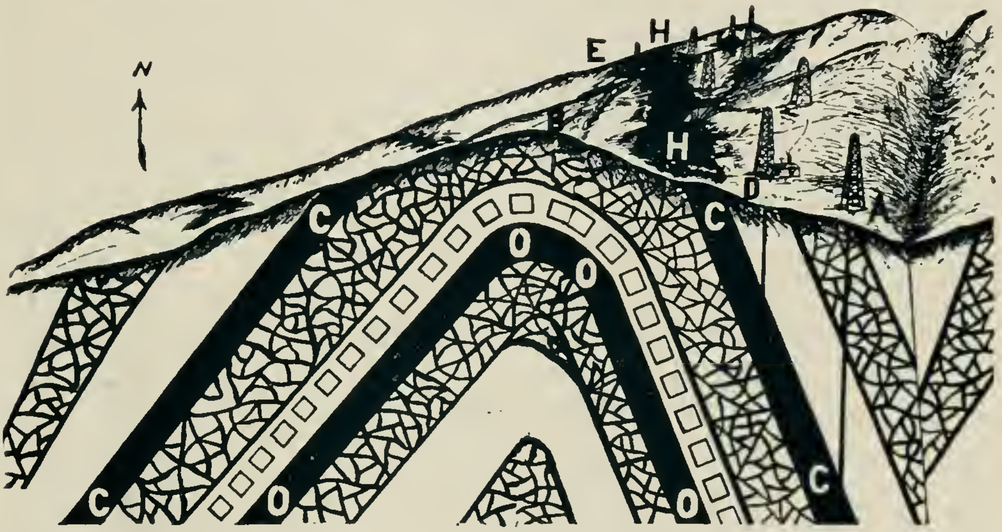
12.4.7. A question here suggests itself as to the depth at which the rocks cease to be affected by folds. It is evident that where the axes of the folds are close together, strata inclined at a moderate angle could not extend to a great depth; but where the angle of the dip approaches the vertical, the lowest portion of the inclined strata may be deeply buried. A simple calculation shows that in the case of folds, the axes of which are 1200′ apart, other things being equal, the greatest depth attained by strata dipping at 50°, 60°, 70°, and 80°, respectively, would be: At 50°, 715′; at 60°, 1039′; at 70°, 1648′; at 80°, 3403′. In any case, there is little doubt but that the smaller folds disappear as great depth is attained, and that strata in the zone underlying them are affected by greater folds, to which the smaller folds are secondary structures.

12.4.8. It is reasonable to suppose that compressed folds do not extend to a great depth in a uniform curve, but that the rock-masses have been readjusted by reciprocal movement. Wherever there has been so much stratigraphical disturbance as is the case in the Coast Ranges, it is evident that structural conditions must be affected, not only by faults and fractures, but also by the thinning or thickening of the softer strata, on account of the compression to which they have been subjected.

12.4.9. A supposed case will illustrate the relation of anticlinal folds to oil-lines. Thus, let Fig. 19 represent oil-yielding strata as CC and OO and the inclosing rocks thrown into an anticlinal fold, the axis of which extends between points B and E. HH is the line of outcrop, or the line along which the oil-sand comes to the surface. An examination of this outcrop and a study of the geological structure of the formation would enable operators to determine a suitable point at which to sink their first well. The derricks shown in this illustration indicate that an oil-line has been developed on the east side of the fold. It will be observed that the oil-line runs parallel to, and at no great distance from, the axis of the fold.

Distance DA represents the breadth of the oil-line, which is supposed to include only two rows of wells, for east of point A the oil-sand might lie too deep to be profitably reached by the drill. If the investigations showed that the geological formation had been thrown into a fold such as that shown in Fig. 19 and an oil-line had been developed on the east side of the fold, it would be reasonable to expect the existence of a similar oil-line on the opposite or west side of the fold, and that, like the oil-line on the east side, it would run parallel to, and at no great distance from, the axis of the fold. (See Fig. 20.) On the west side of the fold the angle of the dip is less than it is on the east side. Therefore, the oil-line is wider on the west than on the east side of the fold, thus permitting more than two rows of wells to be drilled with profit.

PHOTO 35. Overturned Fold, San Pedro Peninsula, Los Angeles County.



Ideal section of oil field on anticlinal fold; oil-line developed on one limb of the fold.

Fig. 19.

Ideal section of oil-field on anticlinal fold; oil-line developed on both sides of fold.

Fig. 20.

In order to further prospect the territory, well X might be deepened, and a second stratum of oil-sand discovered. It is obvious that a discovery of a second oil-sand would greatly increase the value of the territory, for not only might wells be drilled which would tap both strata of oil-sand, but remunerative wells, such as Y and Z, might be drilled and derive their oil entirely from the second oil-sand. It might be, that while one side of the fold furnished valuable oil-territory, the formations on the other side would be so crushed and broken that remunerative wells could not be obtained; or, as shown in Fig. 21, the oil-line might be cut in two by a fault, or a part of it might have slipped down to too great a depth for the oil-sand to be reached by the drill.

As previously mentioned, the dark line HH on the east side of the fold represents the outcrop of the oil-sand with seepages of oil. On the west side of the fold the slope of the hill is supposed to be covered with alluvium. The line of outcrop of any stratum is the line along which it comes to the surface.

12.4.10. In prospecting for petroleum or any other mineral the outcrop is a most important guide. Thus, supposing the black line HH to be the oil-sand, an examination of the outcropping stratum would show the direction in which the oil-sand extends, and the angle at which it dips or is inclined. Consequently, the depth at which the oil-sand could be struck by drilling at any distance from the outcrop might be calculated. When, however, the exposed rocks are situated near the axis of a fold, or the fold of which they form a part is overturned, they are by no means an infallible guide as to the prevailing angle of the dip. In locating an oil-well, the character of the fold affecting the rocks about to be prospected should be taken into account, as demonstrated by the type-folds described in this paper.

In most instances, however, only glimpses of the outcrop can be obtained. As in the case of stratum OO (Fig. 19), the oil-sand may be covered by a great thickness of overlying rock, and the existence of oil-yielding formations may be indicated only by an oil-spring, or they may have been accidentally discovered by drilling. When such buried oil-yielding formations have been discovered on any particular fold, and the position of the oil-sand with regard to the inclosing rocks has been determined, the probable course of the oil-lines may be ascertained by tracing the course of the fold. It is quite important to ascertain whether or not the oil-sand lies conformably beneath the rocks which cover it; or, in other words, whether or not the oil-sand is folded in the same way as the rocks which are exposed at the surface. In hills and mountains, however, it is more than likely that the prospector will be assisted by glimpses of the oil-sand in ravines and cañons, where the overlying rocks have been cut through by erosion.

12.4.11. There are structural conditions of the rocky strata besides that of folding which may determine the existence and the course of oil-lines. The most important of these are faults. As there are many who may not have studied structural geology, it might not be out of place to say a few words on that subject.

Faults are breaks or displacements in the rocky strata, whereby blocks of the earth's crust have been elevated, depressed, or pushed over one another. Where only depression or elevation has taken place, they are called normal or gravity faults; where pushing over has occurred, they are called reversed or thrust faults. The fractures are occasioned by the stretching or compression of the rocky strata. In the case of thrust faults, the controlling power is the thrust or stress occasioned by the compression; and, in the case of gravity faults, it is the force of gravity.

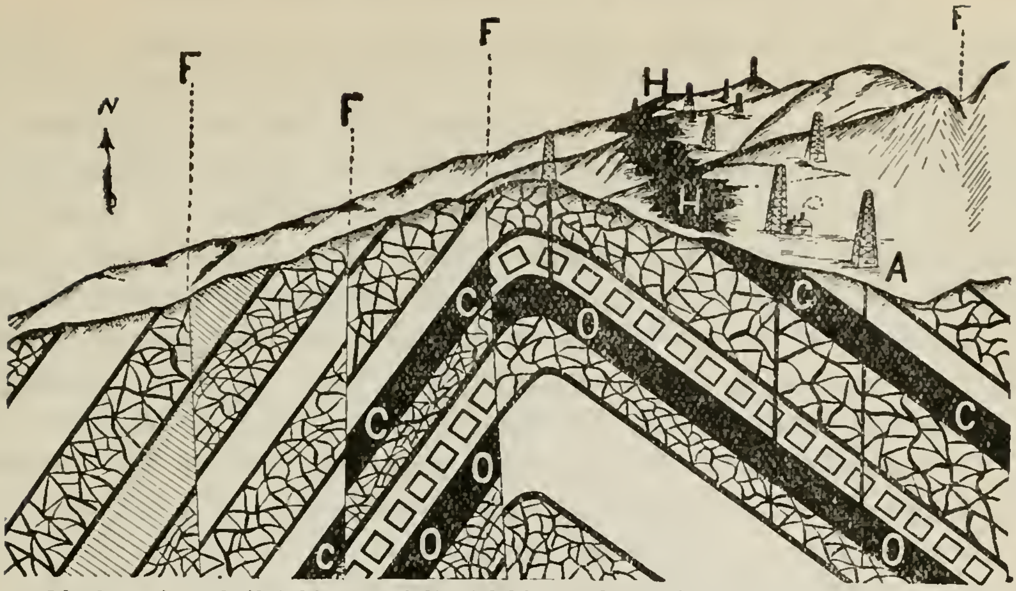
In areas of great compression, like that of the Coast Ranges, it might be supposed that all the faults would be thrust faults, but in many instances the fracture which occasioned the fault is nearly vertical to the plane of the horizon, in which case the force of gravity may control the thrust.

The faults most likely to result in the formation of oil-lines are those which have been caused by fractures extending in the direction of the strike of the formation, and which have allowed blocks of the earth's crust to slip past one another, so that they are arranged in the form of steps.

12.4.12. Let Fig. 22 represent a series of rocky strata inclosing a stratum of oil-sand, the dip being at an angle of about 30°. If well Z is 2000′ deep, the oil-sand west of this well would be too far below the surface to be profitably reached by the drill. Let us suppose that, owing to fractures at points B and D, a fault was formed by block BD slipping down, as shown in Fig. 23. When erosion has worn away the surface (see Fig. 23) two oil-lines might be formed, and the oil might be reached by wells of moderate depth between points E and B, as well as between B and D.

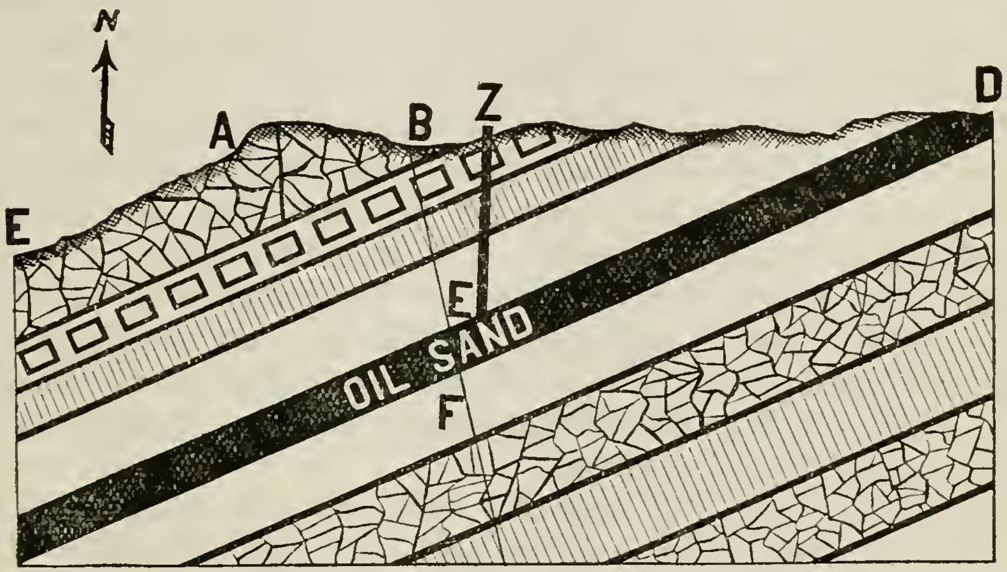
In Fig. 23 a gravity fault is used for purposes of illustration, and it will be observed that the fracture slopes toward the block which has slipped down. Thrust faults, when the fissures which formed them are nearly vertical, might produce similar results, so far as the multiplication of the oil-line is concerned; but in the case of thrust faults the fractures would slope toward the block which has been elevated. When faults are close together the rocks are likely to be so crushed that the oil-line has been destroyed.

12.4.13. Lines of geological disturbance may show faults at one point and a well-marked fold at another. Other things being equal, the question of faulting or folding is determined by the character of the rocks, the thickness of the strata, and the conditions to which they are sub-



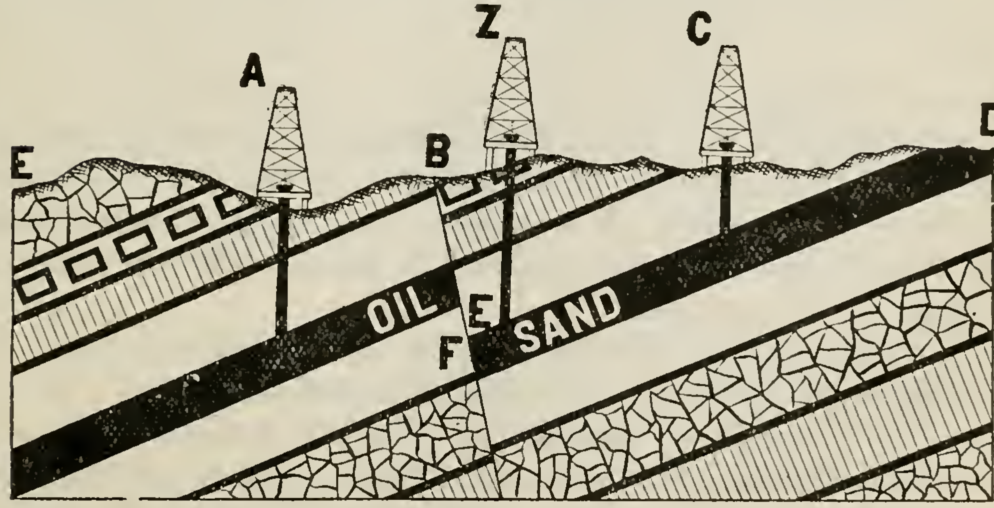
Ideal section of oil-field on anticlinal fold; one limb of the fold broken by faults.

FIG. 21.



Section showing strata inclosing oil-sand stratum.

FIG. 22.



Oil-lines formed by faulting.

FIG. 23.

jected. In the movement which occasioned the faulting or folding, deeply buried strata are more likely to be folded than to be fractured or faulted; while with less deeply buried strata the reverse is the case. In most instances beds of soft material are likely to be more crumpled and folded at acute angles than are harder rocks, but where the hard rocks are thin-bedded they are often as severely crumpled as the softer rocks.

12.4.14. In many localities the rocks are found to be affected by more than one order of folds. In most instances we find dominant folds which have controlled the prevailing strike and dip of the formation, and cross-folds which have a different strike to that of the dominant folds. At points where the cross-folds strike the axes of the dominant folds, the tendency is to form dome-like elevations, or to occasion a great complexity of structure by plication and fracture.

12.4.15. The foregoing remarks on structural geology are sufficient to indicate the structure which, in most instances, controls the course of oil-lines in a country where the formations have been much disturbed.

So far as observed, the oil-lines in the Coast Ranges are governed by structural conditions, such as are described in this paper. A continued study of the development of our oil-fields will still further show how nearly the facts disclosed by the drill conform to the recognized types of geological structure; and a record of such observations cannot fail to be beneficial to the development of the petroleum industry.

Where the rocks are closely folded, as they are in most of the oil-districts of the Coast Ranges, drillers are likely to meet with anomalous experiences, owing to faulting and shifting incidental to the rearrangement of rock-masses, and this necessitates extended observation and great care in making deductions.

12.4.16. The folds and geological structures to be seen in the hills and mountains where the rocks are exposed, do not necessarily terminate in the uplands; they also extend beneath the alluvium of the valleys. Oil-lines that have been discovered in the hills and mountains may be followed into the valleys where the rocks are covered with alluvium.

It would be expected that in districts where there has been much geological disturbance oil-lines would be broken and of irregular extent; this is found to be the case in California. In the Coast Ranges the longest unbroken oil-line yet developed is that of the Central oil-field at Los Angeles and its western extension, which constitute an oil-line more than 2 miles in length.

12.4.17. The financial risks of prospecting for oil vary greatly. Oil-prospecting propositions may be divided into two orders:

First—The "orthodox" proposition. In this case the prospectors have in view a definite oil-yielding stratum, which has proved remunerative in adjacent territory, and from which stratum they expect to obtain their oil. Moreover, they have satisfactory geological evidence in sight that the oil-stratum they have in view forms an oil-line through the territory they are about to prospect.

Second—The "wild-cat" proposition. In this instance the prospectors have no definite oil-stratum in view which has proved remunerative in adjacent territory, or they have not satisfactory geological evidence in sight that an oil-yielding stratum, which is known to be productive in adjacent territory, forms an oil-line through the land they are about to prospect.

In prospect wells of the first order the least risk is taken where the outcrop of an oil-sand, which has proved remunerative in a certain oil-field, can be actually traced through the territory to be prospected, and the geological structure of the locality is known.

More risk, however, is undertaken where there is no outcrop of the oil-sand, although the strike and dip of a remunerative body of oil-sand in an adjacent oil-field are known, and the rocks overlying the oil-sand can be traced to the territory about to be prospected. When an oil-line has been developed on one side of a fold, under certain conditions shown in Fig. 19, and an outcrop of oil-sand has been discovered on the other side of the fold, propositions to prospect this side must be classed among the more risky "orthodox" propositions.

Most oil-mining enterprises which have for their object the development of new territory, especially when operations are conducted at a distance from any known oil-field, are "wild-cat" propositions. Some idea of the conditions regulating the amount of risk involved in such enterprises may be gathered from the following statements:

The least risky "wild-cat" proposition is the case in which the strike and dip of a remunerative stratum of oil-sand in adjacent territory have been ascertained, and, although there is no conclusive geological evidence in sight, it is found after carefully platting a map of the territory that, if the stratum of oil-sand were extended in the direction of its strike, without any material alteration of the angle of the dip, it would form an oil-line across the territory to be prospected. It is a more risky "wild-cat" proposition to prospect the side of a fold opposite to that on which an oil-line has been developed (as shown in Figs. 19, 20, 21, and 23) in cases where surface indications warrant the assumption that the same sequence of formation exists on both sides of the fold, and yet no outcrop of oil-sand has been discovered on the side about to be prospected.

It is a still more risky "wild-cat" proposition when a stratum of oil-sand has been discovered, concerning which nothing is known except that the sand gives evidence of containing oil, and a well is sunk for the first time to determine whether or not the oil-sand contains oil in remunerative quantities.

It is a much more risky "wild-cat" proposition where no outcrop of oil-sand has been discovered, but where a well has been sunk in a certain formation because it shows some irregular seepages of petroleum, or because the formation appears to be similar to that containing a remunerative body of oil-sand in other places.

12.4.18. It is well for oil-prospectors to study the risk they are about to take before expending money, and care should be taken to control sufficient territory that they may have sufficient room to develop their oil-field, in case their venture proves successful. No one should undertake the more risky forms of prospecting unless he can well afford to lose the money to be put into the enterprise.

12.4.19. In California petroleum is found in shales, limestones, sandstones, and conglomerates, and in a few instances crystalline rocks are found impregnated with it; but in nearly all of the productive wells the oil is found saturating sandy strata. In this State the folding of the rocks has brought these oil-soaked strata near the surface, and the oil-lines, or lines along which remunerative wells can be obtained, are parallel to the axes of folds, or to the lines of faulting. The oil-lines extend in breadth only a certain distance down the limbs of the folds or down the block of tilted strata, which has been isolated by faulting. The lateral extent of the oil-line is limited at its upper margin by the outcrop of the oil-sand, or by a line of geological disturbance such as a fault, or by the oil-sand being brought too close to the surface at the axis of the fold on which the oil-line is situated. On its lower margin it is limited by the dip of the formation, which carries the oil-yielding stratum to too great a depth for it to be profitably reached by the drill; or, where the oil-sand is struck below a certain depth, it may be found that water has displaced the oil.

12.4.20. As geologists and oil-men know, the dip and the strike of the oil-sand are of the greatest importance in locating the site of an oil-well, and in the case of prospect wells the dip and the strike have to be ascertained from the exposed rocks.

Many people are not familiar with geological terms, therefore it is in order to describe what is meant by the dip and the strike of a stratum of rock, and to give simple methods for determining the conditions represented by these terms.

The dip of a stratum of rock is the angle which its surface, when inclined, makes with the horizon. The strike is the horizontal direction in which a stratum of rocks extends, and is always at right angles to the dip. Therefore, if the direction of the dip is known, the strike can be readily determined.

The direction of the dip of an inclined stratum corresponds to a line drawn along the inclined surface in the direction of its greatest inclination, and is always at right angles to the strike. (See article by the writer in the "Mining and Scientific Press," Feb. 4, 1899.)

12.4.21. The following is a simple method for determining the dip of exposed strata with sufficient accuracy for practical purposes:

In Fig. 24 let P Q D C represent the surface of an inclined stratum. It is required to determine the direction in which it dips, and the angle at which it is inclined.

If a plumb-bob be suspended from a partly open rule, as shown in Fig. 24, and the open ends of the rule be turned in the direction of the dip until the plumb-line forms one side of a triangle with the two limbs of the rule, then the lower limb G H will lie in the direction of the dip; for the plumb-line will only complete the triangle with the limbs of the rule when its lower limb is placed on I K, the line of greatest inclination of stratum P Q D C. This can be seen by turning the rule so that limb G H falls on line L M or N O, neither of which is the line of greatest inclination of the stratum. It will then be seen that, while the limb G H is in either of these positions, or any other position except the one which coincides with the line I K, the plumb-line and the limbs of the rule will not form a triangle.

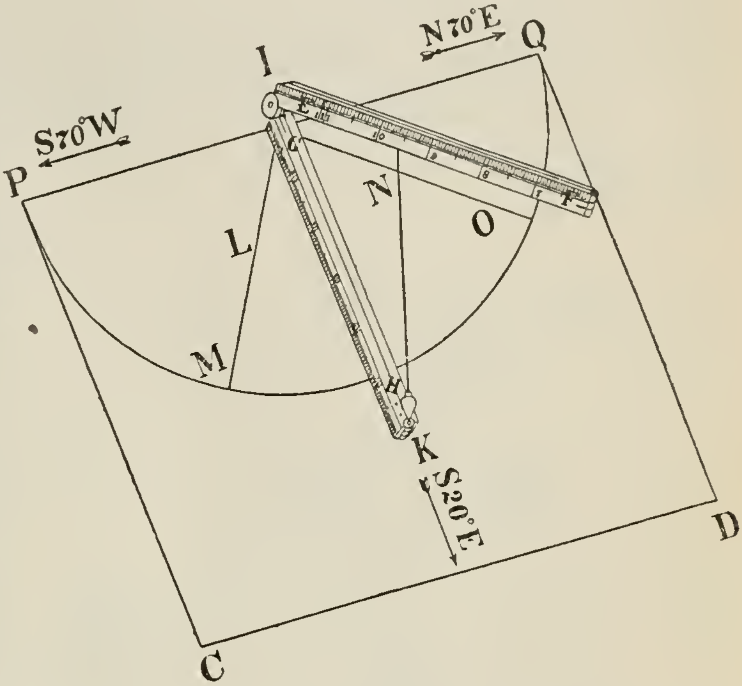


FIG. 24.
Diagram illustrating method of determining dip of exposed strata.

If E F, the upper limb of the rule, be placed in a horizontal position and the lower limb G H on I K, the line of greatest inclination, the side of the triangle formed by the plumb-line will be opposite the angle of the dip. The value of this angle may be found from the two sides of the triangle formed by a portion of the upper limb of the rule and the plumb-line.

The angle of the dip may also be ascertained with approximate accuracy by carefully laying the rule, opened as explained in the preceding paragraph, on a piece of paper, drawing the angle and measuring it with a protractor.

Some rules are furnished with a clinometer scale, by which the angle formed by the open limbs of the rule is indicated.

It will be apparent to mathematicians that, if the upper side of the triangle be considered as radius, the plumb-line will represent the tangent of the angle of the dip; and if the hypothenuse, i. e., the lower side of the triangle, be considered as radius, the plumb-line will represent the sine of the angle of the dip.

As previously mentioned, the strike is always at right angles to the dip. Thus, in the case of stratum P Q D C, if the direction of the dip, as shown by line I K, is found to be S. 20° E., the strike will be represented by line P Q, at right angles to line I K, and the stratum will extend in a horizontal direction with a strike of S. 70° W., or N. 70° E.

Care should be taken that the surface of the stratum, the dip of which is to be ascertained, really is a bedding plane. It must be borne in mind that the bedding planes are seldom true planes, as they are subject to many inequalities.

Therefore, if possible, the dip should be estimated at several places on the same stratum, and the average of the results taken as the dip. In estimating the dip of a stratum of rock by this method, it is well to clear off a space on the surface of the stratum, and to lay thereon a board, thus getting a better surface on which to work.

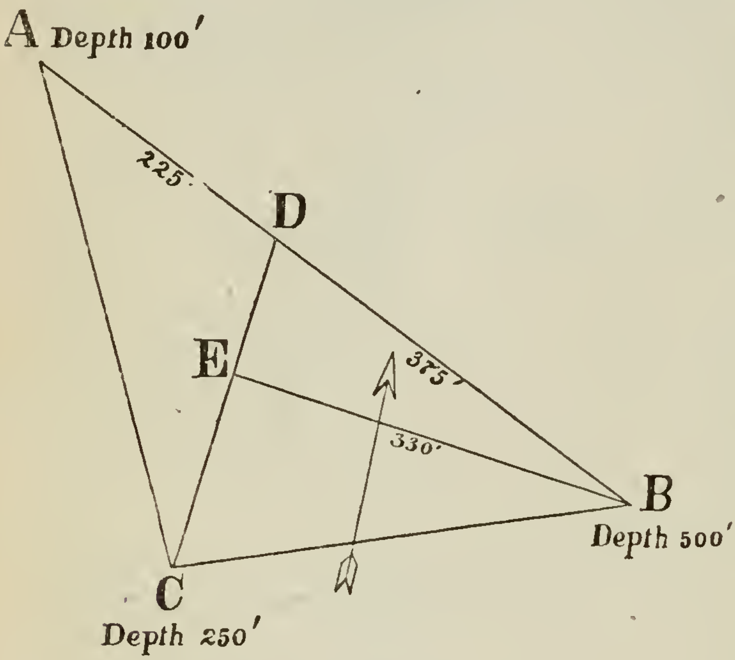


Fig. 25.
Diagram illustrating method of determining strike of oil-sand stratum.

12.4.22. When a remunerative oil-yielding stratum has been discovered, its strike and dip should be determined by drilling three wells according to the following method:

In Fig. 25 let A, B, and C be three wells in which the oil-sand has been struck at 100′, 500′, and 250′, respectively, below any datum-plane, such as a horizontal plane touching the top of well A. Draw A B, and let it represent a horizontal distance of 600′. If a point be found between wells A and B, at which the oil-sand can be struck at a depth of 250′ below the datum-plane, a line drawn from well C to that point must necessarily be drawn along the strike of the formation; and if a line be drawn at right angles to the strike of the formation and toward the deepest well, that line will necessarily be drawn in the direction of the dip of the formation. Moreover, the figure contains the elements from which the angle of the dip may be calculated.

The question is, at what point along the line A B will a well strike the oil-sand at 250′ below the datum-plane. The distance A B is 600′;

the difference in the depth of wells A and B is 400′; therefore, the grade of the surface of the oil-sand A and B is 400′ in 600′, or 2′ in 3′. Hence, wells situated along line A B and sunk to strike the stratum of oil-sand, would, if measured from the datum-plane, increase in depth as well B was approached, and the depths would be in proportion to the distance from A measured along A B.

It is required to find a point along the line A B at which the oil-sand may be struck 250′ below this line, or 150′ deeper than at A. Since the increase in depth of wells which may be sunk from the datum-plane to the oil-sand along the line A B is at the rate of 2′ in depth to every 3′ of horizontal advance toward B, the distance from well A to the required point will be to the increase of depth of well at the required point as 3 to 2, or one and one half times 150′, which is 225′. Lay off A D = 225′. As point D is 225′ distant from well A, along line A B, a well sunk at point D will strike the oil-sand at a depth of 250′ below the datum-plane. Hence, a line drawn from C to D will give the direction of the strike of the oil-sand stratum.

Or the proposition may be stated thus: The grade of the stratum of oil-sand between wells A and B is 400′ (the difference between the depth of the wells at A and B) divided by 600′ (the horizontal distance between the two wells), which gives two thirds of a foot in depth to one foot along A B. Dividing 150′ (the difference of depth of wells A and C) by two thirds of a foot, we obtain the distance 225′, which is the distance A D. Therefore, if a well were sunk at D, the oil-sand would be struck at a depth of 250′. Draw the line C D. Now, it is evident that a well sunk at any point along C D would strike the oil-sand at a depth of 250′. Hence, as before stated, the line C D is the direction of the strike of the oil-sand stratum. Moreover, any line drawn at right angles to line C D, and in the direction of the deepest well, will be drawn in the direction of the dip of the formation.

It is now required to find the angle at which the oil-sand dips, and this can be found as follows: From B draw B E at right angles to C D (the line of strike). This line E B is the direction of the dip of the formation. By measurement, we find that line E B is 330′. If a well were sunk at point E, it would strike the oil-sand at a depth of 250′ below the datum-plane. Therefore, the grade along the surface of the oil-sand in the direction of E B is 250′ in 330′; and this grade represents an angle of about 37°. If the meridian be represented by the arrow in Fig. 25, then the oil-sand penetrated by the wells A, B, and C dips S. 80° E., at an angle of about 37°, and, consequently, the strike is N. 10° E.

12.4.23. When a remunerative stratum of oil-sand has been struck and the angle at which it dips has been ascertained, as shown in the foregoing paragraphs, the distance from any of the wells, as B, to the point at which the oil-sand ought to crop out at the surface of the ground, if it were on a level with the datum-line, can be determined. This is done by the following method:

Let Fig. 26 represent a vertical cross-section drawn through the ground-plan of Fig. 25, along line B E, and extended along the line of dip toward the outcrop. Let B *b* represent 500′, the depth of well B, and let E *e* represent the depth of a well which, if sunk at E, would strike the oil-sand at a depth of 250′, as explained in a preceding paragraph. It is required to find the point at which the stratum of oil-sand, struck in well B, ought to crop out at the surface of the ground, provided the surface were on a level with the datum-line and not covered with alluvium. Through points *b* and *e*, or the top of the oil-sand stratum, draw *b e*, and extend it until it cuts the datum-line; the point where it cuts this line is at L. If the distance between B and L be measured, it will be found to be about 660′, which is the distance between well B and the outcrop. If the surface of the ground sloped upward from the datum-line, as indicated by the outline H Y, it is evident that the oil-sand would crop out at a point above the datum-line. This point can be found by extending line *b* L till it strikes the surface. It is obvious that if the surface of the ground sloped downward from any point, such as H on the datum-line, the outcrop would be below the datum-line.

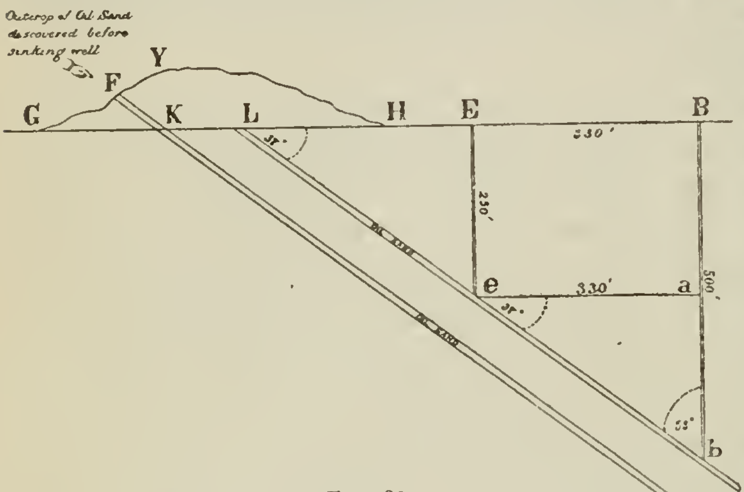


FIG. 26.
Diagram illustrating method of determining dip of oil-sand stratum.

The angle at which the oil-sand dips, and the distance from well B to the outcrop, may be found by measurement and the simple methods already given, with sufficient accuracy for practical purposes. But, if a closer estimate is desired, it can be obtained by the following trigonometrical formulas:

From the right-angled triangle *a e b* (see Fig. 26), of which *a e* = 330′ and *a b* = 250′, we have:

$$\text{Cot. of angle of dip } (a\ e\ b) = 330' \div 250' = 37^\circ\ 8'\ 48''.$$

From the right-angled triangle B L *b*, of which B *b* = 500′, and angle *a e b* = angle B L *b* = 37° 8′ 48″, we have:

$$\text{B L} = 500' \times \text{cot. } 37^\circ\ 8'\ 48'' = 660'.$$

That is to say, the distance from well B to the outcrop at L, measured on the datum-plane, equals the depth of the well multiplied by the cotangent of the angle of the dip.

12.4.24. If in the first instance an outcrop of oil-sand had been discovered at point F, and well B had been sunk to strike it, then it becomes important to determine whether or not the previously discovered outcrop of the oil-sand is identical with the outcrop of the oil-sand as determined by calculation. It has been found that the angle of the dip would cause the oil-sand struck in well B to come to the surface at point L or Y. Therefore, it is reasonable to suppose that the discovered outcrop which comes to the surface at F represents a stratum of oil-sand underlying that penetrated by wells A, B, and C. (See Fig. 25.)

If an outcrop of oil-sand had been discovered at F and well B sunk and oil-sand had been struck at 500′, it would naturally be supposed that the oil-sand stratum discovered at point F had been reached. If struck a little sooner than expected, it might be accounted for on the supposition that there is some irregularity in the dip; but when three wells are sunk and the dip, calculated by the method of triangulation already explained, shows that the stratum of oil-sand struck in wells A, B, and C ought to appear at L or Y, it is presumptive evidence that the outcrop of oil-sand discovered at F is a stratum underlying that penetrated by the wells. When no outcrop of oil-sand has been discovered, it is important to find out where the outcrop ought to be in order that some idea may be had on the ground as to the width of that portion of the oil-line which lies between the well and the outcrop.

In all these calculations everything must be reckoned with reference to a common datum, which is preferably the horizontal plane passing through the highest or lowest part of the oil-field in which the calculations are made. Oil-fields should be developed by this method of triangulation, or some modification of it. In the development of an oil-field in California it is expected that many cases will occur where the calculations will not tally with the results, for the reason that there are irregularities in the formation; but taken as a whole, progress by triangulation is the only safe method of procedure.

It will be evident to mathematicians that the calculations herein set forth may be made by various formulas.

12.4.25. From the foregoing paper it will appear that, although the element of risk is inseparable from petroleum mining, it is greatly diminished by competent and careful preliminary work, consisting of:

First—A study of the structural features of the locality wherein operations are to be conducted.

Second—By following a systematic method of triangulation for determining the strike and dip of the oil-sand, and the site of new oil-wells.

When a remunerative oil-line has been discovered it should be developed gradually; and in districts where there has been much geological disturbance, it is better to limit the distance between wells to about 300′.

If oil-lines are discovered on both sides of an anticlinal fold, it is well to develop them simultaneously, by which means a correct idea as to the structure of the fold may be obtained.

By prospecting and developing territory on the lines mentioned in this paper, a few wells may be so located as to demonstrate in most instances the value of the territory; whereas wells drilled without due regard to the geological conditions of the locality demonstrate nothing more than the value of the rocks they actually penetrate, and several wells may be drilled which prove only the same fact instead of the group of facts on which the value of an oil-field depends.

12.4.26. From the foregoing discussion it is apparent that the depth of oil-wells depends on the angle at which the oil-sand dips, and the distance the wells are from the outcrop of the oil-sand, or from the axis of the fold or the fault-line on which the wells are situated. As a general statement it may be said that the most productive wells are about 1000′ in depth, some being much deeper.

12.4.27. The "life" and yield of such wells are naturally varied. Some wells are "spouters" and "start off" by flowing several hundred barrels of oil a day, but in most instances the flow subsides and the well becomes an ordinary "pumping-well." In some instances wells have "started off" with a yield of 100 bbls. or more a day by pumping, but, in the course of from two to six years, the yield has diminished to 10 bbls. or less a day. In other instances the first yield was less than 100 bbls. a day, but the rate of production was better sustained during the "life" of the well. In some oil-fields, the wells are considerably less than 1000′ in depth, but, as a rule, their yield is not so great as that of the deeper wells.

12.4.28. The cost of drilling wells varies according to the accessibility of the locality where the well is situated, and the character of the formation penetrated.

The following statement as to the cost of drilling 1000′, exclusive of the cost of casing, is a consensus of opinion obtained by correspondence with several well-known oil-producers:

Locality.	Cost of Drilling 1000′.
Los Angeles and the Kern River district	$1,000 00 to $3,500 00
The Puente Hills	3,500 00 to 7,000 00
Newhall and Territory on the north side of the valley of the Santa Clara River	5,000 00 to 7,500 00
The foothills of the Coast Ranges on the west side of the San Joaquin Valley	2,000 00 to 7,000 00

12.4.29. A review of the oil-fields in the Coast Ranges leads to the conclusion that the most favorable locality in which to drill "prospect wells" is one wherein a definite stratum of oil-sand has been discovered in a formation belonging to a geological horizon known to include productive oil-measures in other places; preferably there should be seepages of liquid petroleum at or near the locality in which prospect wells are to be drilled, and the angle at which the oil-sand dips should not be more than 50° nor less than 10°. As stated in a previous chapter, it may be said that, in a general way, the oil-lines, or lines along which remunerative wells may be found, follow the strike of the axes of folds in the rocks, or the course of faults which have isolated blocks of strata inclosing the oil-yielding rocks. It is evident that the oil-yielding formations, in common with the other rocks of the Coast Ranges, show great geological disturbance, and the complex structure resulting therefrom gives rise to somewhat difficult geological problems. It follows that the tracing of oil-lines in this State, and the development of oil-fields, necessitate a competent knowledge of structural geology, without which the risks of oil-mining are greatly increased.

CHAPTER 5.

THE CHARACTER OF CALIFORNIA PETROLEUM, FUEL VALUE, ETC.

12.5.1. The character and fuel value of California petroleum were treated at some length in Bulletins Nos. 3 and 11, published by the State Mining Bureau. Since these bulletins are out of print, the leading facts concerning the character and fuel values of California petroleum are recapitulated in this chapter, and other data available at this writing are added hereto. It is not within the scope of this paper to enter into a lengthy discussion concerning the vexed question as to the origin of petroleum; still it is in order to give a short summary of the principal hypotheses by which the formation of petroleum has been explained. As is well known, the origin of petroleum has been accounted for in three ways:

First—By the chemical combination of inorganic matter.

Second—By chemical change, with or without natural distillation, of animal matter.

Third—By chemical change, with or without natural distillation, of vegetable matter.

The first of these hypotheses requires either that petroleum must have been originally produced by the actual combination of carbon and hydrogen then existing in the cosmical matter of which the earth is made, or that it results from chemical reactions between the substances formed from the primitive elements, such as the action of water on metallic carbides. The advocates of the first theory refer to the fact that hydrocarbons similar to those forming petroleum have been formed in the laboratory by the action of water on metallic carbides, notably that of steam on iron carbide; also by the action of water on calcium carbide. The latter process is now one of common use in the production of acetylene gas for domestic purposes. The occurrence of bituminous matter and the occlusion of hydrocarbon gases in meteorites have also been referred to by the advocates of the first theory. They mention the fact that bitumen has been found in trappean rocks and in quicksilver deposits, and refer to the discovery of boracic acid in water accompanying springs of petroleum at the Island of Trinidad.

According to the second hypothesis, petroleum is derived from animal organisms. Supporters of this theory point out that petroleum has been manufactured in the laboratory from fish-oil soap and from fish-oils; also, that petroleum is found in limestones rich in animal remains, and that nitrogen is a constituent of many petroleums, in some forming as much as 1% of the mass.

According to the third hypothesis petroleum is derived from vegetable matter. The supporters of this theory rely on the facts that petroleum has been manufactured in the laboratory from vegetable oils; from vapors arising from boiling varnish, and by the distillation of wood, and from decaying seaweed from which air has been excluded. Some of them point out that putrefaction and decay would destroy the animal matter before it could be converted into petroleum. At first sight the objection to the animal-matter theory on the ground of rapid putrefaction seems a very serious objection, but inquiry shows that when fish are cast upon a sandy shore they are frequently buried in the sand before many tides have rolled over them. It is not the larger animals only which are to be regarded as a probable source of petroleum. The corals and the microscopic foraminifera and diatoms, the skeletons of which in some places are the principal constituents of strata hundreds of feet in thickness, must be regarded as contributing no inconsiderable quota of hydrocarbon material from which petroleum might be formed. Bearing in mind the immense amount of seaweed which in all ages has flourished in the ocean, it is impossible not to recognize this material as a probable source from which petroleum may have been formed. This view is strengthened by the fact that water accompanying petroleum in the Central Valley of California is rich in iodine. (See Bulletin No. 3.)

Since it is evident that hydrocarbons similar to those found in petroleum can be manufactured in the experimental laboratory by any one of the processes named, there does not appear to be any reason why petroleum should not be formed by any or all of such processes in the greater laboratory of nature; nor is it possible for us to figure out what reactions may take place between the hydrocarbons themselves in deeply buried strata when they are subjected to temperatures and pressures of unknown quantities.

TABLE No. 1.

Temperature at which Distillate was Cut Off.		Samples from Central Oil-Field, Los Angeles.						
		A	B	C	D	E	F	G
	Gravity of crude oil	17° B.	17° B.	17° B.	17° B.	17° B.	16° B.	16° B.
150° C.	Naphtha	Traces.	Traces.	Traces.	Traces.	Traces.	Traces.	Traces.
200° C.	Naphtha	Traces.	Traces.	Traces.	Traces.	Traces.	Traces.	Traces.
250° C.	Illuminating oil	8.0% 38° B.	7.0% 38° B.	6.0% 39° B.	9.6% 40° B.	8.0% 42° B.	1.6%	2.2%
300° C.	----------	13.6% 32° B.	15.3% 29° B.	16.8% 31° B.	17.6% 36° B.	12.0% 32° B.	11.4% 32° B.	11.2% 30° B.
350° C.	Lubricating oil	3.0%	7.1% 27° B.	8.0% 27° B.	5.0% 27° B.	4.0%	3.4%	7.0% 29° B.

TABLE No. 1—Continued.

Temperature at which Distillate was Cut Off.		Mackintosh Well, Los Angeles.	Oil from Maltman Tract.	Summerland, Santa Barbara County.				Sunset Oil-District, Kern County.
				A	B	C	D	
	Gravity of crude oil	13° B.	14° B.	15° B.	17° B.	15° B.	15° B.	15° B.
150° C.	Naphtha	Traces.	Traces.	Traces.	Traces.	Traces.	Traces.	----------
200° C.	Naphtha	Traces.	Traces.	Traces.	Traces.	Traces.	Traces.	0.6% 37° B.
250° C.	Illuminating oil	Traces.	1.0%	2.0%	Traces.	Traces.	Traces.	5.0% 36° B.
300° C.	----------	1.6%	8.0% 31° B.	11.0% 36° B.	19.4% 34° B.	11.6% 36° B.	6.0%	8.6% 31° B.
350° C.	Lubricating oil	4.4%	9.6%	5.0% 30° B.	12.0% 26° B.	6.8% 27° B.	5.0%	5.2% 30° B.

12.5.2. A general idea of the character of the petroleum obtained in the Tertiary rocks of California may be formed by inspecting the following tables. The samples of petroleum included in Table No. 1 (page 203) are from oil-measures which, as before described, are referred to the lower portion of the Middle Neocene formations. These oils are essentially fuel oils, as is shown by their fractional constituents. The percentages given are volumetric and the temperatures are those in the head of the retort.

The samples included in Table No. 2 are from oil-measures which, as before described, are referred to the Eocene formations. These oils are of a much lighter specific gravity and contain more volatile constituents than are found in the oils included in Table No. 1.

TABLE No. 2.

Temperature at which Distillate was Cut Off.		Tar Creek. A	Tar Creek. B
	Gravity of crude oil	23° B.	23° B.
100° C.	Naphtha	------	------
150° C.	Naphtha	7.6% 60° B.	8.4% 63° B.
200° C.	Illuminating oil	11.0% 55° B.	8.0% 58° B.
250° C.	Illuminating oil	10.4% 41° B.	10.4% 45° B.
300° C.	Lubricating oil	12.4% 34° B.	14.2% 33° B.
350° C.	Lubricating oil	6.0% 29° B.	4.0%

TABLE No. 2—Continued.

Temperature at which Distillate was Cut Off.		Four Forks.	Kentuck.	Coalinga (Oil City).
	Gravity of crude oil	22° B.	25° B.	34° B.
100° C.	Naphtha	------	------	0.6%
150° C.	Naphtha	Traces.	6.0% 64° B.	32.0% 45° B.
200° C.	Illuminating oil	6.9% 52° B.	8.6% 54° B.	27.0% 38° B.
250° C.	Illuminating oil	16.8% 45° B.	10.0% 44° B.	16.6% 30° B.
300° C.	Lubricating oil	9.7% 38° B.	12.2% 36° B.	------
350° C.	Lubricating oil	6.6% 33° B.	2.5% 32° B.	12.0% 24° B.

The samples included in Table No. 3 are for the most part of a lighter gravity than the samples included in Tables Nos. 1 and 2. Samples marked A, B, and C were distilled by the late W. D. Johnston, chemist to the California State Mining Bureau. The sample from the Puente wells is from formations which, as previously described, are referred to the lower portion of the Middle Neocene series, although the gravity of the oil suggests a source of greater age. The same remarks apply to the sample from the Pacific Coast Oil Company's wells, and also to the oils obtained at the Torrey Cañon and from the Bardsdale wells in Ventura County. The sample from Tunitas Creek is from rocks of Eocene age, and it is probable that the sample from Moody Gulch was obtained in formations belonging to a similar geological horizon.

TABLE No. 3.

	Puente Oil-Wells.		Pacific Coast Oil Company, Pico Cañon Well No. 4.	Tunitas Creek, San Mateo County.	Moody Gulch, Santa Clara County.
	Sample No. 1.	Sample No. 2.	A	B	C
Gravity of crude oil	23° B.	28° B.	40° B.	45° B.	44° B.
Temperature at which distillate was cut off:					
100° C.	----	----	9.1% 69° B.	9.9% 68° B.	9.4% 65° B.
125° C.	----	----	10.4% 59° B.	17.3% 59° B.	----
150° C.	Traces.	10.2% 61° B.	9.3% 54° B.	19.5% 54° B.	24.4% 57° B.
200° C.	15.9% 52° B.	13.5% 55° B.	13.4% 48° B.	17.2% 46° B.	17.1% 47° B.
250° C.	10.8% 45° B.	12.2% 43° B.	13.9% 41° B.	11.8% 37° B.	14.8% 39° B.
300° C.	9.3% 35° B.	10.2% 36° B.	8.3% 35° B.	6.0% 33° B.	3.6% 34° B.
350° C.	2.9% 33° B.	8.3% 34° B.	----	----	----

A scrutiny of these tables indicates that on the ground of physical composition alone there is a wide range in the products that can be manufactured from California petroleum.

With the exception of a sample of oil from the Cretaceous formations of Colusa County, all the samples of oil which have been examined by the writer showed an asphaltic base; i. e., the residuum, after the distillation of the lighter hydrocarbons, was an asphalt, or a heavy tar of asphaltic character. These asphaltic oils form asphaltum on exposure to the atmosphere.

12.5.3. The residuum from the Colusa County oil is not an asphalt; physically, it resembles the residuum from Eastern asphaltum. The Colusa County oil does not form asphaltum on exposure to the air. Two samples of the Colusa County petroleum were distilled by the writer, and their distillates compare with distillates from a sample of asphaltic oil, as follows:

Sample A, from Colusa County.

	By Volume.	Specific Gravity.
Crude oil	----	0.982, about 12° B.
Distillate below 250° C.	1%	------
Distillate between 250° C. and 325° C.	60%	0.950, about 17° B.

Nearly all the distillates came over 300° C.

Sample B, from Colusa County.

This sample contained b. s. (sludge).

	By Volume.	Specific Gravity.
Crude oil	--------	0.9835, about 11° B.
Distillate below 280° C.	Traces	------
Distillate below 300° C.	16.250%	0.9111, about 24° B.
Distillate below 350° C.	3.122%	0.9600, about 16° B.
At a somewhat higher temperature	43.750%	0.9788, about 13° B.

Sample of Oil from Los Angeles.

	By Volume.	Specific Gravity.
Crude oil	--------	0.9534, about 17° B.
Distillate below 150° C.	Traces	------
Distillate below 200° C.	Traces	------
Distillate below 250° C.	8%	0.8330, about 38° B.
Distillate below 300° C.	13.6%	0.8653, about 32° B.
Distillate below 350° C.	3%	------

Sample of Oil from Kern River Oil-Field.

(Analysis by Thos. Price & Son, of San Francisco.)

Specific gravity of crude oil, 0.962 (15° B.).
One bbl. of 44 gals. will weigh 352.72 lbs.
Sample was free from water, clay, and sand.
1,000 volumes of the oil, on fractional distillation, yielded as follows:

Degrees.	Volume.	Specific Gravity.	Degrees B.	Weight.
240° to 300°	109	.874	30	95.26
300° to 350°	100	.896	26	89.60
From 360° gradually up to a dull red heat	134	.915	23	122.61
	140	.925	21	129.50
	143	.928	20¾	132.70
	143	.930	20½	133.00
	183	.939	19	171.83
	21	.958	16	171.83
	27	.958	16	20.01
				77.49
	1.000			960.00

Flashing point of crude oil, 400° F.

"The uniformity of the various products for a range of temperature from 360° F. to a dull red heat is a good characteristic in a fuel oil, as such oils will exhibit great regularity in burning. At a temperature of 140° C., this oil is very fluid. The calorific value of the oil is 22.985 British thermal units. The theoretical evaporation per pound of oil, at a pressure of 8 atmospheres, is $17\frac{6}{10}$ lbs. Under similar conditions, the best coals coming to this market (San Francisco) show an evaporation of from 12 to 13 lbs."

12.5.4. The ultimate analyses of samples of oil from California and the Eastern States compare as follows:

Locality where Oil was Obtained.	Specific Gravity.	Nearest Degree.	C.	H.	O.	N.	S.	By Whom Analyzed.
Oil Creek, Pa.	0.730	62° B.	82.0	14.8	3.2			Deville
West Virginia	0.840	36° B.	84.3	14.1	1.6			Deville
California			86.934	11.817		1.1095		Peckham
California	0.920	22° B.	84.0	12.7	1.2	1.7	0.4	Salathè

An examination of the foregoing table shows that in the California oils the content of carbon as compared to that of hydrogen is greater than it is in oils from Eastern States. Concerning crude oils from Los Angeles and Ventura counties, Dr. Salathè says:

12.5.5. "These crude oils, all of which carry asphalt, are held in combination with the high boiling members of the hydrocarbon series and are of a very complex constitution, which conditions render their refining exceedingly difficult. By a series of chemical reactions and fractional distillations, I have succeeded in isolating various hydrocarbons which define clearly the presence of the following hydrocarbon series:

"(*a*) Hydrocarbons of the paraffin, or fatty, series.

"(*b*) Hydrides, or hydron, additional products of the benzole series, and homologous hydrocarbons.

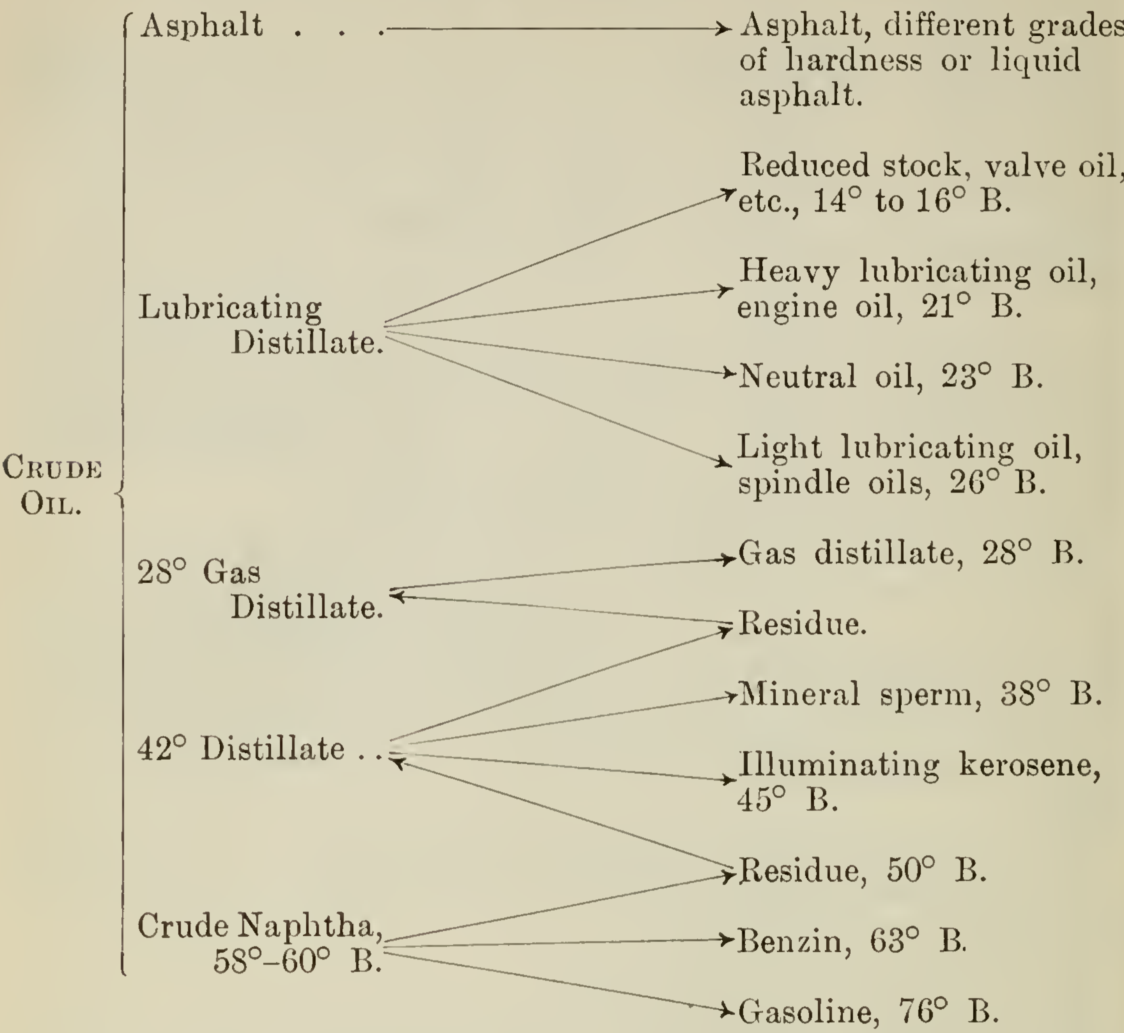
"(*c*) Pyridin and chinolin series.

"(*d*) Isomeres of the terpéne series.

"(*e*) Sulphureted hydrocarbons.

"The refining of the crude California oils is not an easy task, and they require refining methods different from those practiced with Eastern or Russian oils. The complicated nature of this class of asphaltic crude oils necessitates complete elimination of all unstable hydrocarbons by inexpensive practical processes. Another great difference exists between the specific gravities of Eastern oil distillates and those of California oils. Viscosity of distillate or reduced stock being equal, the gravities are from 5° to 6° B. lower in California oil fractions than in those of Eastern oils. Flash and fire tests are from 10° to 30° F. lower in California oil distillates than in Eastern distillates of the same gravity.

"The following is a diagram of products available from California crude oil by refining, showing where re-distillation is required:



"The average yield of products from 100 bbls. of Ventura County mixed crude oils of 24° B., determined by actual running on a large scale, is as follows:

Gasoline, 76° B.	3 bbls.
Benzin, 63° B.	4 "
Kerosene, 45° B.	15 "
Heavy kerosene, 38° to 40° B.	8 "
Gas distillate, 28° B.	21 "
Light lubricating (spindle) oil, 26° B.	10 "
Neutral oil, 23° B.	12 "
Heavy neutral oil, 21° B.	6 "
Reduced stock, lubricating oil, 14° B.	5 "
Asphalt, crude	11 "
Loss	5 "

"The extraction of pyridin bases with dilute sulphuric acid should be done before the re-distillation of the distillates, as the treatment of those distillates with concentrated sulphuric acid will otherwise form certain sulpho-conjugated products, which, during the washing process with water and alkali, decompose and re-enter into solution with the refined products."

(See résumé of Original Researches and Analysis and Refining

Methods of Petroleum, mainly from the southern counties of California, by F. Salathè, Ph.D., in Bulletin No. 11 of the California State Mining Bureau.)

12.5.6. Several years ago Dr. C. P. Williams made a careful examination of certain of the lighter distillates from Southern California petroleum. His experiments showed that the samples tested were composed of the following hydrocarbons:

Name of Hydrocarbon.	Approximate Amount Contained in Sample.
Paraffin	25%
Olefin	30%
Aromatic hydrocarbons	20%
Naphthalene	25%

12.5.7. As is well known, the petroleum of the Eastern States is composed principally of hydrocarbons of the paraffin series. As previously mentioned, by far the greater portion of the California oil is used for fuel, and that in a crude state. It is the general opinion of those who use oil as fuel that, weight for weight, there is not much difference between the fuel value of oils of different specific gravities, provided the oils are clean, or a suitable allowance is made for water and other foreign substances which they contain. A portion of the oil is used for fluxing asphaltum and for the manufacture of illuminating gas, and a portion is refined. The portion refined yields crude naphtha, illuminating oil, gas distillate, lubricating oil, and asphaltum. The naphtha distilled from California oils is of special value for use in gasoline engines. Those who have made comparative tests of California and Eastern gasoline in gasoline engines claim a superiority for the California product.

12.5.8. As might be expected from the foregoing statements concerning the relative composition of petroleum from the Eastern States, and the asphaltic oil of California, illuminating oil manufactured in this State contains more carbon and less hydrogen than does illuminating oil manufactured from Eastern petroleums. The result is that when burned under similar conditions, California oil gives a more smoky flame than does oil manufactured from Eastern petroleum. This is due to the fact that it requires more oxygen to effect the complete combustion of carbon than it does to consume hydrogen.

12.5.9. As previously stated, the petroleum obtained from the Cretaceous formations of Colusa County is not an asphaltic oil. Should the petroleum from this county prove to be paraffin, and be obtained in sufficient quantities, it might yield distillates which would blend with the illuminating oil manufactured from our asphaltic petroleum and offset the excess of carbon which it contains.

A comparison of the fractional distillations of the Colusa County oil with that of the asphaltic oil from Los Angeles shows a marked discrepancy in the boiling-point and in the specific gravity of the distillates;

the excessive gravity and high boiling-point of the Colusa County oil indicate that it is a valuable lubricant.* There is no doubt that as time goes on, more use will be made of the constituents of our asphaltic oils in chemical manufacture. One use was pointed out by Dr. Salathè, who says: "The occurrence of pyridin and chinolin bases in California crude oil opens up a new resource for these products, which are largely used for the synthetical production of alkaloids, dyes, etc., and in a large measure for denaturalizing alcohol in Europe."

12.5.10. In 1896, the writer made calorimetric experiments on the fuel value of California petroleum, as stated in Bulletin No. 11 of the California State Mining Bureau, Part 4, Chapter 3. In the publication referred to, the fuel value of the petroleum, as determined by the calorimetric experiments, is compared with the fuel value of Nanaimo coal; also with the fuel value of petroleum as computed from practical working tests in locomotives on the Southern California Railroad. In Bulletin No. 11 there is also a record of calorimetric tests of the fuel value of petroleum, made by Prof. H. Stillman in the laboratory of the Southern Pacific Railroad. In 1898, calorimetric tests were made by Messrs. Jaffa and Colby of the University of California on samples of a heavy grade of petroleum from Summerland, Santa Barbara County. The fuel values, determined by these different estimates, compared as follows:

FUEL VALUES OF CALIFORNIA PETROLEUM COMPARED WITH FUEL VALUE OF COAL.

	Available Heat Units in one kilogramme	Available Heat Units in One Ton, calculated as 909 kilogrammes	One Ton of 2,000 lbs. Nanaimo Coal and equivalent in bbls. of Petroleum
Nanaimo coal	6,684	6,075,756	
Sample of petroleum, 15° B., from practical working test in locomotives on Southern California R. R.	--------	9,886,585	3.870
Sample of crude petroleum, 16.5° B., tested by Prof. Stillman	9,800	8,908,200	3.487
Sample of lubricating oil, 16° B. to 17° B., tested by Prof. Stillman	10,788	9,796,192	3.834
Sample of Los Angeles oil, 13° B., tested by W. L. Watts	10,203	9,274,527	3.630
Maximum fuel value obtained in calorimetric tests by W. L. Watts	10,381	9,436,329	3.693
Minimum fuel value obtained in calorimetric tests by W. L. Watts	9,991	9,081,819	3.554
Sample of Summerland oil (crude), tested by Messrs. Jaffa and Colby	9,688	8,806,392	3.447
Sample of Summerland oil extracted by naphtha, by Messrs. Jaffa and Colby	10,242	9,309,978	3.644

* See analysis of oil from Berryessa Valley, Napa County, Part 10, Chapter 4.

It will be observed that the practical tests in locomotives on the railroad gave a higher fuel value to the petroleum than did the calorimetric tests in the laboratory. This is due to the fact that in a furnace it is possible to obtain a more complete combustion of petroleum than of coal. In the calorimetric tests made by the writer, the petroleum was cut with gasoline, and the fuel value of the gasoline was deducted from the total calorific value. By this method, an estimate was obtained which corresponds to that by "the gasoline cut" in common use among oil-dealers for determining the amount of foreign matter in petroleum.

12.5.11. "The gasoline cut" consists in mixing, in a graduated glass, equal volumes of crude oil and gasoline. The water and foreign matter sink to the bottom of the oil, and the relative amounts of oil and foreign matter may be noted by reading the scale on the side of the graduated glass at the point of contact between the oil and residuum. The residuum at the bottom of the glass consists of earthy matter, water, and sludge, or b. s., as it is known to the trade. In many instances the sludge, or b. s., constitutes several per cent of the sample. It is usually a brown flocculent precipitate, heavier than oil and lighter than water.

The calorific value of sludge was estimated by Messrs. Jaffa and Colby at 4,149 kilogramme calories, or a little more than 40% of the fuel value of the sample of oil, which was dissolved in naphtha. Prof. T. Price, of San Francisco, who has examined samples of sludge from the California oils, states that it is composed principally of asphaltene.

12.5.12. The relative fuel value of coal and Los Angeles oil as shown by combustion in furnaces, is as follows:

The heating furnaces of Los Angeles Steel and Iron Company: One ton Wellington coal equals 2.50 bbls. of oil; for steam purposes, one ton of Wellington coal equals 3 bbls. of oil.

Los Angeles Consolidated Electric Railroad Company: Steam purposes, one ton of Wellington coal equals 3.62 bbls. of oil.

Los Angeles Court House: Steam purposes, one ton of good coal equals 3.10 bbls. of oil.

Southern California Railroad Company: Steam purposes, one ton of Nanaimo coal equals 4 bbls. of oil.

12.5.13. A careful experiment was made by the Western Sugar Refinery on the relative fuel value of Coalinga petroleum and coal, and the following record of it is from a valuable paper by E. H. Denicke of the College of Mining, University of California:

EVAPORATIVE TEST OF COALINGA OIL.

Duration of test	22 hours.
Oil burned	5,233 lbs.
Water evaporated	61,208 lbs.
Temperature of water	67° Fahr.
Steam pressure above atmosphere	90 lbs.
Actual water evaporated per pound of oil	11.69 lbs.
Equivalent evaporation from and at 212°	13.9 lbs.

It was originally intended to run this test four days continuously, but in consequence of poor combustion, due to defective arrangement of boilers, it was decided to stop at the end of twenty-two hours to make alterations. This was the first test of Coalinga oil at the Western Sugar Refinery, and was made under unfavorable conditions, but on the strength of this test the whole method of heating was changed.

STATEMENT OF COAL BURNED IN 1897,

Showing Average Evaporative Efficiency from and at 212° Fahr. Efficiency Figures from Tests Under Boiler No. 22.

Coal.	Tons.	Evaporation from and at 212° F.
Coöperative	8,986	8.88
Duckenfield	2,957	7.37
Nanaimo	9,850	7.29
Wallawah	676	7.70
Greta	9,207	7.56
Teaham	2,591	8.05
Wallsend	1,080	8.88
Total	35,347	Av. 7.88

From this table, obtained from best results, and the foregoing, there has been prepared the following table, which shows a saving of $46,012.15 per year by burning oil. But as it was based on the first test, it is safe to say that the minimum saving over coal is $60,000. This does not take into account wear and tear on boilers and general convenience:

STATEMENT OF COMPARATIVE VALUE OF OIL AND COAL (Based on the first trial test).

Coal. (Basis of 1897.)

Total bituminous coal received during 1897	35,347 tons.
Average evaporation of that coal from and at 212° Fahr.	7.88 lbs.
Total water evaporated on that basis	624,183,481 lbs.
Fireroom cost of handling that coal, reckoning 300 days at $64.26	$19,278 00
Cost of coal for this work on basis of present price—35,347 tons at $6.55	$231,522 85
Total cost of evaporating above quantity of water	$250,800 00

Oil. (Basis of $1.30 per barrel, and 13.9 evaporation.)

Oil necessary to evaporate above quantity of water	152,739 bbls.
Cost of oil, at $1.30	$198,560 70
Fireroom cost of handling that oil—300 days at $20.76	$6,228 00
Total cost of evaporating the above quantity with oil	$204,788 70
Equivalent value per ton of coal on the above basis $\frac{\$204,788.70—\$19,278}{35,347}$	$5 25
Saving on year's work by burning oil under the above conditions	$46,012 15

COMPARATIVE VALUE OF COALINGA OIL WITH DIFFERENT FUELS USED ON THE PACIFIC COAST.

Coal.	Evaporation at and from 212° Fahr.	Value per ton compared with oil at $1 30.
Coöperative Wallsend	8.88	$5 53
Nanaimo	7.29	4 44
Greta	7.56	4 60
Bulli	7.26	4 42
Wallawah	7.70	4 69

This table is made up of average coal tests and compared with oil at \$1.30 per barrel, and an average evaporation from and at 212° of 15.5 pounds. The intermittent demand for steam at the refinery does not allow them to work all of the time on the most economical methods, and instead of a test evaporation of 16.4 pounds, the average evaporation comes to 15.5 pounds. Many tests have been made at the refinery with air-blowing instead of steam, and it has been found cheaper, but as their demand for steam is subject to extreme fluctuations and as air-blowing does not "respond" as quickly as steam-blowing, it is not used under their boilers. It is now used under their kilns and gives great satisfaction. For a plant where the demand for steam is constant, it is much cheaper to use air-blowing. A different kind of a burner must be used; instead of the lip of the nozzle being 1″ wide, as in a steam burner, it must be from 2½″ to 3″ wide, according to the flame desired. Air-blowing does not give as perfect a flame as steam-blowing, because the latter heats the oil and volatilizes it. In using air to blow with, practical tests show that about 15% more air must be added than is necessary for complete theoretical combustion. From the above record it is apparent that one ton of coal having the average fuel value of the coal used in the experiment would have a fuel value equal to about 3.73 bbls. of Coalinga oil having a specific gravity of 0.852, or 34° B.

12.5.14. Mr. A. S. Cooper, California State Mineralogist, who has made a close study of California petroleum, says: "A comparison of the consumption of fuel oil with that of coal shows 3.33 bbls. of fuel oil to be equivalent to one ton of good imported coal. Figuring oil at \$1.40 per bbl., and coal at \$7.50 per ton in San Francisco, it shows the cost of oil to be \$4.66 as against \$7.50 for its equivalent in coal. Moreover, the labor required to operate with coal is far greater than with oil, in most instances being nearly double. The perfect cleanliness of fuel oil and the ease and simplicity of supply and regulation, make it a most desirable substitute for coal. As long as coal remains at \$7.50 per ton in California, it cannot be expected that oil will fall below its present price, not at least for some time to come. In the year 1899 there were 1,740,027 tons of coal imported into the State of California; to supplant this, 6,794,278 bbls. of oil will be required. As the supply becomes more permanent the uses of fuel oil will multiply."

12.5.15. Several years ago, Mr. A. M. Hunt, C.E., of San Francisco, made a very able report on the relative fuel value of petroleum and coal. As compared with Carbon Hill coal, he found that the relative evaporative equivalents were in the following proportions:

Carbon Hill coal	7.6 lbs. of water to 1 lb. of coal.
California petroleum	15 lbs. of water to 1 lb. of oil.

This gives 1.97 to 1 as the ratio of the value of petroleum to the value of Carbon Hill coal.

Mr. Hunt continues: "The following table shows the equivalent prices of oil and Carbon Hill coal, figured on the above ratio of 1.97 to 1 and taking oil as weighing 310 lbs. per barrel, which is the result of a number of determinations:

Based on Relative Evaporative Equivalents.		All Economies Considered.
Oil, per bbl.	Coal, per ton.	Coal, per ton.
$1 00	$3 66	$3 30
1 10	4 03	3 62
1 20	4 40	3 95
1 30	4 77	4 29
1 40	5 14	4 61
1 50	5 51	4 94
1 60	5 87	5 27
1 70	6 23	5 61
1 80	6 59	5 94
1 90	6 95	6 27
2 00	7 21	6 60

"The third column is figured on the basis of the statements made by Dr. Charles B. Dudley in his lecture before the Franklin Institute. He gives the relative evaporating powers of oil and coal as 1.75 to 1, and then remarks as follows:

" 'There are certain chances for economy in burning oil that do not occur with coal. Of these, there have been pretty well worked out, as just stated, economy in handling coal and ashes, and economy in repairs. The amount of these has been obtained in dollars and cents, and is, perhaps, best expressed by saying that, taking all ascertained economies into account, a pound of petroleum is as good as two pounds of coal.' "

12.5.16. The only places where natural gas assumes sufficient importance to be treated as a factor in the mineral statistics of the State are at Stockton, in San Joaquin County, and the City of Sacramento. The yield of natural gas at Stockton during the last three years has been:

	Cubic Feet.	Value.
For 1897	63,920,000	$62,657 00
For 1898	74,424,650	74,424 00
For 1899	102,960,000	84,880 00

In the City of Sacramento the amount of natural gas produced has been as follows:

	Cubic Feet.	Value.
For 1898	12,000,000	$10,000 00
For 1899	12,000,000	10,000 00

12.5.17. In 1893, the writer made a careful investigation as to the fuel value of the natural gas at Stockton. Its fuel value as compared with that of coke and Nanaimo coal showed as follows:

2,000 lbs. coke, carrying 10% ash = 42,500 cubic feet of gas.
2,000 lbs. Nanaimo coal = 38,800 cubic feet of gas.

As stated in Bulletin No. 4 of the California State Mining Bureau, the absolute value of natural gas is considerably in excess of its calorific value. In the Eastern States, the use of natural gas, instead of solid fuel, has been found to effect a saving of nearly 50%, in addition to that arising from the greater cheapness of gas as compared with coal. This economy results from a saving in labor and wear and tear of plant, and from the fact that a more uniform temperature can be secured by the use of gas than by the use of solid fuel.

CHAPTER 6.

REVIEW OF THE PETROLEUM INDUSTRY IN CALIFORNIA.

12.6.1. The existence of petroleum in California has been known for many years. From time immemorial the California Indians used this mineral, in the form of asphaltum, for various purposes. In the early history of the State, the Catholic fathers utilized it for roofing their missions and other buildings.

It is said that in 1855 or 1856, Andreas Pico distilled petroleum on a small scale for the San Fernando Mission. He obtained his crude oil from Pico Cañon near Newhall, in Los Angeles County; and he was probably the first refiner of petroleum in this State. In 1856, a company commenced work at the La Brea ranch in Los Angeles County, and tried to refine the crude oil. In 1857 an attempt was made to produce illuminating oil from crude petroleum, at Carpinteria, in Santa Barbara County; and there are records of similar attempts having been made in other localities previous to 1860, but they were not successful.

12.6.2. The first scientific report on petroleum in California was made by Prof. B. Silliman, who published his researches in 1865. He spoke favorably of the possibility of obtaining petroleum in remunerative quantities in this State, and gave the results of his experiments on the fractional distillation of California petroleum.

12.6.3. The next decade was marked by a considerable oil excitement in California, and a great many companies were formed for the purpose of petroleum mining, and for distilling crude oil.

In most instances, these companies did not meet with success, but it must be remembered that the pioneer oil-miners did not have the drilling machinery of the present day, and that they only possessed a very limited knowledge concerning the geological conditions pertaining to the occurrences of petroleum deposits.

12.6.4. The pioneer distillers appear to have expected that by the fractional distillation of California petroleum they would obtain products similar to those resulting from the fractional distillation of the petroleum found in the Eastern States, but they were disappointed. It is not surprising that in the course of years the smaller operators became merged in larger concerns.

12.6.5. The most remarkable feature in the recent history of the petroleum industry in California is the development of the Los Angeles oil-field; of the Summerland oil-field, in Santa Barbara County; of Coalinga, in Fresno County; and of the Kern River, the Sunset, and the McKittrick districts, in Kern County. A historical sketch of these districts will be found elsewhere in this Bulletin.

12.6.6. In 1887, when the State Mining Bureau made a reconnaissance of the petroleum industry of California, the only companies actually engaged in petroleum mining were: The Pacific Coast Oil Company, in Pico Cañon; the Puente Oil Company, in the Puente Hills, Los Angeles County; the Hardisson & Stewart Oil Company (subsequently incorporated as the Union Oil Company of Ventura County), and McPherson & Co., in Moody Gulch, in Santa Clara County.

12.6.7. In July, 1900, there were about 250 companies producing oil in California, about 1590 producing wells, and about 470 prospect wells.

During the last decade there has been a steady increase in the amount of petroleum produced in California, as is shown by the comparative statement at the end of this chapter.

12.6.8. The first refinery that can be considered a commercial success was that of the California Star Oil Company, which was situated near Newhall, in Los Angeles County, and managed by T. H. Scott. Subsequently, refineries were erected at Alameda, by the Pacific Coast Oil Company, and at Santa Paula by the Union Oil Company. At the present day there are refineries at Los Angeles, Chino, Ventura, Alameda, Terminal Island in Los Angeles County, and at the Sunset oil-district in Kern County; also at Oleum in Contra Costa County, to which place the refinery of the Union Oil Company has been removed.

12.6.9. The following is a comparative statement showing the growth of the petroleum industry in California, from statistics compiled by Chas. G. Yale, statistician of the California State Mining Bureau:

County.	1897.		1898.		1899.	
	Product.	Value.	Product.	Value.	Product.	Value.
Fresno	70,140	$70,840	154,000	$154,000	439,372	$439,372
Kern	----------	----------	10,000	10,000	15,000	13,500
Los Angeles	1,327,011	1,327,011	1,462,871	1,462,871	1,409,356	1,409,356
Orange	12,000	12,000	60,000	60,000	108,077	108,077
Santa Barbara	130,136	130,136	132,217	112,549	208,370	191,288
Santa Clara	4,000	10,000	3,000	6,000	1,500	3,000
Ventura	368,282	368,282	427,000	571,000	496,200	496,200
	1,911,569	$1,918,269	2,249,088	$2,376,420	2,677,875	$2,660,793

PETROLEUM.

Year.	Bbls.	Year.	Bbls.
Prior to 1876	175,000	1888	990,333
1876	12,000	1889	303,220
1877	13,000	1890	307,360
1878	15,227	1891	323,600
1879	19,858	1892	385,049
1880	40,552	1893	470,179
1881	99,562	1894	783,078
1882	128,636	1895	1,245,339
1883	142,857	1896	1,257,780
1884	262,000	1897	1,911,569
1885	325,000	1898	2,249,088
1886	377,145	1899	2,677,875
1887	678,572		

Total .... 14,893,879 bbls.

TABLES OF

FOSSILS REFERRED TO IN THIS BULLETIN.

The fossils mentioned in the following tables have been identified and classified by Dr. J. C. Merriam, of the University of California.

The numbers given in Table I refer to the following localities:

No.	Station.	Sketch-Map. Fig.	Character of Formation.	Locality.
16	--------	--------	Calcareous stratum in shale----	Cañon near Black Star Coal Mine, Santa Ana Mountains.
18, 25	--------	--------	Coal measures------------------	Abandoned coal mine (4 miles S. of Corona), Sec. 12, T. 4 S., R. 6 W., S. B. M., north slope of Santa Ana Mountains.
21	--------	--------	Calcareous stratum in sandstone.	About 5 miles S. W. of Corona, north slope of Santa Ana Mts.

TABLE I.

Cretaceous and Eocene.

	Santa Ana Mountains, South Side.	Santa Ana Mountains, North Side.		
	16	18	21	25
Acteonella (aff.) oviformis	----	----	x	----
Arca (aff.) brewerianus	x	----	----	----
Astarte tuscana	x	----	----	----
Avicula (aff.) pellucida	x	----	----	----
Cinulia mathewsoni	----	x	----	----
Dentalium (?)	----	----	----	x
Dentalium stramineum	----	x	x	----
Dosinia inflata	x	----	----	----
Indet. New	----	x	----	----
Indet. Probably new	x	----	----	----
Notica sp.	----	x	----	----
Nucula truncata	----	x	----	----
Ostrea (?)	----	----	----	x
Pectunculus veatchii (?)	x	----	----	----
Tellina (?)	----	----	----	x
Trigonia sp. indet.	x	----	----	----
Turritella sp.	x	----	----	----
Venus sp.	x	----	----	----

The numbers given in Table II refer to the following localities, as shown on the accompanying sketch-maps:

No.	Station.	Sketch-Map. Fig.	Character of Formation.	Locality.
6	....	G	Whitish sandstone	Piru Creek, Ventura County.
7	....	....	Shale underlying conglomerate.	South side of San Felician Creek, Ventura County.
12, 22, 23	550	B	Whitish sandstone formation ..	Santiago Cañon.
20	551	B	Lower portion of whitish sandstone formation.	Santiago Cañon.
24	....	....	Whitish sandstone formation ..	S. E. cor. Sec. 12, T. 4 S., R. 6 W., S. B. M., south slope of Santa Ana Mountains.
31	....	F	Whitish sandstone formation ..	S. Joaquin Peak, Orange County.
32	....	M	....	Tar Cañon, Avenal oil-field, Kreyenhagen district, Kings County.

TABLE II.

Miocene or Lower Neocene (California equivalent: Monterey Group).

	Santiago Cañon.	Piru Creek and Vicinity.	San Joaquin Valley.
Ostrea tayloriana. Cited as Miocene by Gabb	----	6	----
Fiscus sp. indet. Probably new	----	7	----
Ostrea sp. indet.......................................	12	----	----
Pecten n. sp.	12	----	----
Balanoid barnacle......................................	20	----	----
Cardium sp.	20	----	----
Shark's tooth..	20	----	----
Ostrea sp..	22	----	----
Turritella ocoyana (?).................................	22	----	----
Zirphæa sp...	22	----	----
Turritella ocoyana	23	----	32
Turritella variata.....................................	23	----	----
Mytilus sp. (?)..	24	----	----
Ostrea	24	----	----
Turritella ocoyana	24	----	----
Pecten, like cerrosensis. Possibly new	31	----	----
Pecten n. sp.	31	----	----

The numbers given in Table III refer to the following localities, as shown in the accompanying sketch-maps:

No.	Station.	Sketch-Map. Fig.	Character of Formation.	Locality.
1, 7	----	----	Light-colored shale underlying conglomerate.	San Felician Creek, Piru, Ventura County.
2	----	G	Conglomerate	Five miles N. E. of Camulos, Ventura County.
3	----	G	Fine conglomerate and coarse sandstone.	One mile N. of Camulos, Ventura County.
4	----	G	Coarse conglomerate	One mile N. of Camulos, Ventura County.
8	----	G	Conglomerate	Mt. Olivette, Piru.
33	----	G	Conglomerate	East side of Piru Creek, near R. R. bridge.
15	540	B	Conglomerate	Foothills, Santa Ana Mts.
29	----	----	Sandstone and shale	T. 3 N., R. 17 W., S. B. M., Simi Valley, Ventura County.
30	25	A	Calcareous stratum in bituminous shale.	Brea Cañon, Puente Hills.
37, 38, 39	----	A	Shale and sandstone immediately underlying conglomerate.	About one mile E. of Chandler wells, Puente Hills.
40	----	A	----	Bank of creek about one mile N. of Chandler wells, Puente Hills.

TABLE III.

Middle Neocene (California equivalent: San Pablo Group).

	Puente Hills.				Piru Creek and Vicinity.					Other Localities
	15	30	38	40	1	2	3	4	33	
Arca n. sp. (*a*)	x	x	----	----	----	x	----	x	---	----
Arca (cf.) sulcicosta	----	x	----	----	----	----	----	----	----	----
Acila castrensis	----	----	----	----	----	----	----	x	----	----
Balanoid casts	x	----	----	----	----	----	----	----	----	----
Bittium asperum (?)	----	x	----	----	----	----	----	----	----	----
Bison, horn of, n. sp.	----	----	----	x	----	----	----	----	----	----
Bulloid n. sp.	----	----	----	----	----	----	x	----	----	----
Cancellaria n. sp. (*a*)	----	----	x	----	----	x	----	----	----	----
Cancellaria n. sp. (*b*)	----	x	x	----	----	----	----	----	----	----
Cardium sp. indet.	----	----	----	----	----	x	----	---	----	----
Chlorostoma sp.	----	----	----	----	----	----	x	----	----	----
Chrysodomus n. sp. (*a*)	x	----	----	----	----	x	----	----	----	----
Chrysodomus n. sp. (*b*)	----	x	x	----	----	----	x	x	----	- --

TABLE III—Continued.

	Puente Hills.				Piru Creek and Vicinity.					Other Localities
	15	30	38	40	1	2	3	4	33	
Chrysodomus (cast) sp. indet.									x	
Chrysodomus sp. indet.		x								
Clementia subdiaphana							x			
Clementia subdiaphana (?) cast								x		
Conus sp. indet. Probably new			x							
Conus californicus (?)									x	
Conus californicus		x				x				
Conus (cast) sp. indet.							x			
Corbula n. sp.							x			
Crepidula sp. indet.			x							
Dentalium sp. indet. Possibly new		x								
Dosinia sp. ponderosa (?)							x			
Dosinia sp.		x								
Drillia sp. Probably new			x							
Echinarachinus, near excentricus					x					
Fish vertebræ					x					
Fusus ambustus								x		
Hinnites, near giganteus. Possibly new			x							
Indet. Probably new								x		
Indet. Probably new									x	
Indet. Possibly new							x			
Indet. New		x								
Indet. Probably new									x	
Leda cælata						x	x			
Lucina sp.		x								
Lucina sp. Probably new						x				
Lucina nuttalli		x								
Lucina richthofeni		x								
Lutricola alta (?)								x		
Macoma, near secta					x					
Macoma secta						x				
Mammal bones (fragments)						x				
Mangelia (conf.) variegata		x								
Mangelia sp. Probably new							x			
Muricidea incisa		x								
Nassa californica						x				
Nassa indet.					x					
Nassa perpinguis		x								
Natica sp. indet.						x				
Natica (Lunatia) lewisii	x						x	x		
Natica (Neverita) recluziana		x								
Natica (Neverita) (aff.) recluziana			x							
Nucula n. sp.								x		
Nucula sp. Probably new							x			

TABLE III—Continued.

	Puente Hills.				Piru Creek and Vicinity.					Other Localities
	15	30	38	40	1	2	3	4	33	
Olivella bœtica	----	x	----	----	----	----	----	----	----	----
Operculum, probably of Pachypoma n. sp. (*a*)	x	----	----	----	----	----	----	----	----	----
Ostrea sp. indet. (*a*)	----	37	----	----	----	----	----	----	----	----
Ostrea sp. indet. (*a*)	----	39	----	----	----	----	----	----	----	----
Ostrea sp., like (*a*)	----	----	----	----	8	----	----	----	----	----
Ostrea sp.	----	x	----	----	----	----	----	----	----	----
Ostrea veatchii (?)	----	----	----	----	----	----	----	x	----	29
Ostrea veatchii (?)	----	----	----	----	----	----	----	x	----	----
Pachypoma n. sp. (*a*)	----	----	----	----	----	x	----	----	----	----
Pachypoma, probably n. sp. (*a*)	----	----	----	----	x	----	----	----	----	----
Patelloid sp. indet.	----	----	----	----	----	----	----	----	x	----
Pecten cerrosensis (?)	----	----	----	----	----	----	x	x	----	----
Pecten indet.	----	----	----	----	x	----	----	----	----	----
Pecten meekii	----	----	----	----	x	----	----	----	----	----
Pecten indet.	----	----	x	----	----	----	----	----	----	----
Pecten sp.	----	x	----	----	----	----	----	----	----	----
Priene oregonensis	----	----	----	----	----	----	----	x	----	----
Priene (aff.) oregonensis	----	----	x	----	----	----	----	----	----	----
Ranella californica	----	----	x	----	----	----	----	----	----	----
Solen indet.	----	----	----	----	----	----	----	----	x	----
Solen sicarius	----	x	----	----	x	----	----	----	----	----
Tapes sp. indet.	----	----	----	----	----	----	----	----	x	----
Tapes tenerrima	----	x	----	----	----	----	----	----	----	----
Trochita n. sp.	----	x	----	----	----	----	----	----	----	----
Trochita sp. indet.	----	----	----	----	----	----	----	----	x	----
Trochita sp. indet.	----	----	x	----	----	----	----	----	----	----
Turritella n. sp. (*a*)	----	----	----	----	----	x	----	----	----	----
Turritella cooperi	----	x	----	----	----	----	----	----	----	----
Venericardia borealis	----	x	----	----	----	----	----	----	----	----
Vola sp. indet.	----	----	----	----	----	----	----	----	x	----
Yoldia lanceolata	----	----	----	----	----	----	x	----	----	----

The fossils in Table IV were obtained from a shallow well at San Juan Capistrano, Orange County:

TABLE IV.

Pliocene or Upper Neocene (California equivalent: Merced Group).

Arca (cf.) sulcicosta.
Crepidula excavata (?).
Indet. Possibly new.
Indet. Possibly new.
Nassa mendica.
Natica (near clausa).
Ostrea sp. Probably new.
Leda sp. Probably new.
Turritella cooperi.
Venericardia borealis.
Vola sp. indet.

The numbers in Table V refer to the following localities, as shown in the accompanying sketch-maps:

No.	Station.	Sketch-Map. Fig.	Character of Formation.	Locality.
5			Auriferous conglomerate	Cook Gold Mine, San Felician Creek, Ventura County.
9, 10		F	Upper oil-sand and sandstone	West side of inner bay, Newport, Orange County.
14, 19		F	Diatomaceous shale & sandstone	Newport, Orange County.
32			From a depth of between 920′ and 1320′.	In a well at Bell Station, Terminal R. R., L. Angeles County.
34		E	Sandstone	Shore-line, San Pedro.
35		E	Lower stratum of sandstone	Dead Man's Island, San Pedro.
36		E	Upper stratum of sandstone	Dead Man's Island, San Pedro.
26			From a depth of 496′	In a well on a ranch of L. Pelanconi, Sepulveda Station, Los Angeles County.

TABLE V—Quaternary Fossils.

	Newport Bay.				San Pedro Peninsula.			Other Localities
	9	10	14	19	34	3	36	
Amiantis callosa								32
Amycla carinata					x	x	x	
Amycla tuberosa						x		
Anomia sp. indet.								32
Anomia lampe			x					
Bittium asperum		x						
Bittium asperum							x	
Bryozoan remains	x							
Cardium sp. indet.					x			
Cardium panamense			x					
Chama sp.			x					
Chama sp.						x		
Chione simillima			x	x		x		
Chione succincta			x					
Chlorostoma funebrale					x			
Clementia subdiaphana						x		
Conus californicus					x		x	
Crepidula adunca	x				x			
Crucibulum spinosum			x					
Cryptomya (aff.) californica							x	
Cryptomya californica					x			
Cumingia californica						x	x	
Dentalium preposium						x		
Drillia sp.						x		
Drillia (cf.) torosa					x			
Drillia (cf.) moesta					x			
Echinoid plates (E. excentricus?)								32
Equus hoof								26
Equus tooth								5
Fusus ambustus					x			
Indet.	x							
Lucina borealis						x		

TABLE V—Continued.

	Newport Bay.				San Pedro Peninsula.			Other Localities
	9	10	14	19	34	35	36	
Lucina californica	x					x		
Lucina nuttalli						x	x	
Macoma inquinata	x		x		x	x	x	
Macoma nasuta					x			32
Monoceros engonatum	x				x			
Myurella (aff.) simplex								32
Nassa cooperi					x	x		
Nassa fossata	x				x	x	x	
Nassa mendica					x		x	
Nassa perpinguis	x				x	x	x	
Natica (Neverita) recluziana				x	x			
Natica (Lunatia) lewisii (?)					x		x	32
Ocinebra interfassa (?)						34		
Olivella biplicata	x				x	x	x	
Olivella bœtica					x			32
Olivella intorta							x	
Ostrea sp.			x		x	x		
Pecten æquisulcatus			x			x		
Pecten caurinum (?)						x	x	
Pecten sp.	x							
Petricola carditoides	x				x		x	
Pholadidea (aff.) ovoidea					x			
Placunanomia macroschisma (?)			x					
Platyodon cancellatum		x						
Pomaulax undosus (operculum)			x					
Pomaulax undosus				x				
Raeta undulata								32
Saxidomus gracilis							x	
Saxidomus gracilis (?)						x		
Schizothærus nuttalli					x			
Serpulorbis squamigerus							x	
Solecurtus californianus						x		
Solen sicarius						x		
Standella (aff.) planulata					x	x	x	
Surcula carpenteriana					x			
Tapes staminea	x		x		x	x	x	
Tellina bodegensis							x	
Tornatella sp.								32
Turritella cooperi					x	x		
Turritella cooperi var. nov.							x	
Turritella jewettii							x	
Venericardia borealis							x	
Zirphæa orispata			x					

INDEX.

*For wells in Los Angeles, Summerland, and Kern River oil-fields, see lists on pages 63, 103, and 115 respectively.

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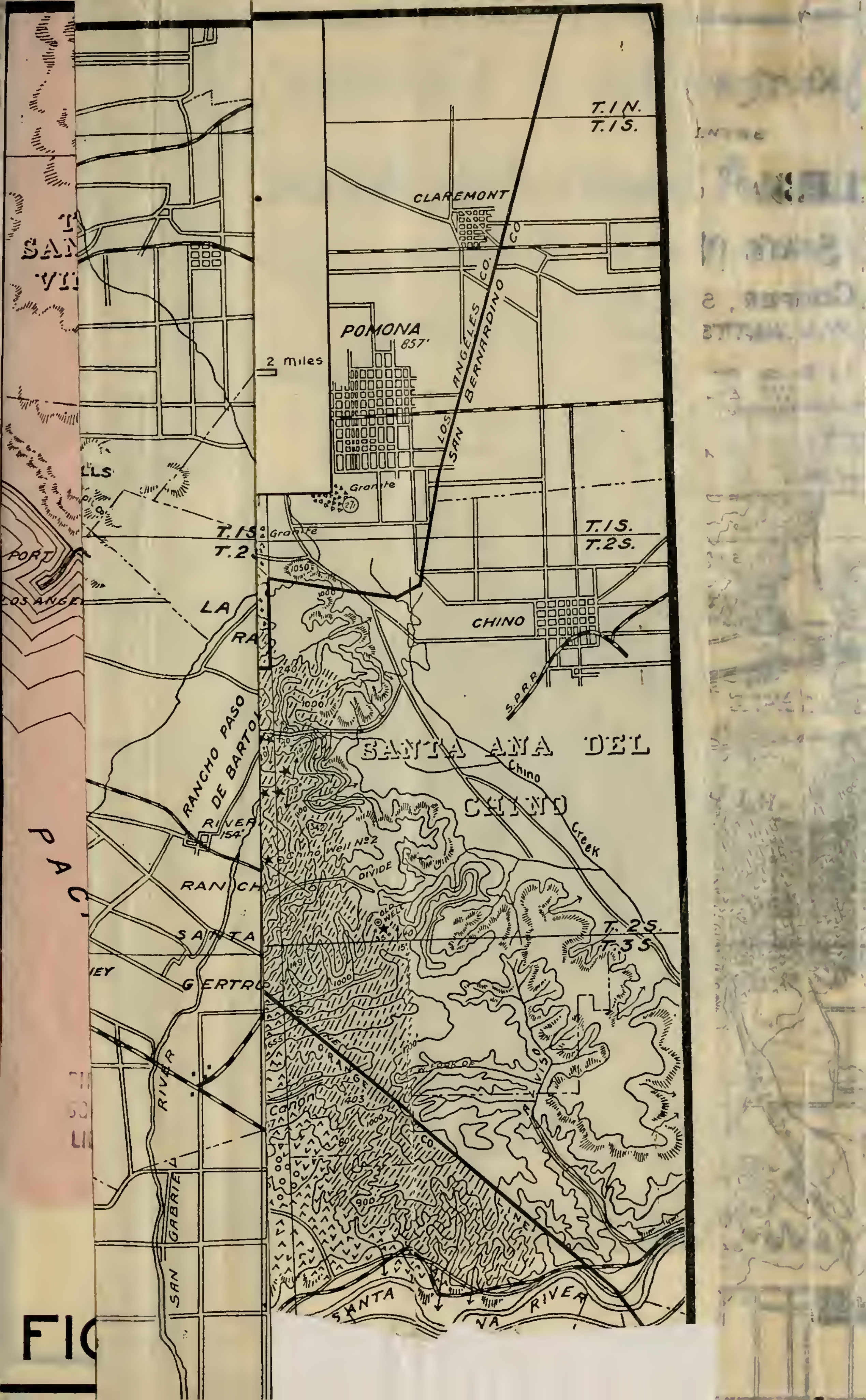

T.1N.
T.1S.
CLAREMONT
POMONA
857'
2 miles
LOS ANGELES
SAN BERNARDINO
CO.
Granite
T.1S.
T.2S.
CHINO
S.P.R.R.
LA
RANCHO PASO DE BARTOLO
RIVER
154'
SANTA ANA DEL CHINO
Chino Creek
Chino Well No 2
DIVIDE
OLD WELL
T.2S.
T.3S.
SANTA
GERTRU
ORANGE CO.
LINE
Canon
SAN GABRIEL RIVER
SANTA ANA RIVER
PORT
LOS ANGEL
PAC

FI

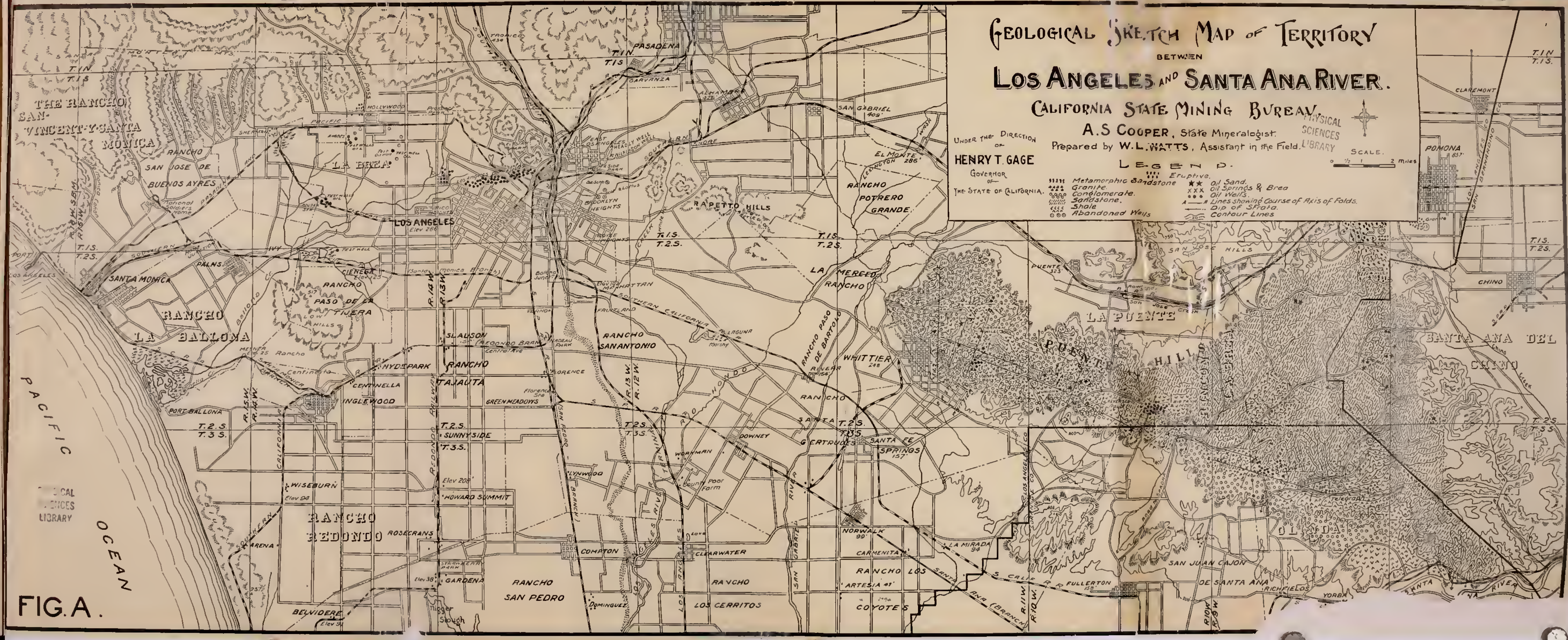

GEOLOGICAL SKETCH MAP OF TERRITORY
BETWEEN
LOS ANGELES AND SANTA ANA RIVER.
CALIFORNIA STATE MINING BUREAU.
A.S COOPER, State Mineralogist.
Prepared by W.L.WATTS, Assistant in the Field.
UNDER THE DIRECTION OF
HENRY T. GAGE
GOVERNOR OF THE STATE OF CALIFORNIA.
LEGEND.
Metamorphic Sandstone
Granite.
Conglomerate.
Sandstone.
Shale
Abandoned Wells
Eruptive.
Oil Sand.
Oil Springs & Brea
Oil Wells.
Lines showing Course of Axis of Folds.
Dip of Strata.
Contour Lines
SCALE.
2 Miles
PACIFIC OCEAN
LOS ANGELES
PASADENA
GARVANZA
ALHAMBRA
SAN GABRIEL
HOLLYWOOD
LA BREA
THE RANCHO SAN VINCENT-Y-SANTA MONICA
RANCHO SAN JOSE DE BUENOS AYRES
SANTA MONICA
PALMS
CIENEGA
RANCHO PASO DE LA TIJERA
RANCHO LA BALLONA
PORT BALLONA
INGLEWOOD
CENTINELLA
HYDE PARK
RANCHO TAJAUTA
SLAUSON
FLORENCE
GREEN MEADOWS
RANCHO SANANTONIO
DOWNEY
RAPETTO HILLS
RANCHO POTRERO GRANDE
EL MONTE
LA MERCED RANCHO
WHITTIER
RANCHO PASO DE BARTOLO
SANTA FE SPRINGS
RANCHO SANTA GERTRUDES
NORWALK
CARMENITA
LA MIRADA
RANCHO LOS COYOTES
ARTESIA
FULLERTON
PUENTE
LA PUENTE
PUENTE HILLS
SAN JOSE HILLS
POMONA
CLAREMONT
CHINO
SANTA ANA DEL CHINO
SAN JUAN CAJON DE SANTA ANA
OLINDA
RICHFIELDS
YORBA
SANTA ANA RIVER
COMPTON
CLEARWATER
RANCHO LOS CERRITOS
RANCHO SAN PEDRO
DOMINGUEZ
GARDENA
RANCHO REDONDO
ROSECRANS
WISEBURN
HOWARD SUMMIT
SUNNYSIDE
BELVIDERE
ARENA
LYNWOOD
WORKMAN
County Poor Farm
PHYSICAL SCIENCES LIBRARY

FIG. A.

GEO

A PO

SAN

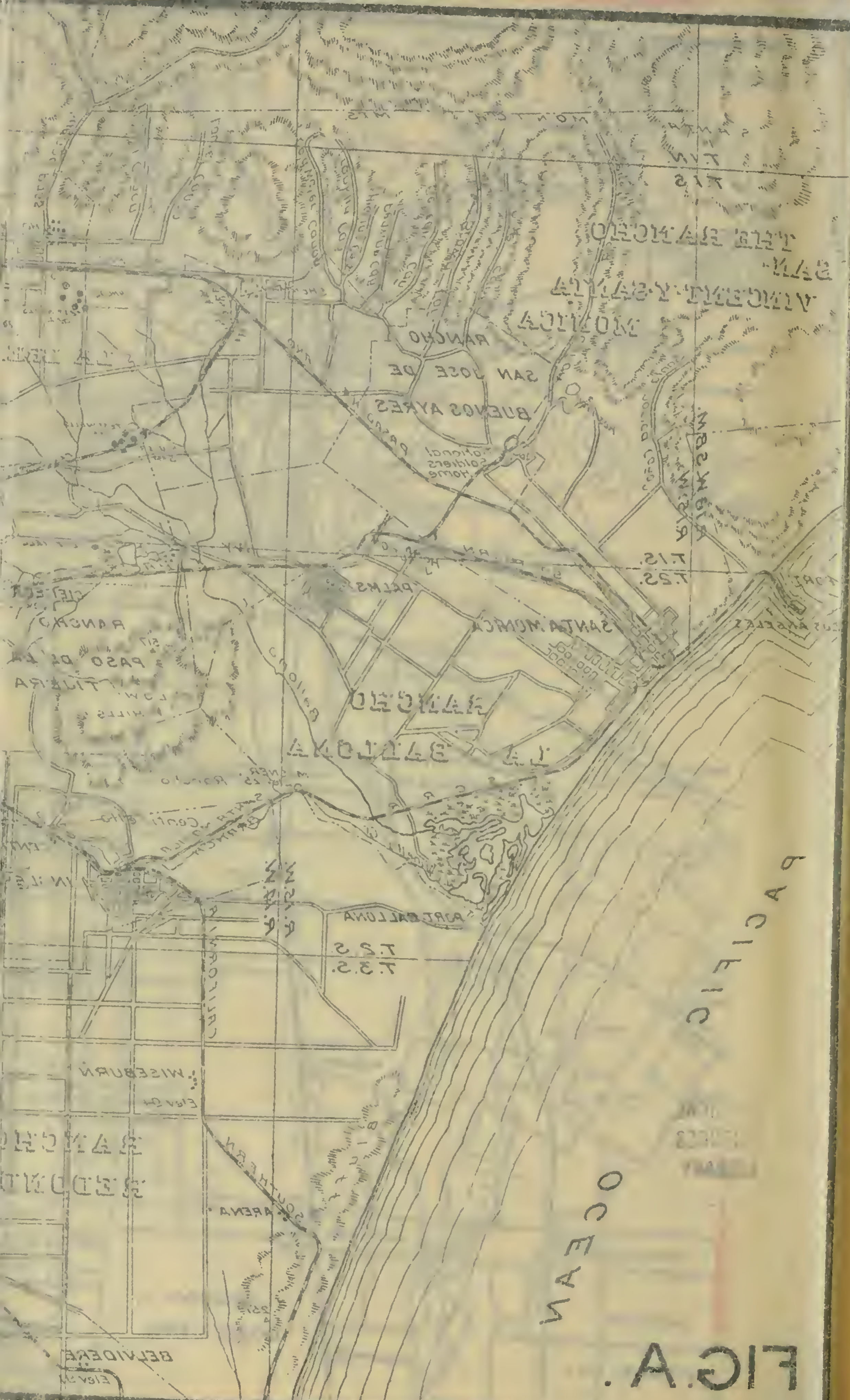
CALIFO

A.S

F

HI

GOVERNO



THE RANCHO SAN VICENTE Y SANTA MONICA
RANCHO SAN JOSE DE BUENOS AYRES
National Soldiers Home
SANTA MONICA
PALMS
RANCHO LA BALLONA
RANCHO PASO DE LA CIENEGA
PORT BALLONA
T.1S.
T.2S.
T.2.S
T.3.S.
WISEBURN
ARENA
BELVIDERE
PACIFIC OCEAN

FIG. A.


GEO
A PO
SAN
CALIF
A.S
HI
GOVERNO

FIG. B.

Geological Sketch Map of a Portion of Foothills of Santa Ana Mountains

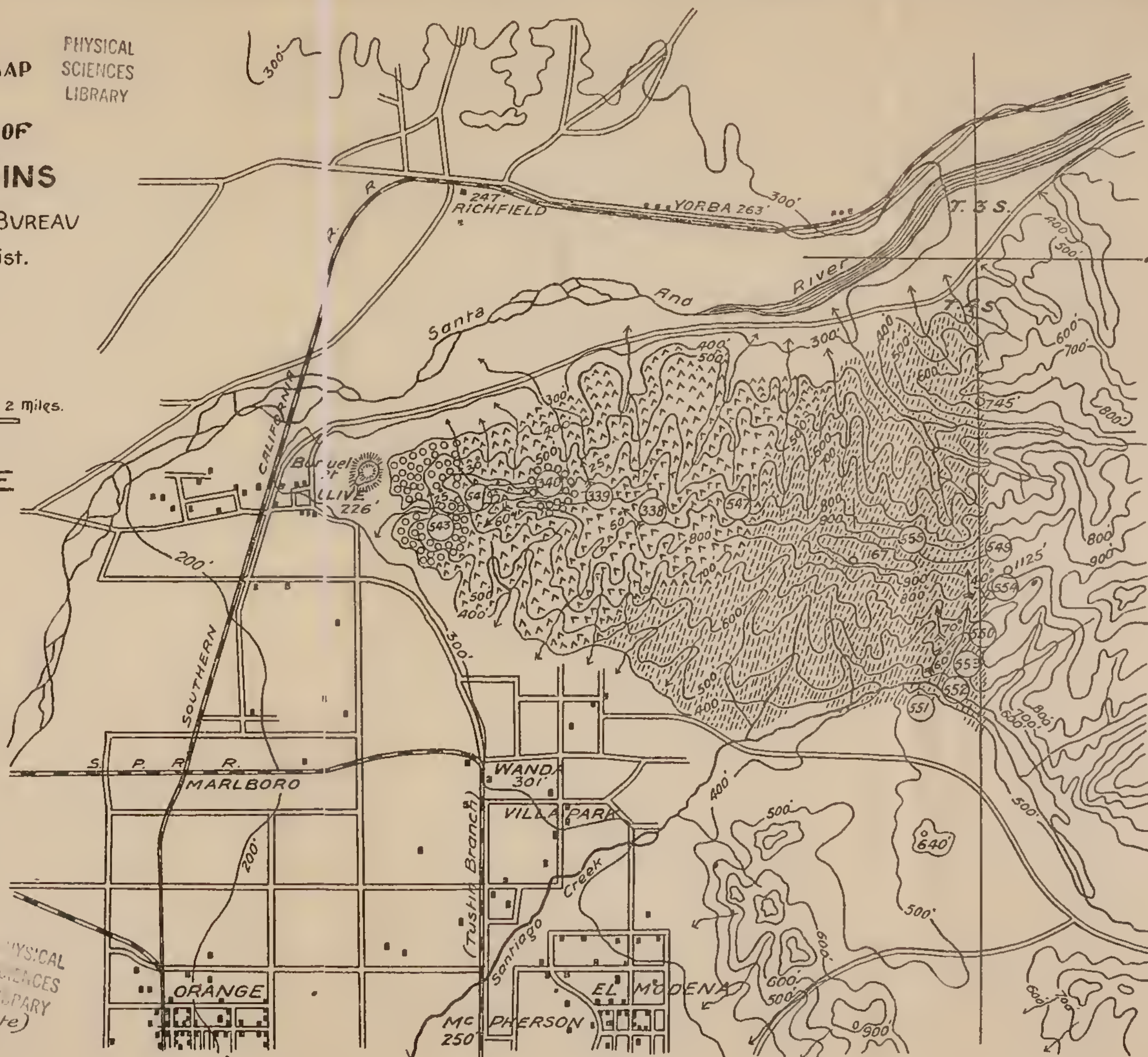
CALIFORNIA STATE MINING BUREAU

A.S. COOPER, State Mineralogist.

Prepared by W. L. WATTS.
Assistant in field.

SCALE:
0 ½ 1 1½ 2 miles.

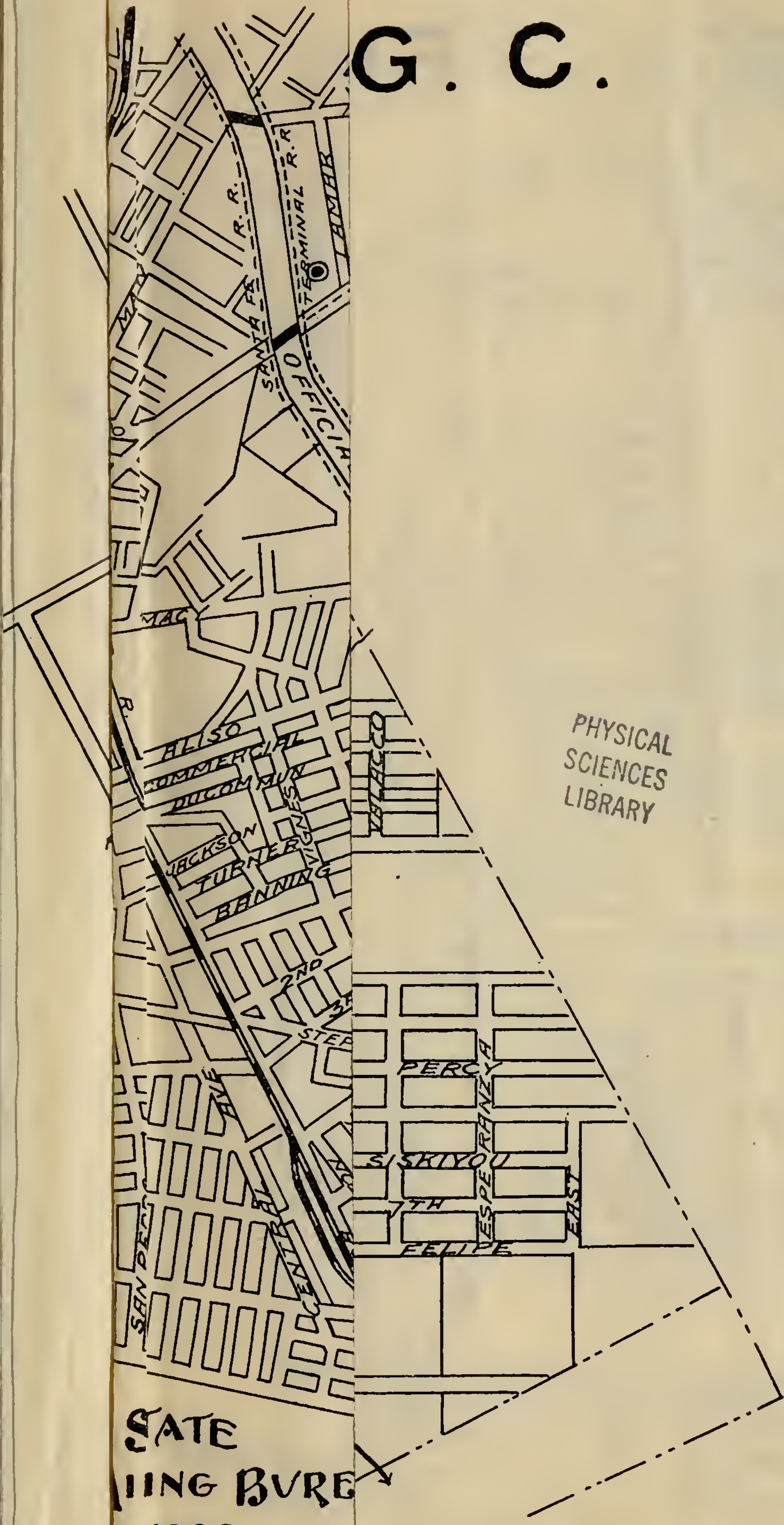
UNDER THE DIRECTION OF
HENRY T. GAGE
GOVERNOR OF THE STATE OF CALIFORNIA.



LEGEND:

- Roads
- Railroads.
- Contour Lines
- Station
- Dip of Strata
- Sandstone Formation
- Shales - (Brown & White)
- Conglomerate "

G. C.



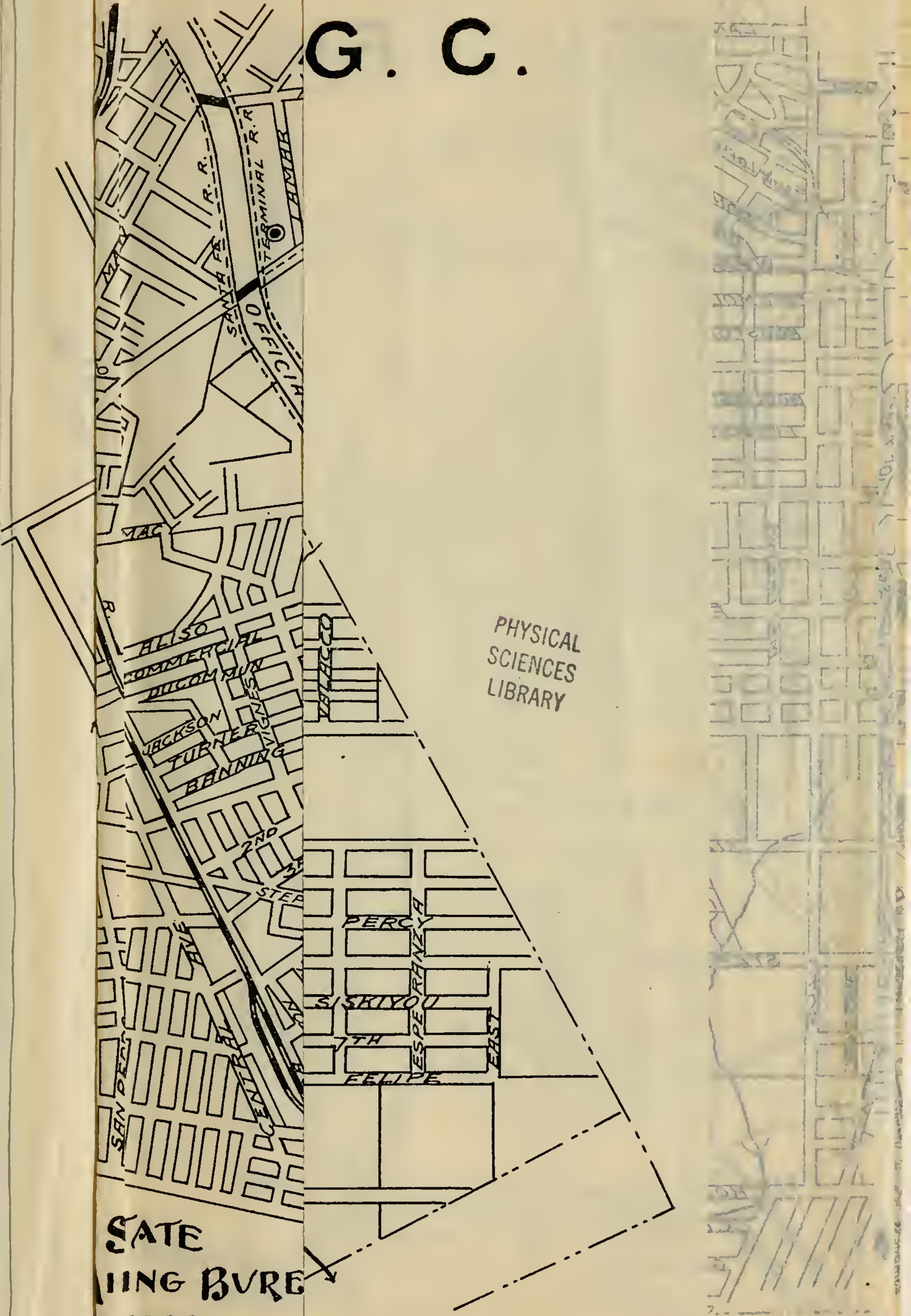
SATE

IING BVRE

·1900.

orf the State of

G. C.



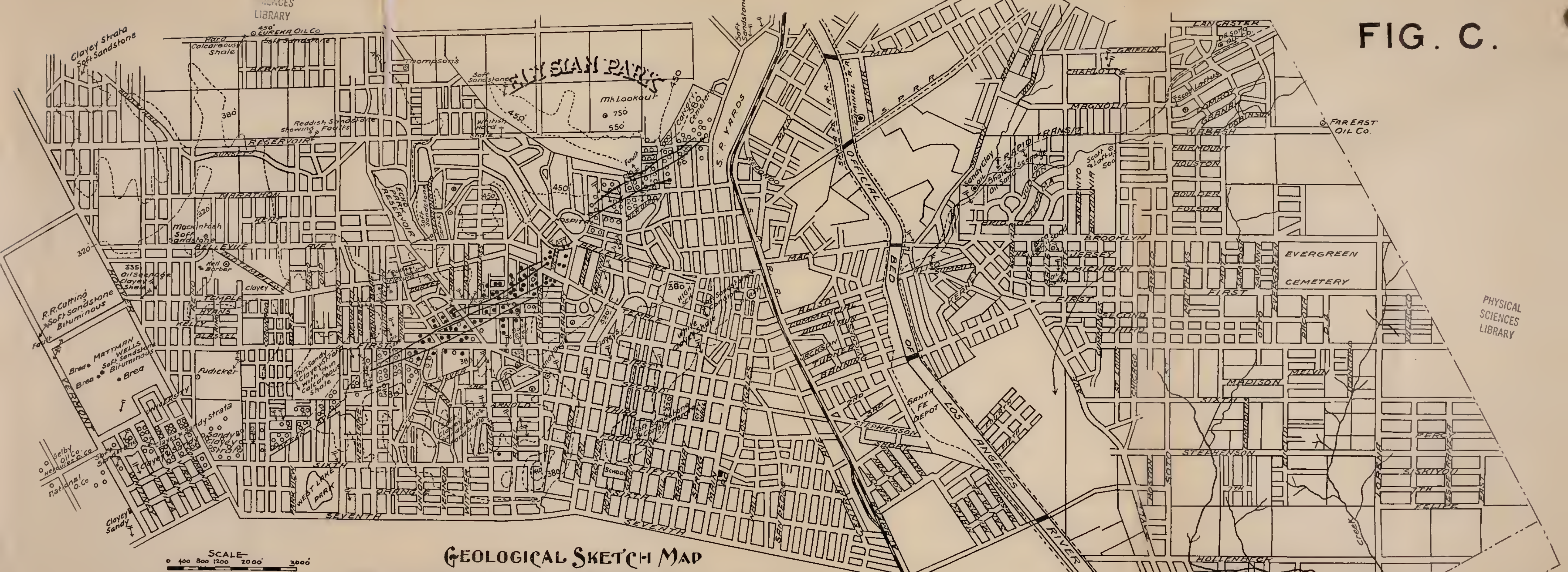
SATE

IING BVRE

·1900.

orf the State of

FIG. C.



- ◉ Abandoned Wells.
- ● Old Wells. o Wells drilled since 1896.
- ⟵ Dip of Formation

GEOLOGICAL SKETCH MAP
LOS ANGELES OIL FIELDS

CALIFORNIA STATE MINING BUREAU

A. S. COOPER, State Mineralogist

Prepared by W. L. WATTS, Assistant in Field. 1898 - 1900.

Under the Direction of HENRY T. GAGE, Governor of the State of California.

FIG. D.

GEOLOGICAL SKETCH MAP (No. 2.) LOS ANGELES OIL FIELD

CALIFORNIA STATE MINING BUREAU - A. S. COOPER, State Mineralogist.

Accompanying Report of W. L. WATTS.

Under the direction of HENRY T. GAGE, Governor of the State of California.


R.13W.
DRUM BARRACKS
THENARD JUNCTION
S.P.R.R.
WILMINGTON LAGOON
S.P.R.R.
TERMINAL
(Rattlesnake)
TERMINAL R.R.
L.A.
SAN PEDRO BAY
SAN PEDRO
15°
Timms pt
Soft Sandstone resting nonconformably on hard Calcareous Strata
DEADMAN ISLD
North
LEGEND:—
Contour Lines.
Railroads.
Public Roads.
Private Roads.
Station.
Dip of Strata.
Abandoned Wells.
Oil Sand.


R.13W.
DRUM
BARRACKS
THENARD
JUNCTION
S. P. R. R.
31'
RO
WILMINGTON
S. P. R. R.
LAGOON
TERMINAL
(Rattlesnake)
TERMINAL R. R.
L. A.
SAN PEDRO BAY
SAN
PEDRO
15°
Timms
pt
Soft Sandstone resting nonconformably on hard Calcareous Strata
ale
DEADMAN ISLD
North
hale
LEGEND:—
20'
Contour Lines.
Railroads.
Public Roads.
Private Roads.
21
Station.
20°
Dip of Strata.
Abandoned Wells.
Oil Sand.

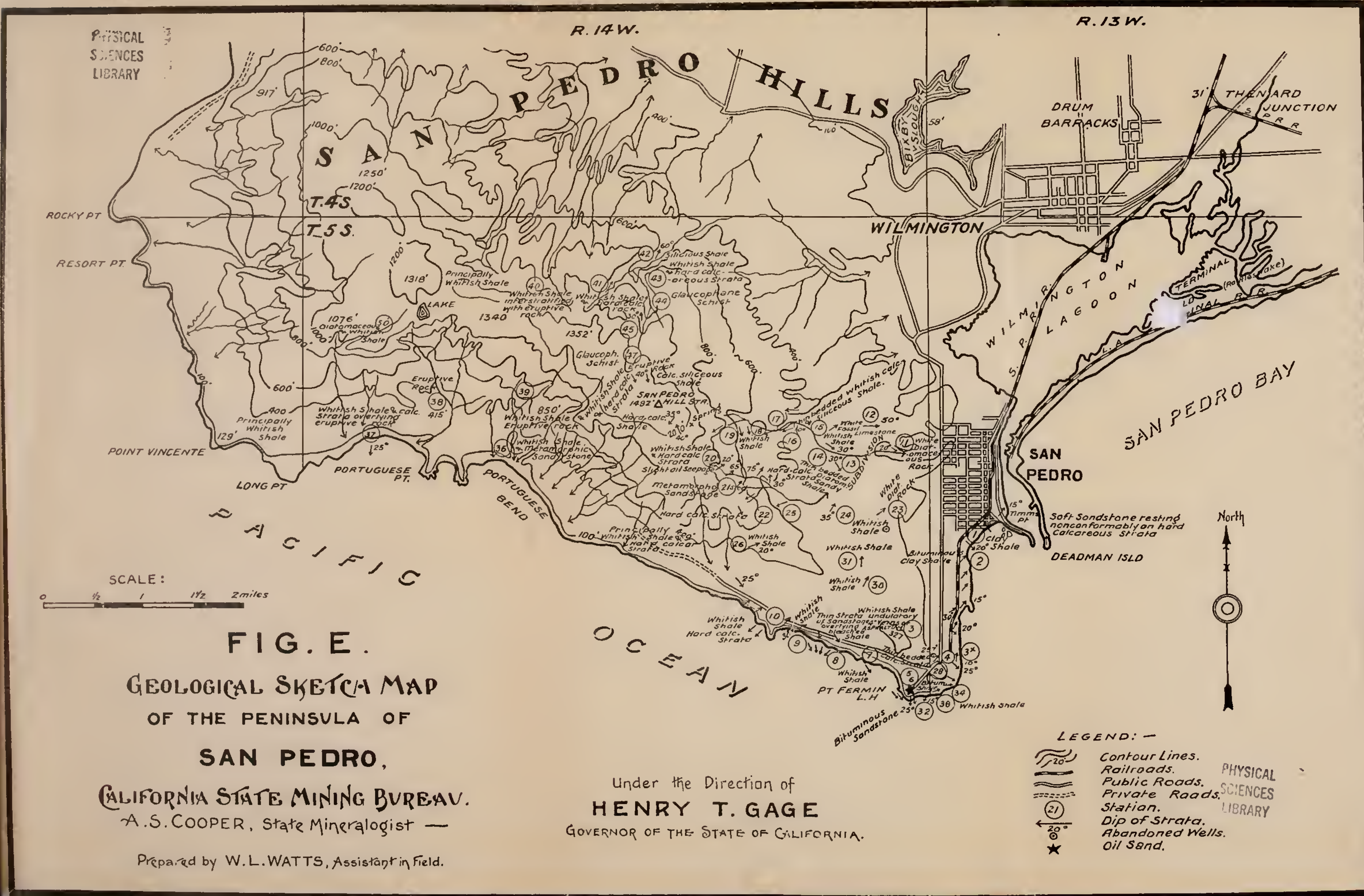


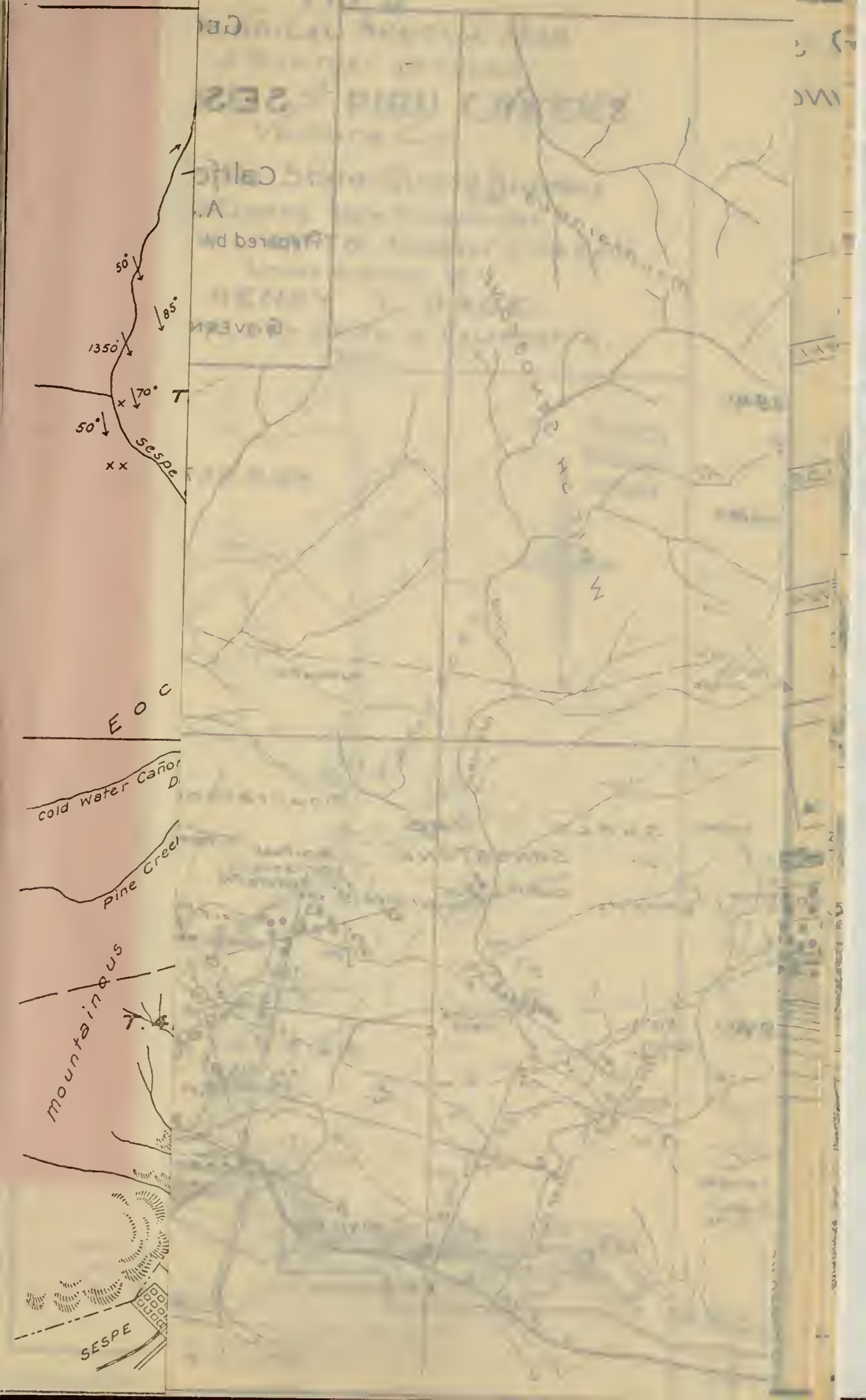
FIG. E.

GEOLOGICAL SKETCH MAP OF THE PENINSULA OF SAN PEDRO,

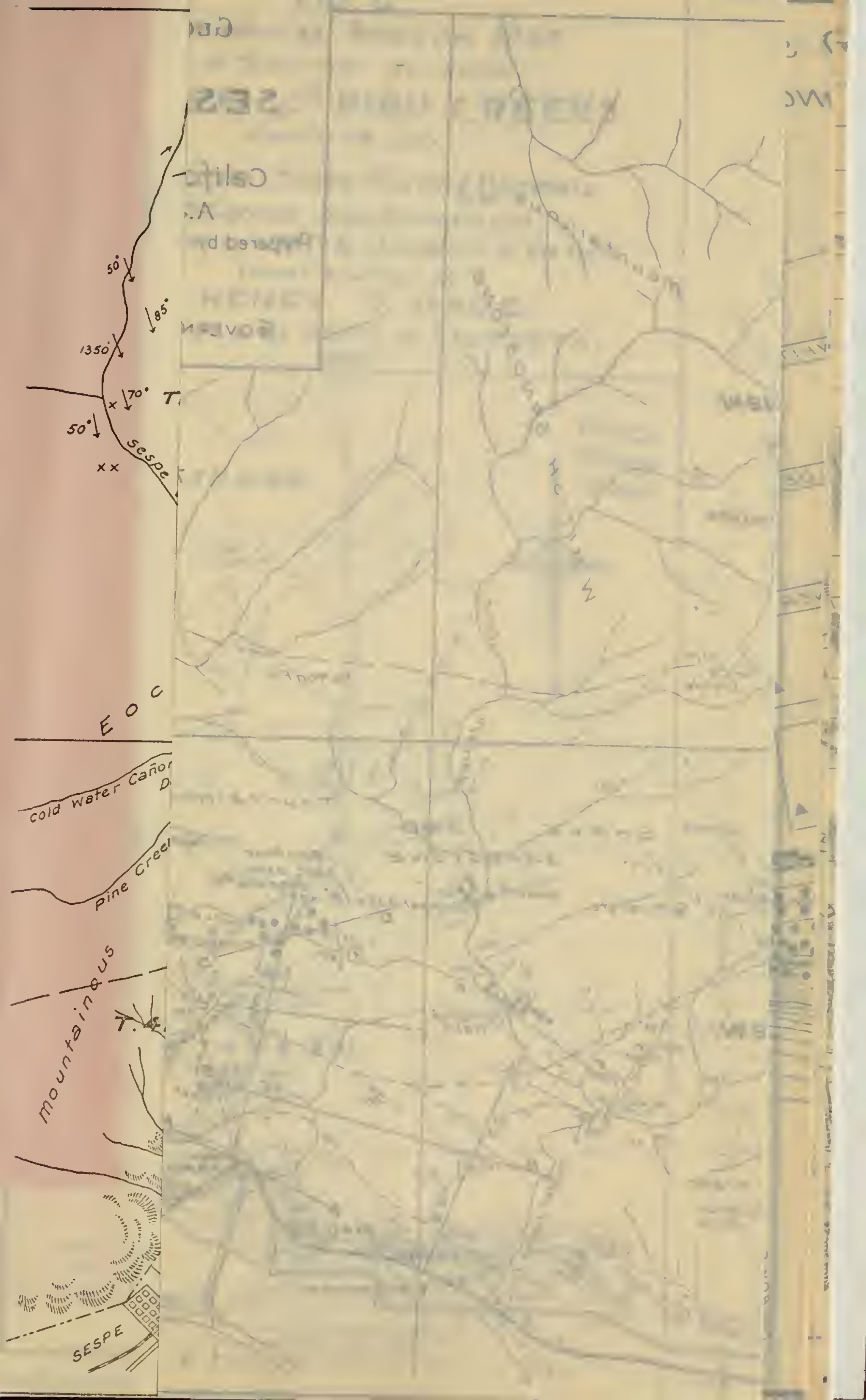
CALIFORNIA STATE MINING BUREAU.
A. S. COOPER, State Mineralogist —

Prepared by W. L. WATTS, Assistant in Field.

Under the Direction of
HENRY T. GAGE
GOVERNOR OF THE STATE OF CALIFORNIA.



50°
85°
1350
70°
50°
Sespe
E O C
Cold Water Cañon
Pine Creek
mountainous
SESPE



50°
85°
1350'
70°
50°
Sespe
E O C
Cold Water Cañon
Pine Creek
mountainous
SESPE

FIG. F.

GEOLOGICAL SKETCH MAP

S. E. PORTION OF ORANGE CO.

CALIFORNIA STATE MINING BUREAU

A. S. COOPER, State Mineralogist.—

Prepared by W. L. WATTS, Assistant in the Field

LEGEND.

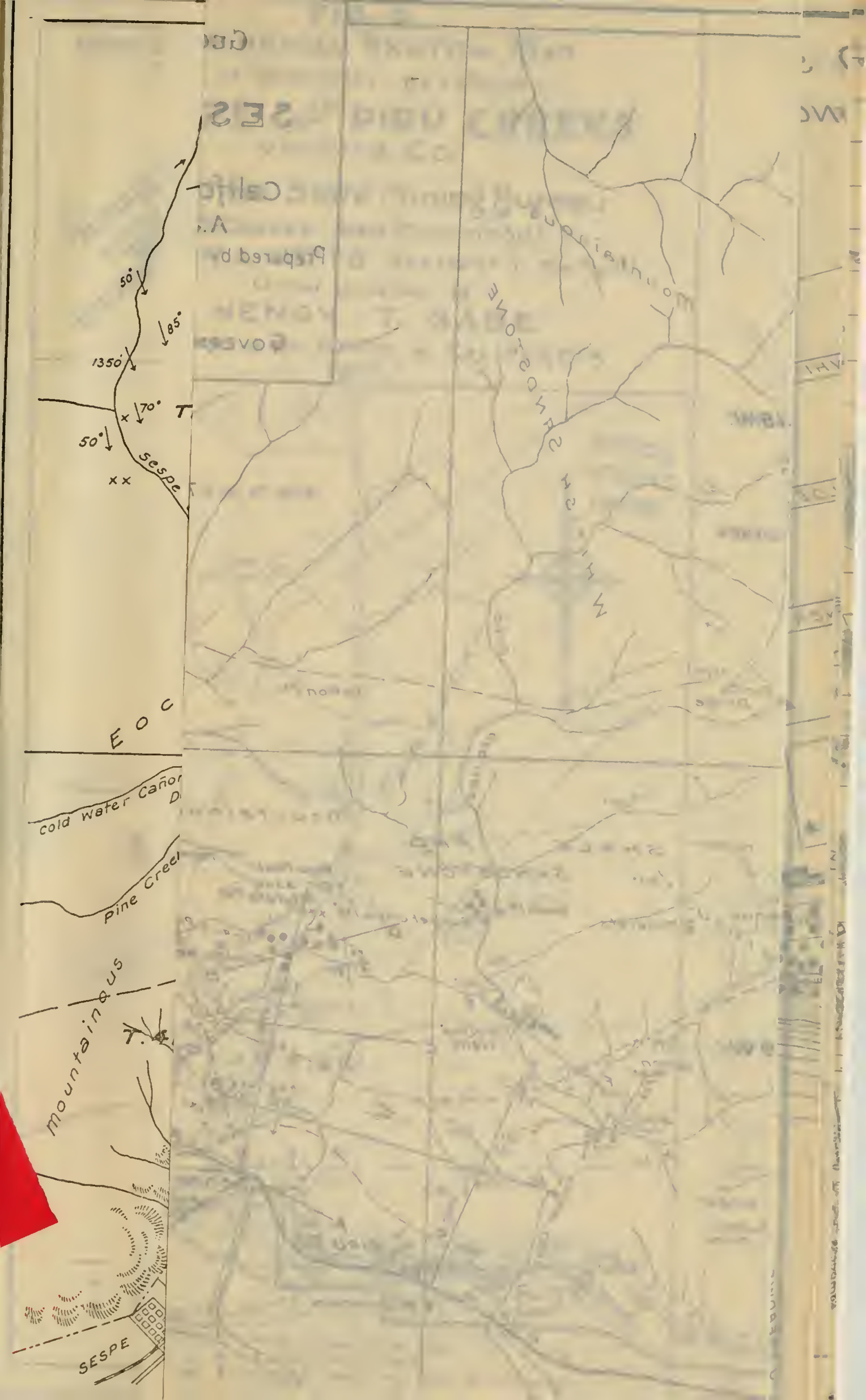
- Conglomerate
- Sandstone
- Shale
- Contour Lines
- Late Pliocene or Quarternary
- Abandoned Wells
- Oil Sand & Springs
- Dip of Strata

Scale: 0 1 2 3 4 5 miles

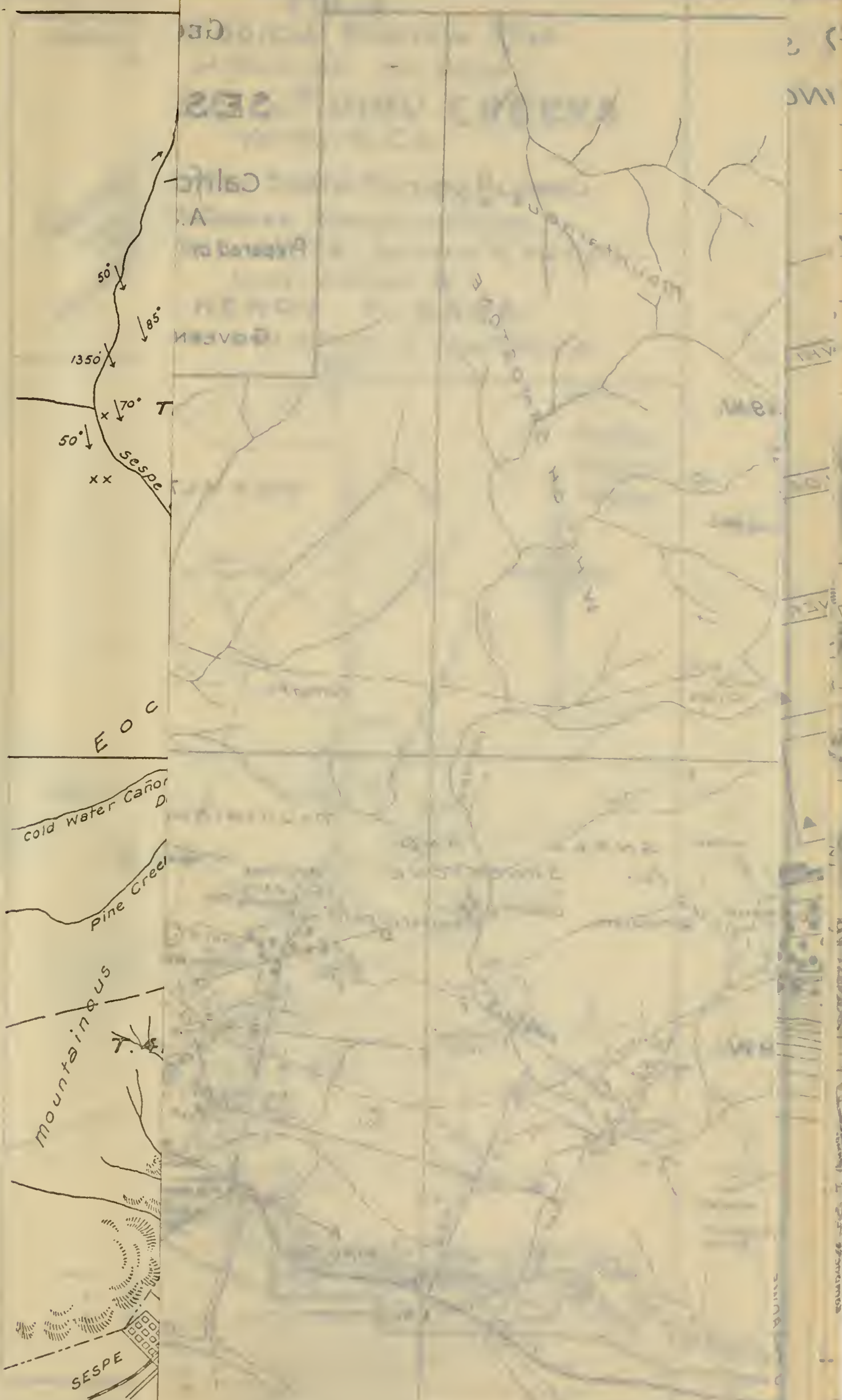
UNDER THE DIRECTION OF

HENRY T. GAGE

GOVERNOR OF THE STATE OF CALIFORNIA

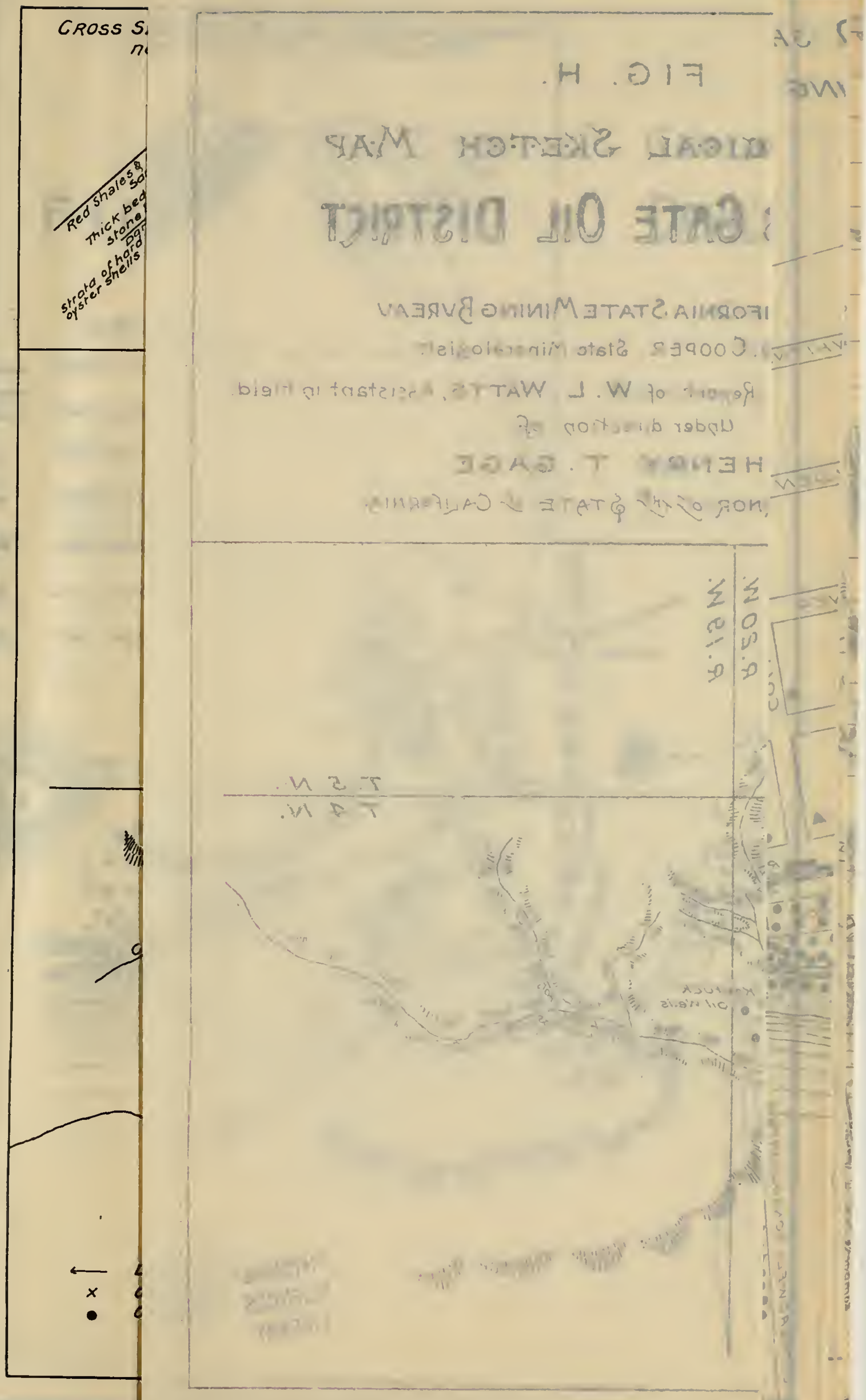


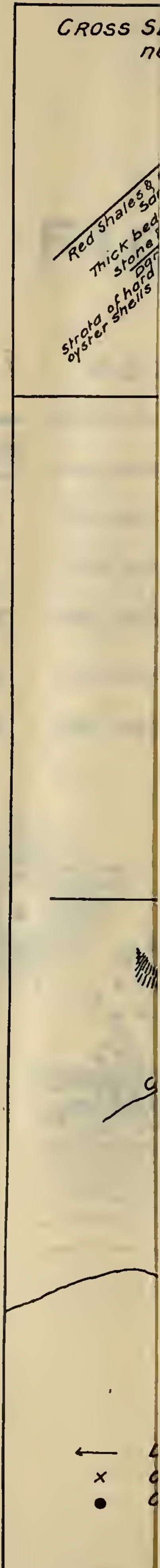
50°
85°
1350'
70°
50°
Sespe
E O C
Cold Water Cañon
Pine Creek
mountainous
SESPE



50°
85°
1350
70°
50°
Sespe
E O C
Cold Water Cañon
Pine Creek
mountainous
SESPE

FIG. 6.
GEOLOGICAL SKETCH MAP
of TERRITORY BETWEEN
SESPE AND PIRU CREEKS
Ventura Co.
California State Mining Bureau
A. S. COOPER, State Mineralogist.
Prepared by W. L. WATTS, Assistant in the field. -
Under direction of
HENRY T. GAGE.
GOVERNOR of the STATE of CALIFORNIA.
1900.


CROSS S
Red Shales &
Thick bed
stone
strata of hard
oyster shells



CROSS S
Red Shales &
Thick bed
stone
strata of hard
oyster shells

FIG. H.

GEOLOGICAL SKETCH MAP

DEVIL'S GATE OIL DISTRICT

CALIFORNIA STATE MINING BUREAU

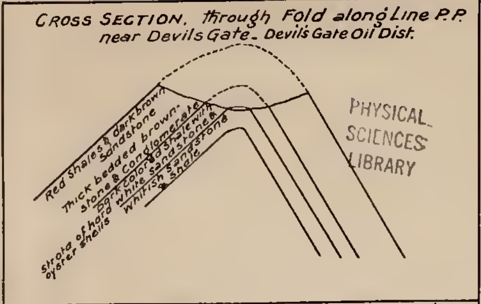
A. S. COOPER, State Mineralogist.

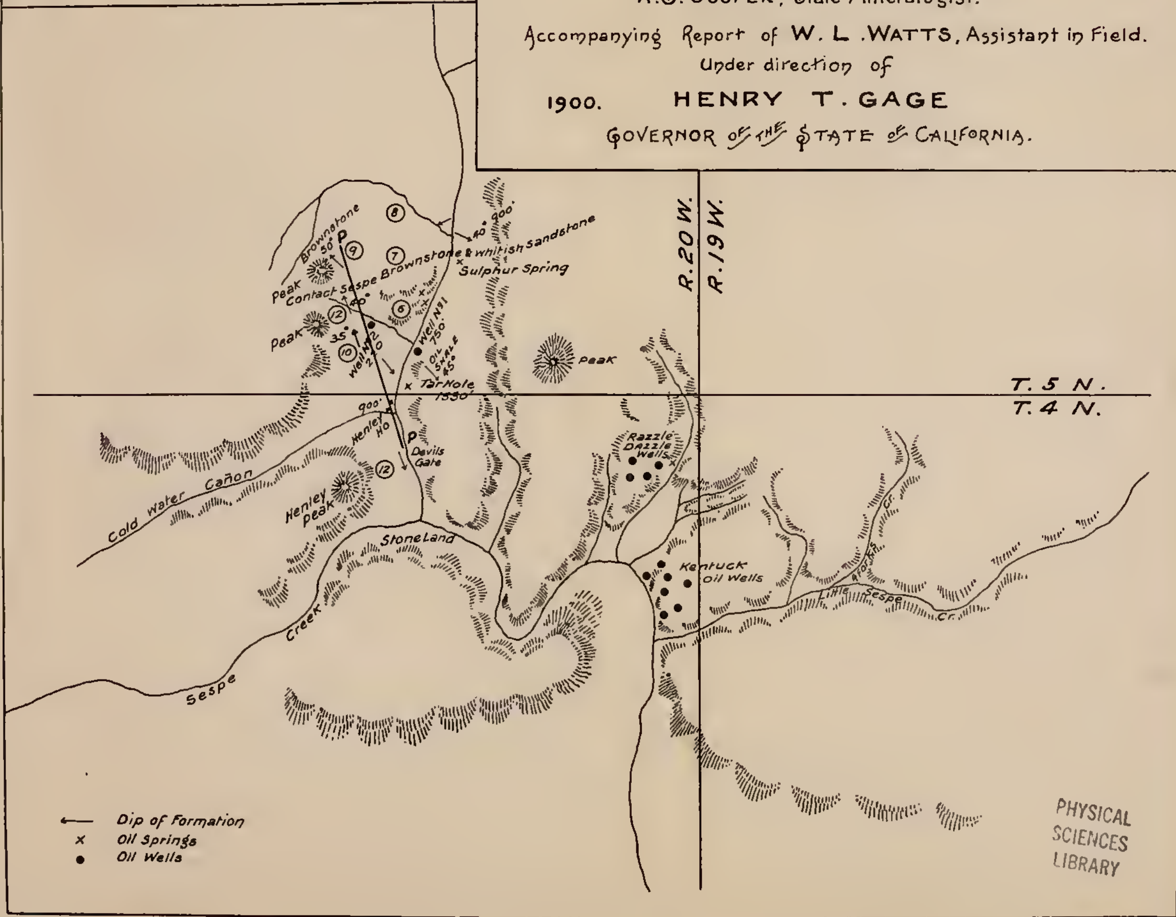
Accompanying Report of W. L. WATTS, Assistant in Field.

Under direction of

1900. HENRY T. GAGE

GOVERNOR OF THE STATE OF CALIFORNIA.

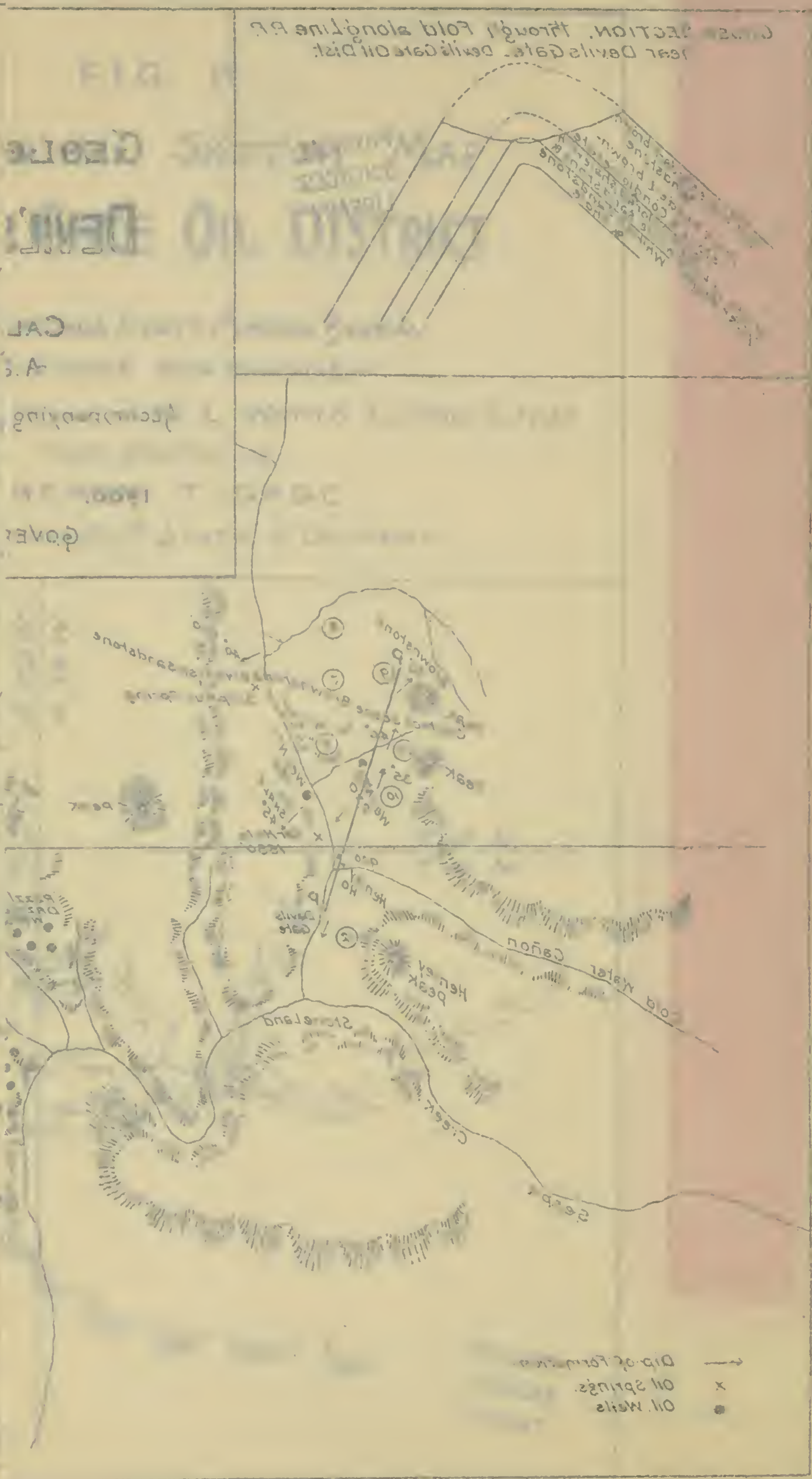




SH

FIG.

LEGEND
Bluffs near the bea
Land along the se
Rigs built.
Wells small prod
Well producing ov
per da
Dry wells.
Gas wells
ORTEGA HILL
LARSON OIL CO.
CHURCHILL OIL CO.
ROBERSON O. CO.
WILLIAMS

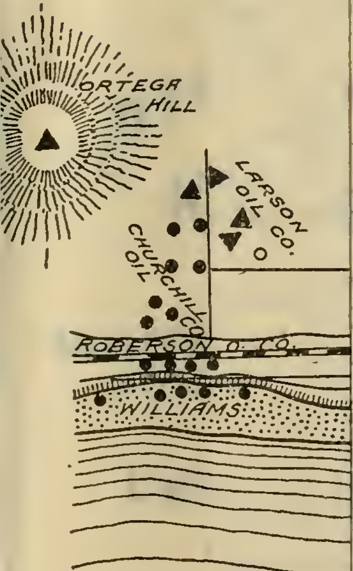

Cross SECTION. Through Fold along Line P.P.
near Devils Gate. Devils Gate Oil Dist.
sandstone
Peak
Cold Water Cañon
Henley Peak
Devils Gate
Stoneland
Creek
Seep
Dip of Formation
Oil Springs
Oil Wells

SH

FIG.

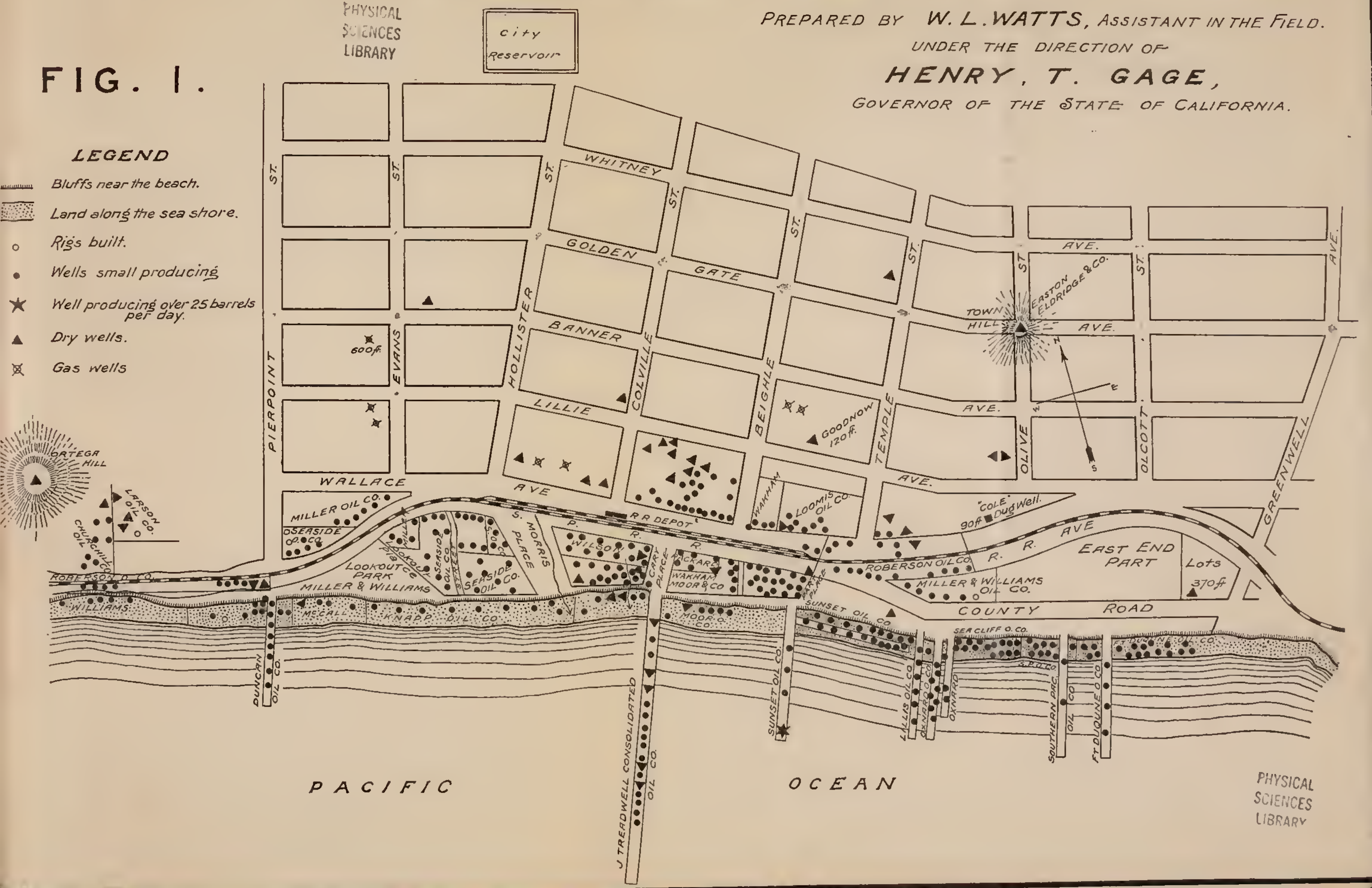
LEGEND

- *Bluffs near the bea*
- *Land along the se*
- *Rigs built.*
- *Wells small prod*
- *Well producing ove per day*
- *Dry wells.*
- *Gas wells*



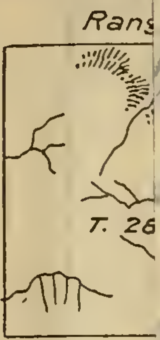
SKETCH MAP OF SUMMERLAND SHOWING OIL WELLS AND WHARVES. ~

CALIFORNIA STATE MINING BUREAU, A.S. COOPER, State Mineralogist.




Rang
T. 26
FIG.
MAP
K
McKIT
Cal
Prepare
Gov


SKETCH MAP OF SUMMERLAND
CALIFORNIA STATE MIN
FIG. 1.
LEGEND
Land along the sea shore
PACIFIC



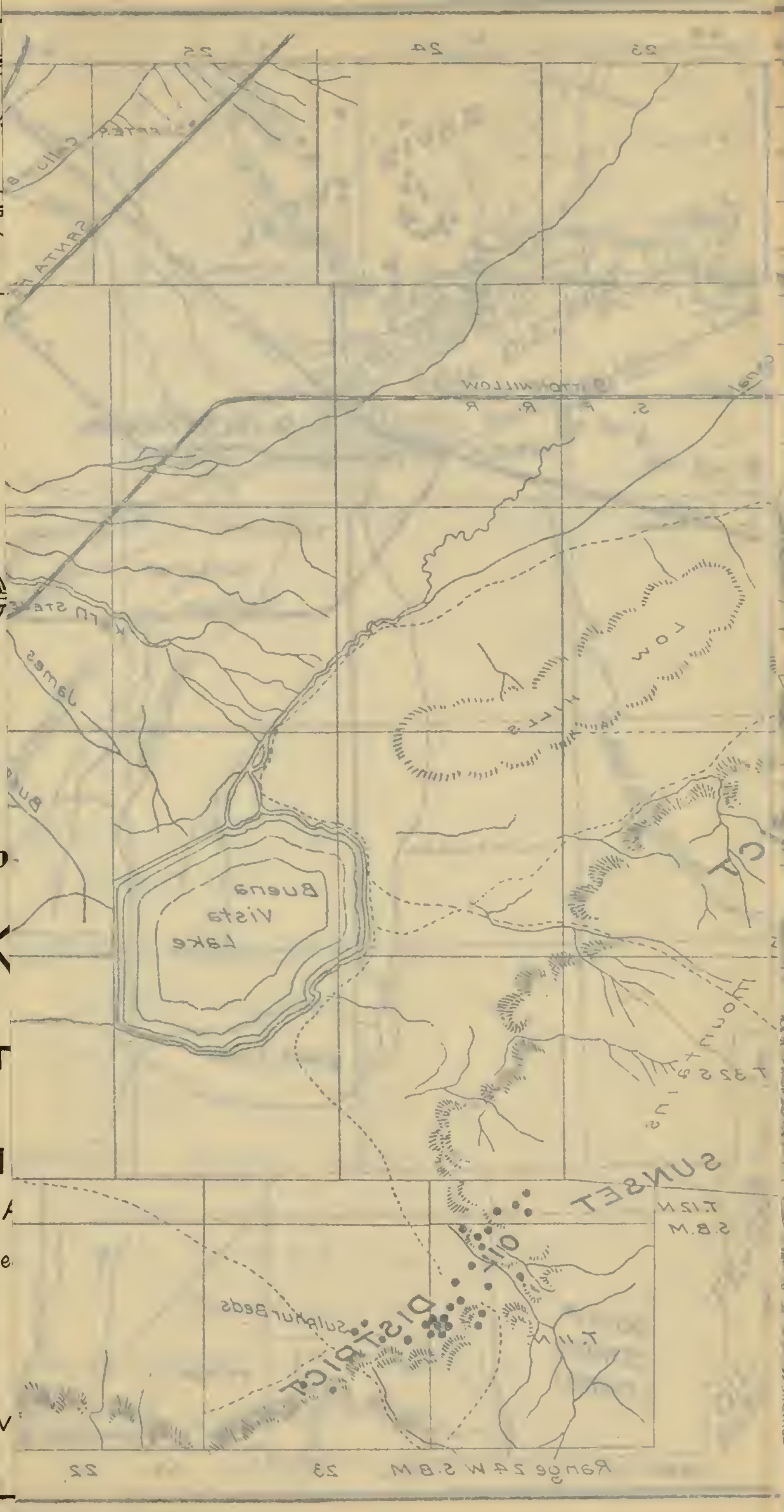


FIG.

MAP

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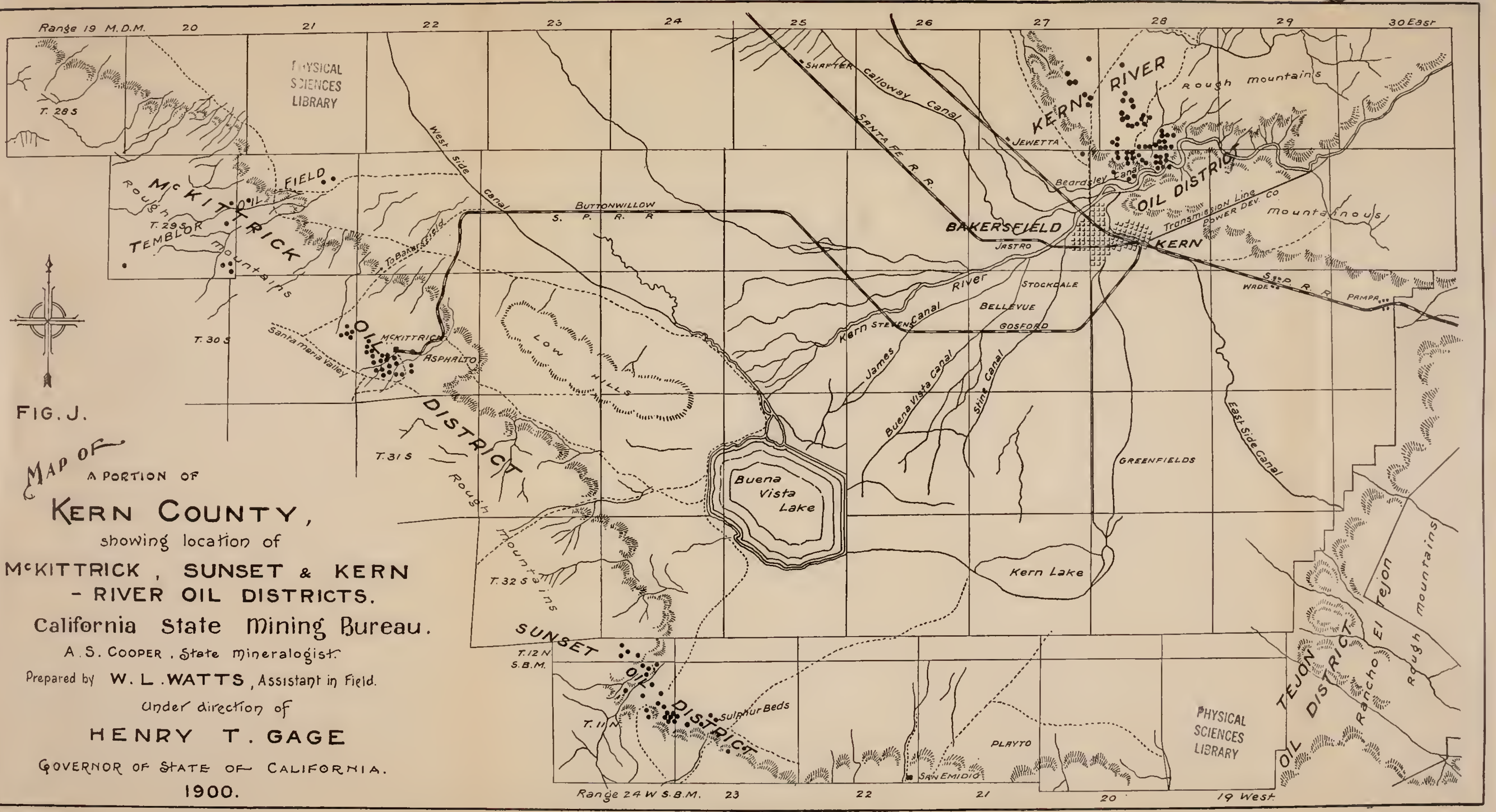


FIG. J.

MAP OF A PORTION OF

KERN COUNTY,

showing location of

McKITTRICK, SUNSET & KERN - RIVER OIL DISTRICTS.

California State Mining Bureau.

A. S. COOPER, State Mineralogist.

Prepared by W. L. WATTS, Assistant in Field.

Under direction of

HENRY T. GAGE

GOVERNOR OF STATE OF CALIFORNIA.

1900.


FIG. J.
Map of
A portion of
Kern County,
showing location of
McKITTRICK, SUNSET & KERN
- RIVER OIL DISTRICTS.
California State Mining Bureau.
A. S. COOPER, State Mineralogist.
Prepared by W. L. WATTS, Assistant in Field.
under direction of
HENRY T. GAGE
GOVERNOR OF STATE OF CALIFORNIA.
1900.
McKITTRICK
ASPHALTO
TEMBLOR
T. 29 S. R.
T. 30 S.
T. 31 S.
T. 28 S.
Santa Maria Valley
Range 19 M.D.M.
20
21
22

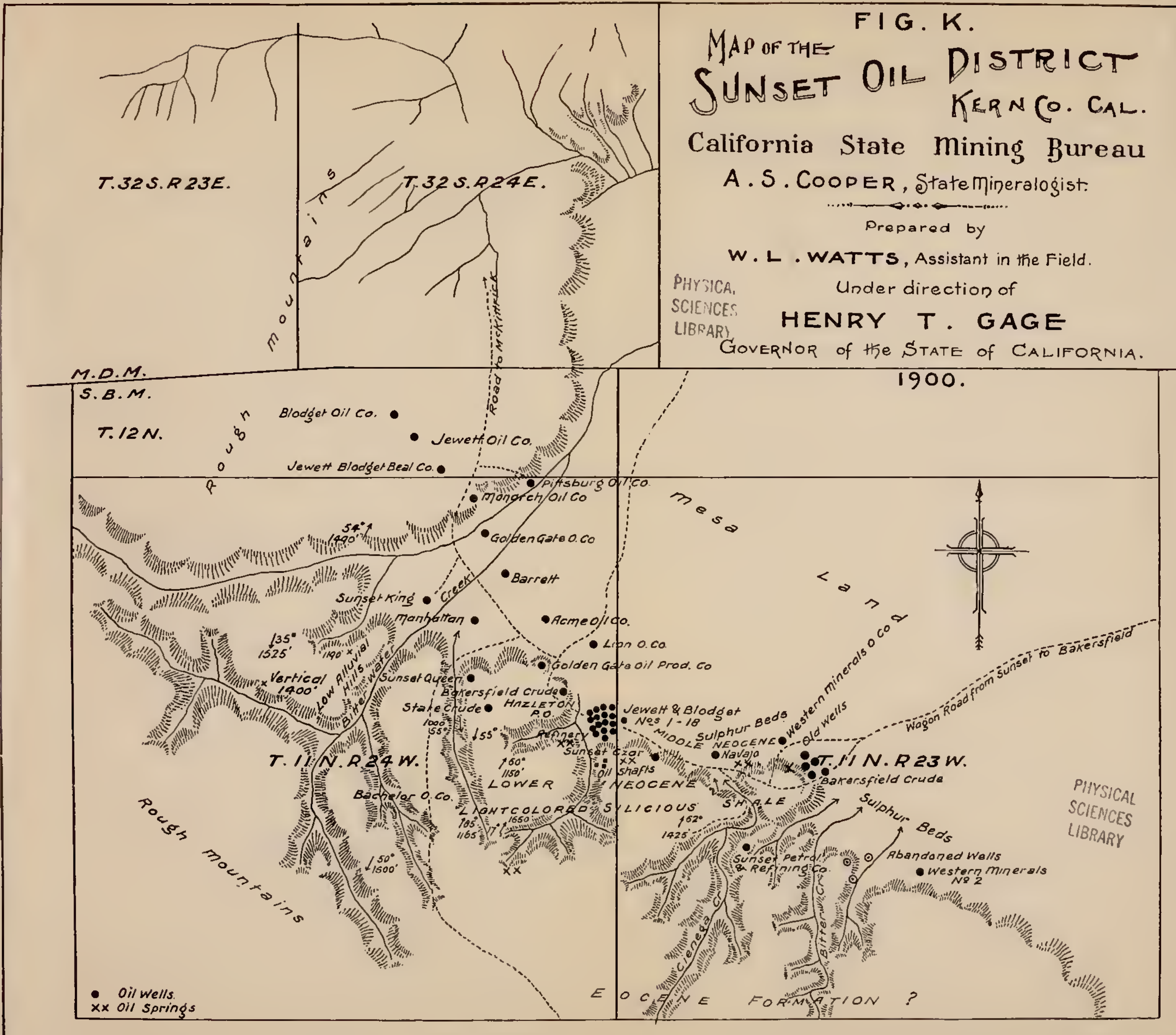


FIG. K.

MAP OF THE SUNSET OIL DISTRICT KERN CO. CAL.

California State Mining Bureau

A. S. COOPER, State Mineralogist.

Prepared by

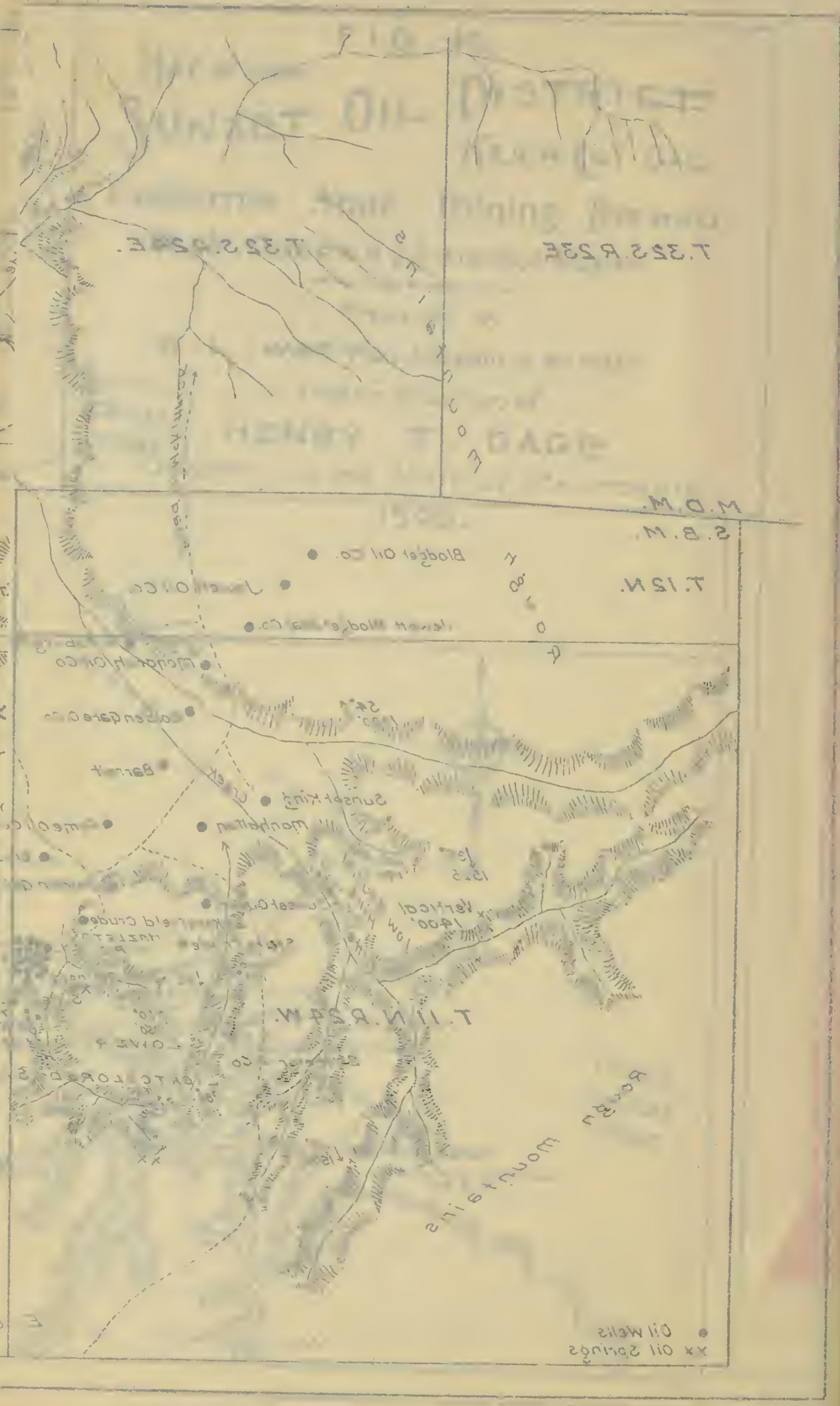
W. L. WATTS, Assistant in the Field.

Under direction of

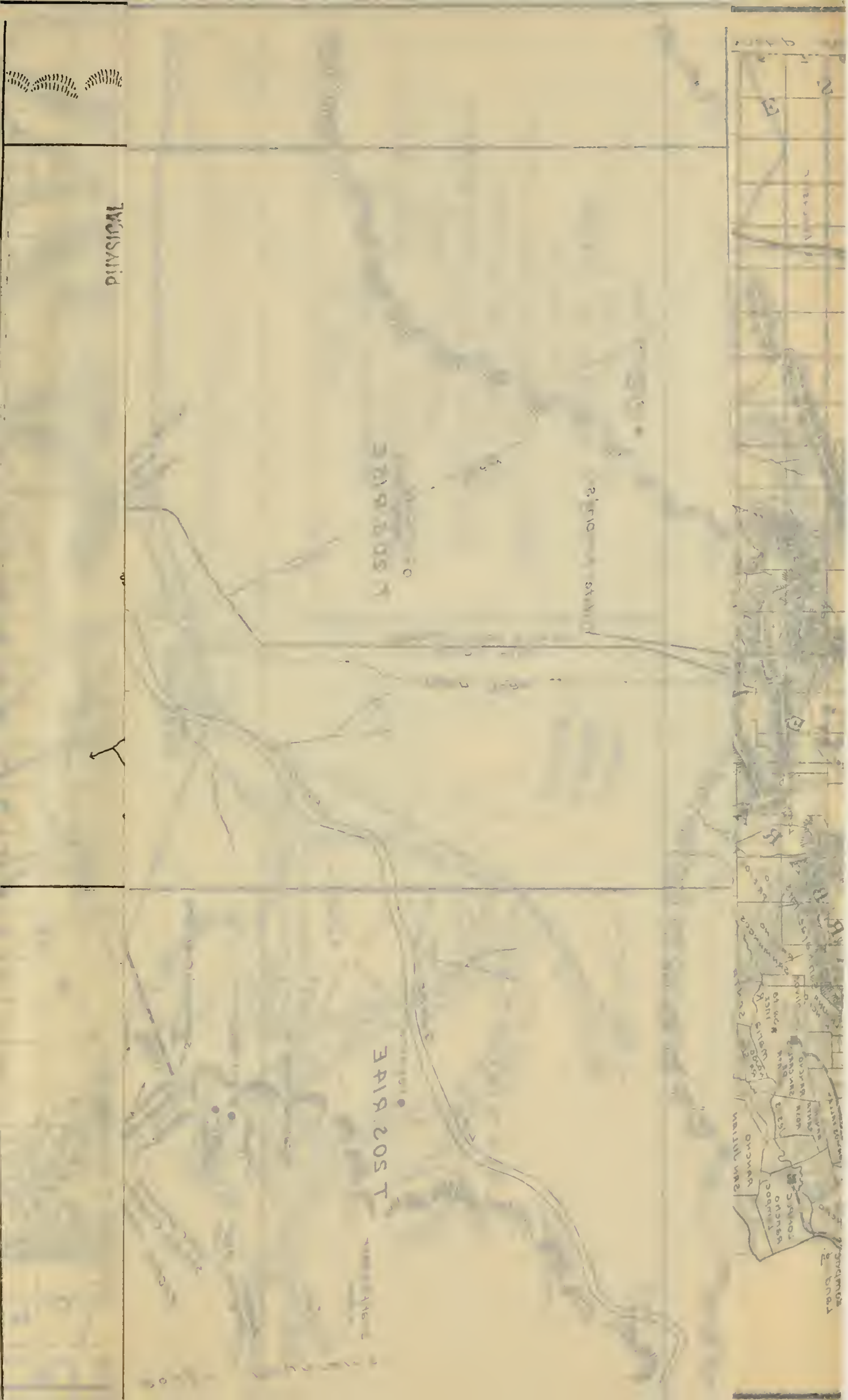
HENRY T. GAGE

GOVERNOR of the STATE of CALIFORNIA.

1900.



T.32S.R23E.
M.D.M.
S.B.M.
T.12N.
Blodget Oil Co.
Sunset King
Manhattan
T.11N.R.24W.
Oil Wells
Oil Springs


PHYSICAL

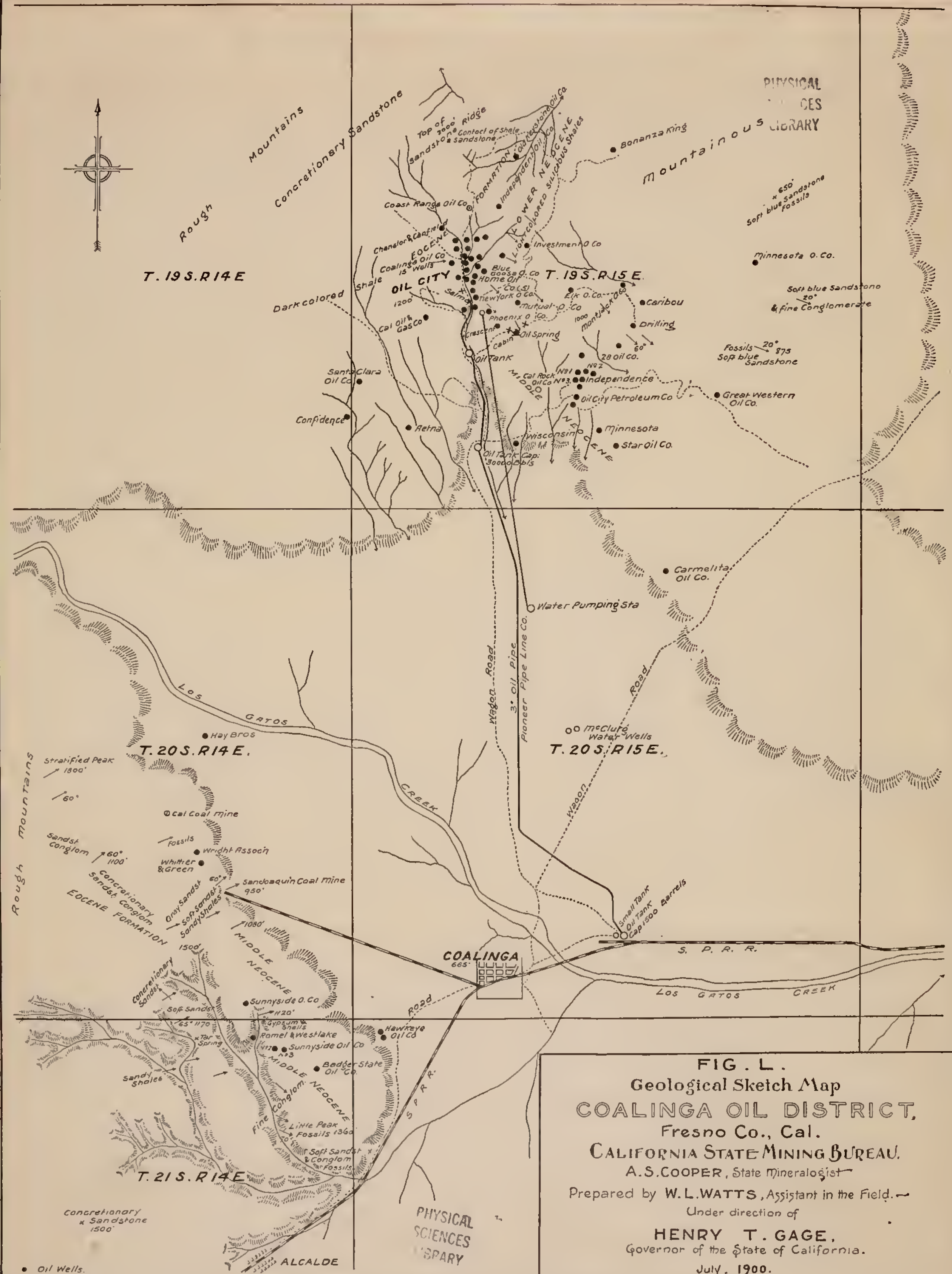
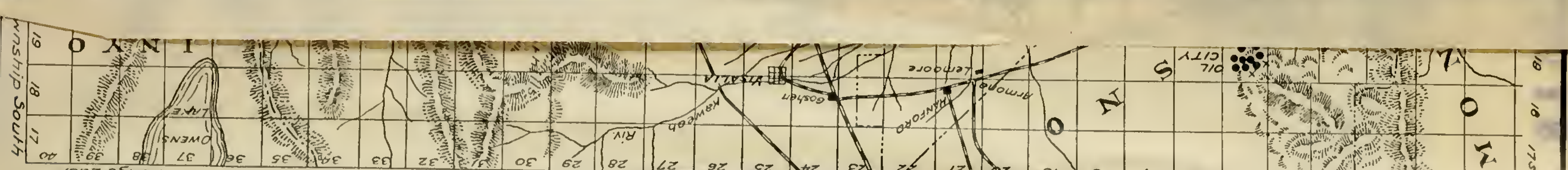
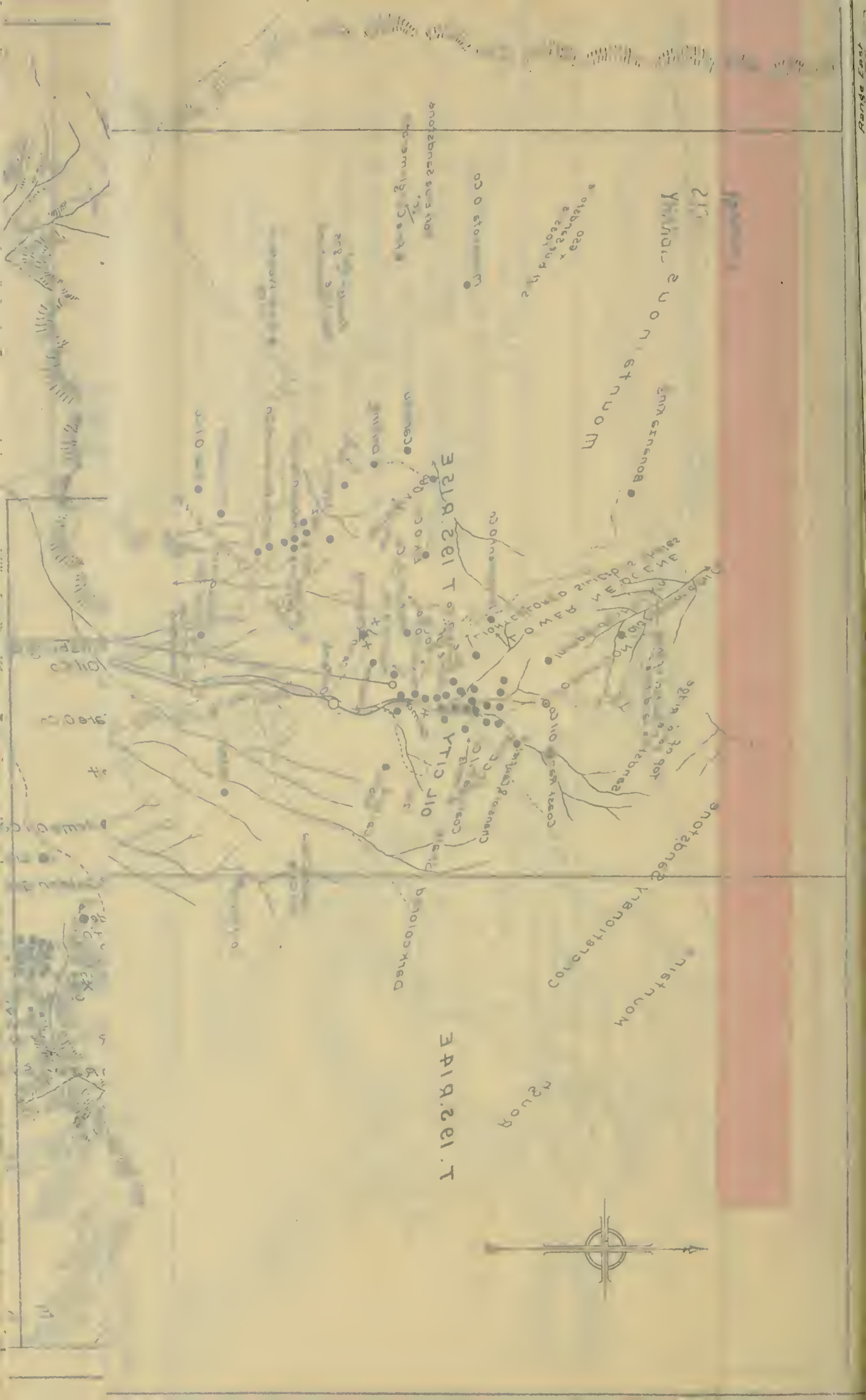


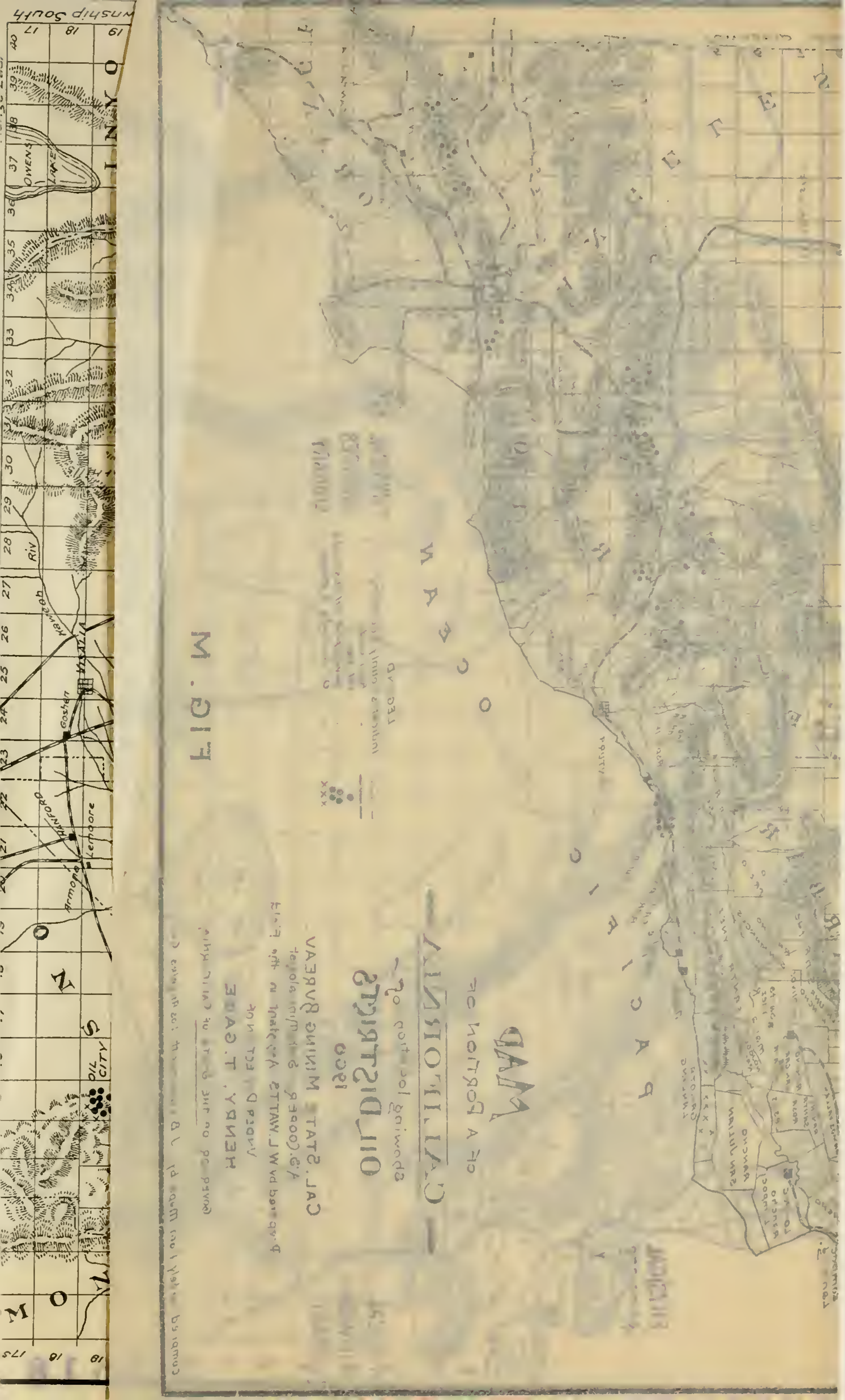
FIG. L.
Geological Sketch Map
COALINGA OIL DISTRICT,
Fresno Co., Cal.
CALIFORNIA STATE MINING BUREAU.
A. S. COOPER, State Mineralogist—
Prepared by W. L. WATTS, Assistant in the Field.—
Under direction of
HENRY T. GAGE,
Governor of the State of California.
July. 1900.


MAP
of A Portion of
CALIFORNIA
Showing location of
OIL DISTRICTS
1900
CAL. STATE MINING BUREAU
Prepared by W. L. WATTS Ass't in the Field.
Under Direction of
HENRY. T. GAGE
PACIFIC
OCEAN
LEGEND
RANCHO SAN JULIAN
XXX

FIG. M


OWENS
LAKE
INYO
Kaweah
Riv.
VISALIA
Goshen
HANFORD
Lemoore
Armona
OIL CITY
Range East
Township South





Township South
OWENS
LAKE
INYO
Kaweah
Riv
Visalia
Goshen
HANFORD
Lemoore
Armona
OIL CITY


MAP
OF A PORTION OF
CALIFORNIA
Showing location of
OIL DISTRICTS
1900
CAL. STATE MINING BUREAU.
A. S. COOPER, State Mineralogist.
Prepared by W. L. WATTS Assistant in the Field.
UNDER DIRECTION OF
HENRY. T. GAGE
GOVERNOR OF THE STATE OF CALIFORNIA.
Compiled largely from Maps by J B Lippincott Los Angeles Cal
LEGEND.
Indicates County Boundary
Railroads
Oil Well
Developed Oil Districts
Oil Springs & Brea
Range East
Township South
Township North
MONTEREY
FRESNO
KINGS
TULARE
INYO
KERN
SAN LUIS OBISPO
SANTA BARBARA
VENTURA
LOS ANGELES
ORANGE
PACIFIC OCEAN
COALINGA OIL DISTRICT
ALCALDE OIL FIELD
OIL CITY
KREYENHAGEN OIL DISTRICT
AVENAL OIL FIELD
DEVILS DEN OIL DISTRICT
MCKITTRICK OIL DISTRICT
ASPHALTO
SUNSET OIL DISTRICT
KERN RIVER OIL DISTRICT
BAKERSFIELD
Tulare Lake
Visalia
Tulare
Lemoore
Hanford
Goshen
Porterville
Delano
Mojave
Lancaster
Newhall
Ventura
Santa Barbara
Summerland
Santa Monica
Redondo
San Pedro
Santa Ana
Fullerton
Anaheim
Pomona
Chino
Capistrano
San Luis Obispo
Port Harford
Paso de Robles
San Miguel
Templeton
Cayucos
Morro
Lompoc
Lompoc Landing
Gaviota Landing
Naples
Los Olivos
Bradley
San Ardo
Antelope plains
Buena Vista
Temblor
Carisa Plains
Owens Lake
El Paso Pk
Sierra Madre Mts
Santa Ynez Mts

FIG. M


DEVILS DEN OIL DISTR
SUNSET DIST
Tulare Lake
8618