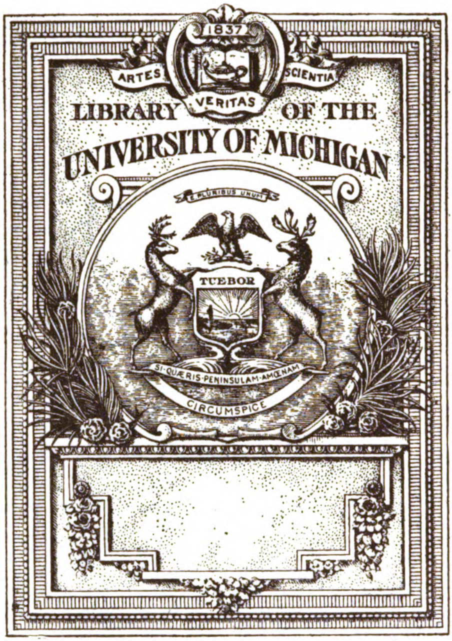
THE GAS AND PETROLEUM YIELDING FORMATIONS OF THE Central Valley of California

W. L. WATTS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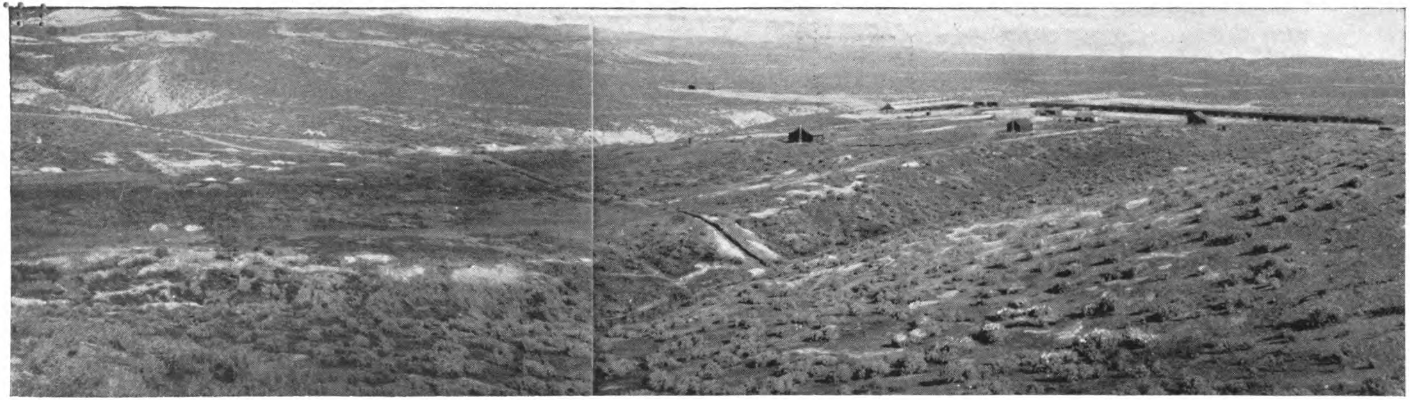
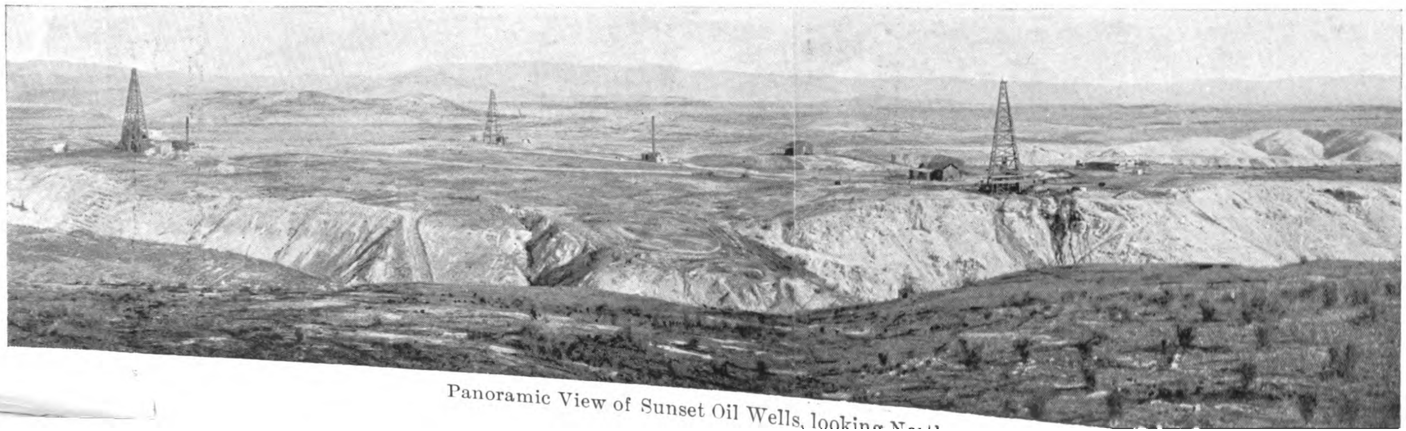
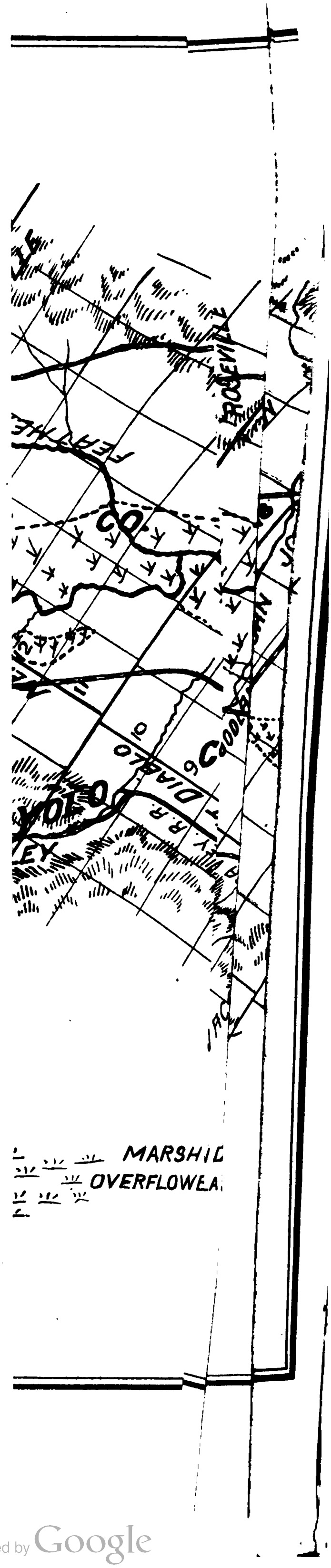


Panoramic View of Asphalto, looking Northwest.



Panoramic View of Sunset Oil Wells, looking N...



CALIFORNIA STATE MINING BUREAU.

J. J. CRAWFORD, State Mineralogist.

BULLETIN NO. 3. San Francisco, August, 1894.

THE

GAS AND PETROLEUM YIELDING FORMATIONS

OF THE

CENTRAL VALLEY OF CALIFORNIA.

BY W. L. WATTS, M.E.,
Assistant in the Field.

ERRATA.

Page 22, on 27th line, read *efflorescent* instead of "*effervescent*."
Page 75, on 14th line, read 18.96 instead of 18.63.
Page 75, on 16th line, read 2.246 instead of 2.207.
Page 75, on 22d line, read 20.890 instead of 20.525.
Page 75, on 23d line, read 20.890 instead of 20.525.
Page 75, on 24th line, read 45.9 instead of 45.3.
Page 79, on 10th line, read 64,000 instead of 63,000.
Page 43, on 15th line, omit the following: ("See table of water analyses.")

SACRAMENTO:
STATE OFFICE, : : : : : A. J. JOHNSTON, SUPT. STATE PRINTING.
1894.

CALIFORNIA STATE MINING BUREAU,
August 1, 1894.

To J. J. CRAWFORD, *Esq., State Mineralogist:*

DEAR SIR: I have in the accompanying article correlated all the information I have as yet obtained concerning the gas and oil yielding formations in the Central Valley of California and the neighboring foothills. Appended thereto are the results of experiments made to determine the fuel value of the natural gas both at Sacramento and Stockton, and in certain localities situated in the upper portion of the San Joaquin Valley.

In recounting experiments and stating results, I have used the metric system, except in the case of the brine analyses, wherein the results are given in terms of grammes to the gallon. To do otherwise would in many instances have necessitated the expression of results by both the English and metric systems, and that would have added to the time which the preparation of this article has consumed, and increased the amount of printed matter.

Yours respectfully,

W. L. WATTS,
Assistant in the Field.

THE GAS AND PETROLEUM YIELDING FORMATIONS OF THE CENTRAL VALLEY OF CALIFORNIA.

By W. L. Watts, Assistant in the Field.

As is well known, the Central Valley of California comprises the Sacramento and San Joaquin Valleys, which are bounded on the east by the Sierra Nevada and on the west by the Coast Range.

THE SACRAMENTO VALLEY.

It is on the tide-water lands at the southern base of the Potrero Hills in Solano County that natural gas is first encountered in the Sacramento Valley. When this locality was last visited by the writer, large quantities of gas were bubbling from several springs. These springs also yield copious flows of water and have washed out basins, one of which is more than 100 feet in diameter, and is said to be 30 feet deep at high tide. One of these springs was dry and gave off only a small amount of gas. It was said that this spring had been very active earlier in the year, and appearances indicated that such had been the case, for the spring had evidently brought up a quantity of light-colored sand, which smelled strongly of petroleum. Other springs were said to exist in the neighboring marsh. The range of these springs is from a northwesterly to a southeasterly direction, and it is quite likely that they mark a line of earthquake fracture. Inflammable gas is said to have been struck in a deep well near Goodyear Station, between Benicia and Suisun; and Dr. Dobbins, of Vacaville, states that while sinking a well about a quarter of a mile from that town, he penetrated a black shale, which smelled strongly of petroleum. This shale can be seen standing at a great angle in the bed of Ulattis Creek not far from Vacaville.

It does not appear that inflammable gas has been found in the valley lands of Yolo County; but in Colusa County natural gas is found in many places, both at the base of the foothills and in the foothills themselves. In this county, natural gas is generally associated with brine springs, as is the case at the head of Salt Creek, in the foothills west of the villages of Arbuckle and Williams. On the Stovall ranch, some 8 miles west of Williams, a well was bored in 1885 to the depth of 150 feet. In this well, which is now filled up, the water was salt; gas bubbled up freely through the water, and was readily ignited. The formation is:

Soil	30 feet.
Shale	30 feet.
Soft sandstone	90 feet.

A few miles west of this well the foothills are reached. The formation is shale and sandstone, which dip in a northerly direction at an angle of about 20°. Not far from where the Freshwater Creek enters the main valley, a 6-inch well was bored in 1864 or 1865 to a depth, as some say, of 300 feet, and as others say, of 900 feet. The casing is now nearly filled up with rubbish which has been dropped into it. A small stream of bitter-tasting brine still flows from the well, and inflammable gas rises through the water. A few yards north of this well, thin strata of shale and sandstone dip a little east of north, at an angle of about 70°. The barometer here showed an altitude of 160 feet. A mile or so farther west, on the Lake County road, near the Mountain House, a spring yielding petroleum is reported. At the McMichael ranch, on the Lake County road, a well was bored for oil many years ago, but it is filled up. On this ranch numerous thin strata of shale and sandstone are exposed. The strike is nearly north and south, and the dip is in an easterly direction at a great angle. The barometer here showed an altitude of about 300 feet. About one and a half miles southeast from McMichael's a second well was bored on the Stovall ranch, which still yields a small quantity of both gas and oil. Farther west the road crosses a divide, on the summit of which the barometer indicated an altitude of 1,200 feet; the formation dips in an easterly direction at a great angle.

As Bear Creek is reached, the stratified rocks are metamorphosed, the strike being west of north, and the dip northeasterly at an angle of about 70°. On this creek, at a short distance from the roadway, is the oil claim of J. P. Rathburn. Here the stratified rocks give place to serpentine with oil exuding from it, and forming small pools upon its surface. (See table of oil analyses at the end of this bulletin.) Between the roadway and Mr. Rathburn's claim, jaspery rocks, impure limestone, and sandstones traverse the creek. Farther up the stream a comparatively unaltered sandstone is exposed, which has a strike of west of north, and from it a heavy petroleum oozes in several places. In the creek near these oil springs gas can be seen rising through the water.

Also on Sulphur Creek there are both natural gas and petroleum, and on this creek fossiliferous limestone crops out, which smells strongly of petroleum. The fossils were principally *Rynchonella Whitneyi*. At the Elgin Mine, on this creek, gas issues from a hole about 3 feet deep, and the writer saw it burning with a flame about 3 feet in height. Immediately above the gas spring, between croppings of sandstone, is a decomposed shale, which emits a fetid odor and inflammable gas when disturbed.

At Sites' Station, close to the foothills in Colusa County, a well was bored in 1886 which yielded salt water and inflammable gas. The formation is stated to be as follows:

Adobe soil	28 feet.
Shale	45 feet.
Hard "slate"	265 feet.

The well-borers state that at a depth of 146 feet a thin vein of auriferous rock was passed through; that in this rock free gold could be seen, and that borings from it assayed at the rate of $360 a ton. Below a depth of 28 feet this well yielded salt water, and the saltness increased with the depth of the well. The salt water appeared to come from seams, which were about 6 feet apart. At a depth of about 130 feet inflammable gas was observed, and the quantity of gas increased as the well was bored deeper. At the completion of this well the salt water stood within 4 feet of the surface.

At the Petersen ranch, about three miles north of Sites, there are several brine springs from which inflammable gas issues. These salt springs are situated in a small valley leading into Antelope Valley at the edge of the foothills, and at an altitude of about 200 feet. During the winter the extremity of the small subsidiary valley is occupied by a shallow lake, which has an area of about 25 acres. This lake dries up during the summer, leaving a deposit of sand and loam washed and blown from the adjacent hills. This accumulation, which is mixed with much salt, lies to the depth of several feet on a bed of bluish clay. From any boring penetrating this clay to a depth of 6 or 7 feet, salt water and inflammable gas are obtained. About 15 feet below the surface a sandy stratum is encountered, which yields a still larger amount of brine and gas than is obtained in shallower wells.

The geological formation of this locality is very interesting. On the northern side of the lake a friable sandstone, streaked with calcite, is exposed, which dips in a southwesterly direction at a great angle. On the southern and opposite side of the lake a similar sandstone is to be seen, but it dips to the east of north at an angle of about 55°. This locality exhibits a similar geological structure to that seen at Tuscan Springs, in Tehama County.

About half a mile east of the salt springs the formation is fossiliferous, and several Cretaceous fossils were obtained in the second tier of hills from the Sacramento Valley. These fossils were submitted to Dr. J. G. Cooper, who determined them as follows:

Trigonia tryoniana, Gabb	Cretaceous.
Actæonina Californica, Gabb	Cretaceous.
Dentalium stramineum, Gabb	Cretaceous B.
Ammonites batesi, Trask	Cretaceous.
Cucullæa truncata, Gabb	Cretaceous.
Lunatia avellana, Gabb	Cretaceous.
Arca breweriana, Gabb	Cretaceous.

The formation from which the fossils were obtained consists of shale and sandstone with thin strata of fossiliferous limestone. The strike is west of north, and the dip northeasterly, at an angle of about 50°. It appears, therefore, that these fossils are of the same age as the fossils found at Tuscan Springs in Tehama County; namely, Cretaceous and of the Chico group.

Passing northward into Glenn County, natural gas appears to have been observed only at one place. The formation yielding the brine, however, seems to skirt the foothills; for it has been struck in wells about 17 miles west of Willows. There are also said to be brine springs about 3 miles west of Elk Creek. If wells were bored in the formation yielding the brine, the probability is that natural gas would be found. The only place in this county where natural gas is reported to have been observed, is at the Rideout ranch, near Norman. On this ranch two wells were bored, each to the depth of 940 feet. The formation penetrated is alternate strata of sand and clay. A small amount of inflammable gas is said to have been observed in these wells when they were first bored. In 1892, a small stream of fresh water was flowing from one of these wells which is about two miles north of Norman, but the gas had either ceased, or had been "cased" off.

In Tehama County, inflammable gas has been observed in several wells which have been dug in the western portion of the county. In a well about half a mile north from Stony Creek Buttes, the formation is stated to be as follows:

Soil	5 feet.
Cement gravel (this stratum yields inflammable gas)	30 feet.
Blue clay	43 feet.

On the Stark ranch, in Sec. 8, T. 26 N., R. 4 W., M. D. M., about 7 miles southwest from Red Bluff, inflammable gas was struck in black clay at a depth of 75 feet. The gas prevented work, and was ignited by the workmen; the well was then abandoned. A similar experience was had in a well dug to the depth of about 60 feet in Sec. 16, T. 28 N., R. 4 W., M. D. M., on what is known as the Oakwood Colony Tract, 11 miles northwest from Red Bluff.

In the autumn of 1891, a well was dug on the Thurman ranch, about 9 miles northwest from Orland, and at a depth of 25 or 30 feet inflammable gas was encountered. This was ignited by a workman while lighting his pipe, and resulted in his receiving severe burns.

Crossing the valley to Tuscan Springs natural gas is again found. At Tuscan Springs, as is well known, inflammable gas issues together with thermal water from the upturned edges of Cretaceous strata, and at one time the gas was used for heating the baths established there. These springs have so often been described that it is sufficient to say the Cretaceous rocks here present an anticlinal, and the water and gas escape from fractures upon its axis. The geological formation at these springs, and at the Petersen ranch, near Sites, in Colusa County, presents great similarity. It is only reasonable to conclude that the gas is of Cretaceous origin.

Research amongst the wells of the Sacramento Valley brought to light an interesting phenomenon. In portions of Tehama County known as the Chaparral Hills and the Adobe Hills, what appear to be currents of air are found, sometimes escaping from, and at other times being drawn into, strata of sand or porous clay; and the direction of these air currents appears to depend on the condition of the atmosphere. (See our XIth report, page 478.)

The only inflammable gas in Butte County, so far as heard from, was on the ranch of M. Wick, about 6 miles northwest of Oroville, where it was struck in boring a well. The gas was ignited and is said to have blazed up for several feet above a 5-inch casing. The formation penetrated is stated to be:

Loam	2 feet.
Cement gravel	6 feet.
Yellow clay	16 feet.
Soft sandstone	8 feet.

In Yuba County inflammable gas was struck in a well bored to the depth of 218 feet at the Buckeye Mill, and in a well 180 feet deep at the waterworks. In boring the well at the Buckeye Mill, the formation was found to be strata of clay, sand, and gravel. Between the depths of 80 and 140 feet much partially decomposed wood was brought up by the auger, and strata of clay were penetrated, which showed the impressions of numerous shells. Gas was struck between the depths of 212 and 220 feet.

At the waterworks and at the Buckeye Mill the gas collects in the air-chamber of the pump, and is frequently ignited from a burner attached to the air-chamber for that purpose. It burns with a fairly luminous flame, but it contains some carbonic di-oxide.

Crossing the Feather River to Sutter County, we find that inflammable gas has been struck in several wells which have been bored to the south of the court-house in Yuba City. These wells are less than 60 feet deep. At one place inflammable gas was noticed issuing from the ground during wet weather. In some of the wells in Yuba City where natural gas was observed, the formation is as follows:

Soil	20 feet.
Quicksand	6 to 20 feet.
Blue clay	40 feet.
Blackish sand, with gas.	

At one well, which is 60 feet deep, a cap was fitted to the top of the casing with a nozzle half an inch in diameter, and the gas was burned therefrom, producing a flame more than 2 feet in height.

In February, 1864, a shaft was sunk to prospect for coal on the ranch of Eli Davis, at the foot of the South Butte, about 6 miles from Sutter City. The shaft was about 40 feet deep, and from the bottom of it a tunnel was run about 40 feet in the sandstone. In this sandstone inflammable gas was struck, which being ignited, resulted in an explosion, to the injury of the miners. The gas escaped from seams in the sandstone, and a roaring sound attributed to it could be heard at the mouth of the shaft. Subsequently another shaft was sunk a short distance from the old one. This second shaft is about 4 feet square and 30 feet deep, and two wells have been bored therein. The first well, which was sunk in the 60s, is 60 feet in depth; it still yields inflammable gas, which smells of petroleum, and burns with a luminous flame, fluctuating from a few inches to about 2 feet, from the top of a 6-inch casing. The formation penetrated by the 4-foot shaft is a somewhat bituminous shale to a depth of 28 feet; in the shale two little seams of water were struck. The boring at the bottom of the shaft was made for 32 feet in sandstone. Below the shale the borings were dry, and it is said that the flow of gas was so strong that it blew the borings out of the drill-hole. A drill and chain are said to have been lost during the boring of this well. In 1891 another well was sunk in the 4-foot shaft. This well is about 2 feet from the first one, and although it was bored to a depth of 130 feet, it yielded but little gas.

As is well known, the Marysville Buttes are principally composed of volcanic rocks, but as the writer has nowhere seen a description of the very interesting sedimentary formations on the flanks of the Buttes, he considers that the following note may be of interest:

Leaving Sutter City by the South Pass road leading to Colusa, a valley is entered, formed by spurs from the Marysville Buttes, and these spurs are covered with micaceous trachytic lava. At the base of the Buttes the sedimentary rocks are exposed. At the Newcomb ranch the creek by the roadside has cut into the bank, showing a bedrock of sandstone and light-colored shale, the strike being north of west. The Buttes are a cluster of volcanic eminences which rise to the height of from 1,827, or thereabouts, to 2,178 feet. On the western portion is a ridge with four principal summits, and on the east are three more isolated peaks, while several spurs and hills of lesser elevation surround the main group of mountains. In ascending the most southerly peak from the Moody ranch patches of light-colored sand, toward the base of the mountain, mark the sedimentary formations and the coal measures. A few fragments of fossiliferous rock, showing Cretaceous fossils, may be found on a portion of the slope. The upper part of the mountain is composed entirely of micaceous trachytic lava, which becomes more crystalline toward the summit. The best exposure of sedimentary rocks was seen at the base of the West Butte, about a mile from the village of that name. On the west side of the Buttes the sedimentary strata are cut through by ravines nearly at right angles to the strike of the formation. In one gulch the evidence of successive displacements can be observed. Near the mouth of the gulch strata of sand and gravel dip in a southwesterly direction at an angle of about 15°. A few yards higher up the creek the formation changes to whitish sand, iron-stained in places, the dip being northwesterly; and in two or three places the dip of the whitish sands is variable, changing from northwest to southwest. The white, sandy formation rests upon Cretaceous shales and clayey sandstones, which dip in a southwesterly direction at an angle of about 70°. The Cretaceous shales are traversed by thin strata of fossiliferous limestone. From the shales and the limestone strata several fossils were obtained by digging. These were submitted to Dr. J. G. Cooper for examination, and he classed them as follows:

Leda *gabbi*, Con.	Cretaceous B.
Lunatia *horni*, Gabb	Cretaceous B.
Olivella *mathewsoni*, Gabb	Cretaceous B.
Nucula *solitaria*, Gabb	Cretaceous.
Nassa *cretacea*, Gabb	Cretaceous.
Turritella *uvasana*, Gabb	Cretaceous.
Turritella *chicoensis*, Gabb	Cretaceous.
Meretrix *horni*, Gabb	Cretaceous B.
Galerus *excentricus*, Gabb	Cretaceous.
Cardita *veneriformis*, Gabb	Cretaceous.
Ostrea *idriaensis*, Gabb	Cretaceous B.
Corbula *parilis*, var?, Gabb	Cretaceous B.
Mysia *polita*, Gabb	Cretaceous B.
Modiola *cylindrica*, Gabb	Cretaceous.
Cardita *planicosta*, Lam.	Cretaceous B.
Arca *horni*, Gabb	Cretaceous B.
Cardium *translucidum*, Gabb	Cretaceous.
Dentalium	Cretaceous.
Morio *tuberculatus*, Gabb	Cretaceous B.
Architectonica *horni*, Gabb	Cretaceous B.
Cucullea	Cretaceous.

Several new species were also obtained from this locality.

The only natural gas observed in the valley lands or foothills of Placer County, was on the Blair placer mining property, where boring showed the following formation:

Auriferous cement gravel	18 feet.
Water.	
White volcanic ash and fragments of quartz and white sand	20 feet.
Coal	21 inches.
White volcanic ashes	15 feet.
Coal	6 inches.
Alternate strata of white ashes and gravel with thin layers of coal, nine altogether, to a depth of	90 feet.

One hundred yards south from this boring a similar formation was observed to a depth of 80 feet; the water rose to within 6 feet of the top of the casing, and gas bubbled through it. After an explosion of giant powder in the well, a flame, extending about 18 inches above the top of the casing, burned for fifteen minutes.

About twenty years ago two wells were bored on the Haggin ranch, on the Norris grant, about 9 miles northeast from the city of Sacramento. One of these was bored to a depth of 2,250 feet, and the other to a depth of 1,600 feet. These wells yielded salt water by pumping, and a small quantity of inflammable gas arose from the deepest.

In 1889–90 a company was formed at Sacramento under the name of the Natural Gas and Water Company, to sink a well for artesian water and gas in the southwestern portion of the city. This company bored a well to the depth of 876 feet. The formation penetrated is alternate strata of clay, gravel, cement, and quicksand; the lower portion of the formation being a hard, porous, sandy cement. Flowing water was struck in coarse sand at a depth of 281 feet, and a slight showing of gas was observed at 392 feet. The flow of water and gas increased with the depth, but at 866 feet operations were suspended, owing to an accident to the casing. It is roughly estimated that the yield of gas from this well exceeded 2,000 feet in twenty-four hours.

In March, 1892, a new well, which we will call the Sacramento Gas Well No. 2, was commenced about 150 feet eastward from the old gas well. In May, 1893, Gas Well No. 2 had been bored to the depth of 965 feet; but the boring was suspended, owing to difficulty resulting from a sand-pump becoming fast at the bottom of the casing. The well-borers state that many of the strata penetrated by this well were very hard and required reaming; also, that the greatest trouble resulted from the sand "packing" around the casing when it was standing on a hard stratum during the process of reaming.

The well No. 2 is cased with 14-inch casing for the first 505 feet, and with 12-inch casing from that depth to the bottom, 965 feet. It is stated that the casing was put down in joints 4 feet in length, and that each *joint was coated internally and externally with asphaltum.*

The value of this latter precaution is very great, since the asphaltum protects the iron from any acid which might accompany the inflammable gas, or which the water flowing from the well might hold in solution. The following samples of strata penetrated are preserved in bottles and labeled with a statement as to the depth at which each sample was obtained:

Depth of Well.	Record of New Well No. 2, as Shown by Contents of Bottles.
66–88 ft.	Quartzose pebbles, with water-worn fragments of wood, at a depth of 87 feet.
90 feet.	Light-colored, porous, sandy clay.
98 feet.	Fine grayish sand.
99 feet.	Grayish sandy clay.
106 feet.	Grayish sand (rather coarse).
108 feet.	Fine micaceous cemented gray sand.
112 feet.	Coarse sand, with fragments of cemented fine sand.
118 feet.	Light-colored clay.
120 feet.	Micaceous sand, with fragments of cemented sand.
128 feet.	Fine micaceous sand, the particles being somewhat agglutinated, but friable.
153 feet.	Cemented fine sand, resembling soft, friable, micaceous sandstone.
170 feet.	Light brown, porous sandy clay, with infiltrations of white clayey matter. [able.
173 feet.	Soft agglutinated fine sand; fri-
178 feet.	Fine sand with small pebbles.
185 feet.	Light-colored clay.
189 feet.	Fine micaceous sand.
192 feet.	Light-colored, sandy clay.
194 feet.	Very fine sand cemented with clayey matter; indurated.
212 feet.	Fine sand, small pebbles, and lumps of cemented sand.
220 feet.	Fine, sandy, light-colored clay.
232 feet.	Micaceous sand and fragments of light-colored cemented sand.
238 feet.	Soft, cemented, fine sand.
240 feet.	Sand, with fragments of wood.
245 feet.	Light-colored, sandy clay.
248 feet.	Light-colored, cemented sand, with white clayey infiltrations.
261 feet.	Grayish sand.
265 feet.	Light-colored clay.
266 feet.	Coarse sand. [sand.
274 feet.	Porous, cemented, light-colored
280 feet.	Friable cemented sand.
287 feet.	Fine sand.
307 feet.	Whitish clay.
310 feet.	Light-colored clay. [mented sand.
318 feet.	Fine sand and fragments of ce-
328 feet.	Light-colored, sandy clay.
329 feet.	Light-colored, sandy clay.
330 feet.	Agglutinated sand, friable.
332 feet.	Whitish clay. [ing water).
334 feet.	Fine micaceous sand; (first flow-
352 feet.	Porous, clayey sand.
356 feet.	Fine sand.
376 feet.	Light-colored clay.
394 feet.	Coarse sand and small pebbles, with flowing water.
400 feet.	Porous, light-colored, sandy clay.

Depth of Well.	Record of New Well No. 2, as Shown by Contents of Bottles.	Depth of Well.	Record of New Well No. 2, as Shown by Contents of Bottles.
413 feet.	Hard, light-colored clay.	632 feet.	Porous cemented sand.
415 feet.	Cemented, fine sand.	640 feet.	Gray cemented sand.
425 feet.	Whitish clay.	642 feet.	Fine micaceous sand.
430 feet.	Micaceous sand, with white quartz and quartzose pebbles at 427 ft.	650 feet.	Cemented sand.
431 feet.	Whitish, sandy clay.	651 feet.	Light brown clay, with white clayey infiltrations.
434 feet.	Porous, sandy clay.	668 feet.	Porous clayey sand.
437 feet.	Agglutinated fine sand, friable.	674 feet.	Loose sand.
450 feet.	Porous, clayey sand.	683 feet.	Light-colored clay.
465 feet.	Porous cemented sand, very hard.	688 feet.	Loose sand.
470 feet.	Very fine, cemented, micaceous sand.	690 feet.	Brown clay.
485 feet.	Micaceous sandstone.	692 feet.	Porous sandy clay.
487 feet.	Whitish clay.	693 feet.	Loose sand.
509 feet.	Micaceous, cemented sand.	695 feet.	Brownish clay.
521 feet.	Loose sand; strong flow of water.	700 feet.	Porous sandy clay.
528 feet.	Sandy clay, hard as sandstone.	715 feet.	Brownish clay.
538 feet.	Cemented, micaceous sand.	718 feet.	Loose sand; at this depth there was an increased flow of water, accompanied by gas.
545 feet.	Light-colored clay.	720 feet.	Sand, cemented with clay.
569 feet.	Coarse sand.	723 feet.	Agglutinated, sharp sand.
570 feet.	Quartzose pebbles.	727 feet.	Loose sand.
575 feet.	Light-colored clay.	732 feet.	Light-colored clay.
578 feet.	Gray, porous sand rock.	736 feet.	Cemented sand, friable.
595 feet.	Light-colored clay.	738 feet.	Light-colored indurated clay.
597 feet.	Agglutinated, fine sand.	739 feet.	Cemented sand.
600 feet.	Clayey sand.	801 feet.	Brownish, sandy clay.
608 feet.	Micaceous sand.	803 feet.	Loose sand.
612 feet.	Soft, clayey, fine sand.	804 feet.	Brownish clay, with white clayey infiltrations.
616 feet.	Fine micaceous sand.	812 feet.	Light-colored indurated clay.
622 feet.	Light-colored clay.	814 feet.	Cemented grayish sand.
623 feet.	Fine micaceous sand.	820 feet.	Loose sand.
625 feet.	Fine cemented sand.		

Between this depth and that of 872 feet the well-borers state that strata of hard sandstone were passed through; that at the depth of from 840 to 845 feet a stratum of very porous sandstone yielded more water and gas; and that blue clay was penetrated between the depth of 860 and 865 feet. The sample which was marked as representing the formation at a depth of 900 feet, contained a light-colored and somewhat calcareous clay.

In reviewing the record of the strata penetrated by this well and the samples from it, which have been preserved, the fact must be borne in mind that when material is first taken from the well during the process of boring, it frequently looks very different from what it does when dried and kept for some time. Nearly all the light-colored clays look blue when first brought up from the well, and the micaceous sands look black, frequently becoming bluish when dry. All the loose micaceous sand is quicksand, and well-borers state that it "runs badly"; *i. e.*, it runs into the boring and casing, and is apt to cover the tools.

The term agglutinated sand is used for that whose grains adhere to one another without any visible cementing material; and the term cemented sand, when the cementing material can be seen.

Many of the samples, when dried, resemble soft, clayey sandstones. The physical appearance of some of them resembles a very recent formation overlying the Ione coal measures cropping out a few miles eastward from Clements, in San Joaquin County.

In a general way, it is obvious that many of the strata penetrated by the gas wells at Sacramento are harder than those encountered at similar depths at Stockton.

The old gas well at Sacramento is about 150 feet from the Gas Well No. 2, and it flows about 18 miner's inches of water. On May 16, 1893, the temperature of this water was 69.5° Fahr. Gas Well No. 2 also yields a copious stream of water. A determination of the temperature of the water in this well, which was made at the same time as that of the old well, was 66.74° Fahr.

The temperature of the water in these wells is said to have been higher when it was previously estimated. It is quite probable that water from the melting snows of the Sierra may cool these subterranean waters during the early summer, as it does the water in the river and streams on the eastern side of the Central Valley of California.

An estimation of the fuel value of the gas from the old gas well at Sacramento will be found at the conclusion of this bulletin. As the gas from Well No. 2 was not collected under a receiver, its fuel value was not estimated. The gas from both wells, when passed through lime water for a few minutes, showed the presence of a small amount of carbonic di-oxide.

GENERAL REMARKS ON NATURAL GAS IN THE SACRAMENTO VALLEY AND NEIGHBORING FOOTHILLS.

The instances have now been traced in which inflammable gas has hitherto been observed in the Sacramento Valley. The larger number of places where the gas was examined, were springs or shallow wells in the Cretaceous formations on both sides of the valley, and were little more than "gas prospects." The only deep wells penetrating the filling of the valley were found at the Haggin ranch, at Sacramento, and near Norman, in Glenn County. At the Haggin ranch, 9 miles north of Sacramento, natural gas and salt water were obtained; and it is noted that the salt water and gas were found together in Cretaceous formations in other places on the sides of the valley. At Sacramento, natural gas was observed at a depth of 392 feet; at the Rideout ranch, in Glenn County, the filling of the valley was penetrated 940 feet, and only a small amount of gas was observed, but this has now ceased. The well at the Blair placer mining property penetrates a late Tertiary formation.

These investigations warrant the conclusion that the natural gas in the Sacramento Valley is principally of Cretaceous origin, although any organic remains that have been subjected to the necessary chemical change beneath the clayey strata of the valley have contributed to the gas stored in adjacent porous formations. There is no doubt that the greater portion of the gas found in the alluvial formations in the Sacramento Valley has escaped from fissures in the older rocks; and that these fissures have been formed, not only by the ancient disturbances which culminated in the formation of the Marysville Buttes, but by earthquakes of the present era.

Comparing the traces of gas in the wells at the Rideout ranch, in Glenn County, with the amount of gas yielded by the wells bored at Sacramento, it might be argued that the Quaternary strata contain more gas in the lower than in the upper portions of the valley, but the results obtained by wells so far apart are insufficient for generalization. Moreover, the water resting on the gas-yielding formations at the Rideout well, in Glenn County, is probably much deeper than in the well at Sacramento.

From the foregoing it appears that the natural gas in the Sacramento Valley occurs under two conditions: First, when it issues from upturned edges of Cretaceous rocks on the sides of the valley, and from shallow wells penetrating that formation; secondly, when it escapes from wells penetrating the porous and more recent formations which fill the trough of the valley.

These researches in the Sacramento Valley and neighboring foothills lead to the conclusion that the gas-bearing formations are distributed through the rocks of the Cretaceous system. At Sulphur Creek gas and petroleum are found associated with rocks of the Knoxville series. At Sites and Tuscan Springs gas and salt water are found in rocks of the Chico group, and the fossils collected around Marysville Buttes, where gas is found, are referred by Dr. Cooper to the Chico Tejon or probably Eocene period.

There are five things which are all-important to consider in geological investigations with reference to natural gas: First, the lateral extent of the gas-bearing formations; second, the thickness of these formations; third, the porosity of the rocks, with a view of approximating their gas-holding capacity; fourth, the pressure under which the gas exists; and fifth, the character of the strata overlying the gas-holding rock; for unless the strata overlying the gas-holding rocks are of such a nature as to restrain the gas beneath them, a profitable gas field can never exist.

Investigation warrants the belief that the Cretaceous formations extend all through the Sacramento Valley, coming to the surface in the foothills and underlying the filling in the central portion of the valley. It is not known that the thickness of the Cretaceous formation in the Sacramento Valley has ever been estimated, but there is reason to believe that the Cretaceous rocks are thicker on the eastern slope of the Coast Range than on the western slope of the Sierra. There is also every reason to believe that many of the Cretaceous strata are sufficiently porous to afford good storage room for gas.

The question of the pressure under which the gas exists is an important one, but unfortunately it is a subject on which we have the least evidence; in the first place, because there are so few gas wells in the Sacramento Valley; in the second place, because the few that exist are full of water.

Of course, any gas that finds its way into the casing of a well, in excess of that which can be held in solution by the water, will come to the surface by its specific gravity; and in a flowing well films of gas are no doubt dragged by the water from the porous strata in which the gas is held.

If a well is only 330 feet deep, the pressure of the gas in the strata at the bottom of the well would have to exceed that of eleven atmospheres; that is, it must be more than 165 pounds to the square inch before the gas could escape. We have already seen that when dry gas was struck in the sandstone at Marysville Buttes, its pressure is said to have been sufficient to blow the borings out of the drill-hole; and it is possible that if the water could be excluded from wells in other portions of the valley, equally strong flows of gas might be obtained.

With regard to the character of the strata overlying the gas-holding rocks, we have abundant evidence. Throughout both the Sacramento and the San Joaquin Valleys borings made to obtain water penetrate sheets of clay, which appear to extend throughout the valley lands, and to overlie the gas-holding formations.

It would be a very interesting experiment to make a deep boring in a well-chosen spot in the Sacramento Valley, and to shut off the water by screw casings from the upper portion of the well, or if that could not be done, to exhaust the water by pumping. We should then know something definite about the pressure of the gas; and appearances certainly indicate that in some places sufficient gas might be obtained to be of practical value if it could be used on the spot.

In the more recent formations, in the central portions of the valley, where flowing water might be encountered, the task of shutting off the water would be difficult, and experiment alone could determine whether it is possible to exclude the water without shutting off the gas. Such is the record, up to date, of natural gas and petroleum in the Sacramento Valley.

NATURAL GAS IN THE SAN JOAQUIN VALLEY.

The Stockton Gas Wells.—In Stockton and vicinity there are more than twenty wells which yield natural gas in sufficient quantities to be of practical value. Indeed, for the last five years it has been an established fact that at Stockton, by boring to the depth of something less than 2,500 feet, sufficient gas can be obtained to light and materially reduce the fuel bill of a large factory, or to supply a group of families with light and fuel. The following record of strata penetrated by one well bored at the Stockton court-house, and by another which was sunk at the Jackson baths, gives an idea of the formation underlying the city of Stockton; and to a certain extent shows the nature of the strata holding the gas, and of the sheets of clay beneath which the gas is stored.

The Court-house Well.—This well, commenced in February, 1890, as mentioned in our Xth Report, was completed in December of the same year. In boring this well, after penetrating soil, hardpan, and clay to a depth of 60 feet, a stratum of blue clay was met, and from that on blue clay alternated with thin strata of sand until a depth of 220 feet was reached. At this depth a stratum of gravel more than 30 feet in thickness was encountered, the pebbles composing which varied from the size of marbles to that of a man's fist. Beneath this gravel, strata of clay, cement, and sand alternated to a depth of 900 feet, and then 30 feet of coarse sand was passed through. This sand yielded a large flow of good water. Beneath this sand the following strata were observed:

Character of Strata.	Depth at which the Strata were Observed to Change.
Coarse sand	to 930 feet.
Dark-colored clay	to 970 feet.
White marl, principally lime	to 990 feet.
Fine grayish quicksand	to 1,040 feet.
Coarse sand	to 1,070 feet.
Bituminous shale or clay (gas)	to 1,100 feet.
Soft, grayish sandstone	to 1,125 feet.
Grayish clay, full of holes, some of which were filled with white clayey matter	to 1,160 feet.
Coarse sand	to 1,200 feet.
Gray, ferruginous, sandy clay	to 1,230 feet.
Quicksand	to 1,280 feet.
Very soft, friable sandstone, with gas	to 1,300 feet.
Grayish, sandy clay, with infiltrations of white clayey matter, very hard	to 1,325 feet.
Light-colored, sandy cement	to 1,350 feet.

Character of Strata.	Depth at which the Strata were Observed to Change.
Sand	to 1,370 feet.
Clay, with little quartz pebbles	to 1,410 feet.
Sandy cement, with gas	to 1,450 feet.
Cement, more clayey	to 1,490 feet.
Coarse sand	to 1,530 feet.
Soft, clayey sandstone	to 1,560 feet.
Clayey sandstone, harder (gas)	to 1,600 feet.
Light-colored, friable sandstone	to 1,630 feet.
Light-colored, friable sandstone, but more clayey (gas)	to 1,660 feet.
Cement gravel (gas)	to 1,700 feet.
Indurated clay (gas)	to 1,800 feet.
Clean, soft, friable sandstone (gas)	to 1,870 feet.
Sample omitted from those sent to the Bureau	to 1,890 feet.
Coarse sand (gas)	to 1,917 feet.

The principal gas-yielding strata were encountered, and the casing perforated, at the following depths: 1,100 feet, 1,300 feet, 1,450 feet, 1,600 feet, 1,660 feet, 1,700 feet, 1,740 feet, 1,800 feet, 1,900 feet. This well is 12 inches in diameter at the top; at a depth of 670 feet it is reduced to 10 inches, and at 1,100 feet to 8 inches. The flow at the completion of the well is said to have been about 30,000 cubic feet of gas every twenty-four hours, and a large stream of water. The record of this well is especially interesting, from the fact that the method of boring allowed samples of the various strata to be brought up in masses, which gave a much better idea of the character of the formations penetrated than methods which pulverize the material before it is brought to the surface. Moreover, samples were preserved and forwarded to the Mining Bureau for examination. The most interesting stratum was the bituminous shale or clay which was struck at a depth of 1,070 feet, and the calcareous stratum which was penetrated between the depths of 970 and 990 feet. The bituminous sample presented no organic structure under the microscope, but some air-dried fragments examined showed the following composition:

Water	0.40 per cent.
Volatile hydrocarbons	55.03 per cent.
Fixed carbon	16.10 per cent.
Ash	28.46 per cent.
	99.99 per cent.

A very small portion of the mass was soluble in carbon di-sulphide.

Of course it is only natural that dried samples when examined in the laboratory should seem much firmer than when first brought up wet from the well. Some of the strata penetrated by the Stockton gas wells, besides the actual sands and clays, are of a fine, loamy nature, varying from sandy to clayey; and resemble the Loess of the Mississippi Valley, except that the said Loess is usually buff-colored or of a reddish cast, while the material brought up from the wells at Stockton is usually of a bluish color. No doubt the reason of this is that the iron contained in the material from the gas wells at Stockton is in the ferrous condition, while that of the Loess in the Mississippi Valley is principally in the ferric, *i. e.*, the more highly oxygenized compound.

The peculiar bluish sand which is frequently brought up during the process of boring deep wells in the Central Valley of California is similar in appearance to the bluish sand composing some of the lower foothills of the San Joaquin Valley, as hereinafter described. Other samples brought up by the sand-pump from the gas wells mentioned resemble the friable sandy formations of the Kern River, which perhaps we may tentatively refer to the Pliocene group. But it is not well to place too much reliance on the comparative lithological structure of sedimentary rocks; for the physical appearance of the newer derivative formations frequently resembles that of the older sedimentary rocks from which they are formed.

Jackson Well No. 1.—This well, as mentioned in our IXth Report, was commenced in 1890. The casing has a diameter of 12 inches at the top, and $9\frac{3}{4}$ at the bottom; the depth of the well is 1,700 feet. The principal flows of gas and water were struck at the following depths: 746 feet (a small flow), 896 feet, 1,180 feet, 1,270 feet, 1,312 feet, 1,350 feet, 1,460 feet, 1,508 feet, 1,654 feet, 1,700 feet. The total yield of gas from this well is estimated at about 70,000 cubic feet in twenty-four hours. The water is used in a swimming-bath which has been built by Mr. Jackson at his wells.

Record of Strata Penetrated below a Depth of 880 Feet.

Coarse sand, with good flow of water and gas	880 feet.
Cement, porous in places, increased flow of water and gas	896 feet.
Cement gravel	914 feet.
Coarse sand	934 feet.
Hard blue cement	964 feet.
Quicksand	980 feet.
Blue clay cement	1,000 feet.
Porous, sandy cement, with gas	1,030 feet.
Tough clay	1,138 feet.
Blue, shaly "joint-clay"	1,170 feet.
Sand, with flow of water and gas	1,180 feet.
Cemented sand	1,230 feet.
Hard clayey cement	1,260 feet.
Porous sand, with flow of water and gas	1,270 feet.
Conglomerate	1,315 feet.
Unctuous clayey cement	1,334 feet.
Hard cement	1,340 feet.
Sand, with a large flow of water and gas	1,350 feet.
Cement	1,360 feet.
Hard, blue, slaty cement	1,426 feet.
Sand and gravel	1,430 feet.
Hard cement	1,445 feet.
Porous rock, with large flow of gas	1,460 feet.
Hard cement	1,500 feet.
Sand	1,508 feet.
Hard cement	1,530 feet.
Sand	1,535 feet.
Hard cement	1,578 feet.
Sandy clay	1,580 feet.
Porous, clayey sand and rock	1,600 feet.
Cement	1,630 feet.
Porous, sandy rock, yielding much gas	1,640 feet.
Loose sand	1,644 feet.
Cement	1,650 feet.
Sand, with large flow of gas and water	1,655 feet.

From this well, the incisor tooth of a horse, a much-worn carnivorous molar, and two fragments of jawbone, were brought up by the sand-pump from a depth of 1,058 feet.

Jackson Well No. 2.—This well, which was commenced in July, 1891, is situated about 110 feet south of the Jackson Well No. 1. The formation is similar to that of the first well. Gas was struck at a depth of 800 feet, and could be ignited in the casing. The water at that depth stood 4 feet from the top of the casing. As the well was bored deeper, it yielded an increased volume of gas, issuing from hard, porous strata; flowing water was struck at a depth of 1,350 feet. This well is said to be 1,400 feet in depth.

The Asylum Wells.—In March, 1892, the depth of Asylum Well No. 1, at the State Insane Asylum, was increased till it reached 1,750 feet. This resulted in a large increase in the flow of gas and water. In addition to the use of the gas in the laundry, the female department of the asylum is now entirely illuminated by it. The gas is also used as fuel for a ten horse-power engine, which pumps the sewage of the establishment, and the three horse-power engine, which pumps water for irrigation.

A new well was commenced at the asylum in 1892, the contract for boring being let to Haas & Jensen, of Stockton. In May, 1892, 600 feet had been successfully bored, and cased with 15-inch No. 12 iron, riveted pipe. A careful selection of specimens of the various strata passed through was being made under the supervision of Major Orr.

The St. Agnes Well No. 2.—This well was bored during 1891–2 at the St. Agnes College, and is about 75 feet south of Well No. 1, which was bored in 1889. This second well was bored to a depth of 1,720 feet, and the strata penetrated resemble those noted in the first well, a record of which is given in our Xth Report. The yield of the new well is more than 25,000 cubic feet of gas in twenty-four hours, and there is also a large flow of water. The well is cased with 10-inch double casing, No. 14 iron, to a depth of 900 feet; at this depth it is reduced to 8-inch, and this carried down to 1,240 feet, below which it is reduced to 6-inch. The 6-inch casing was cut at a depth of 1,100 feet, and pressed down to that depth. In the autumn of 1891 the St. Agnes Well No. 1 ceased to flow, and simultaneously the gas ceased to rise. A trench cutting the pipe of the well about 4 feet below the surface of the ground was then dug from the well to the bank of Mormon Slough. By this means flowing water was again obtained, and the well yielded gas as before.

The Stockton Natural Gas Company.—The officers of this company state that their new well has been completed, and the gas from it turned into the main. This company has built a new gasometer, which holds about 22,000 cubic feet of gas, thus doubling the gas-storing capacity of the plant belonging to the Stockton Natural Gas Company. The officers of the company report that the yield from their first well, *i. e.*, the Haas Well No. 1, is now about 80,000 cubic feet every twenty-four hours; and from their second well, which is said to be about 2,000 feet deep, about 43,000 cubic feet.

During the past year a great improvement has been made by the use of the "Welsh back burner" for household illumination by natural gas. With this burner the Stockton natural gas can be used directly from the meter without carburetting.

Mr. Haas, who bored the wells of the Stockton Natural Gas Company, stated that, while boring the second well, the gas expelled the water from the iron pipe forming the "boring-rod"; the gas was under such pressure that it burst the fire-hose attached to the escape pipe, which happened to be closed. Upon the bursting of the hose, the water again rose in the "boring-rod" and flowed therefrom. To obviate a recurrence of such an accident, Mr. Haas attached a vent-cock to the "boring-rod."

The Stockton Gas Light and Heat Company.—In the spring of 1894 work was still in progress at the well belonging to this company, and the well was said to be 1,400 feet deep. Tools had been lost in the well, but it is stated that they have been recovered.

The Citizens' Well.—This well, which was bored for the Citizens' Natural Gas Company in 1890, is said to yield 42,000 cubic feet of gas in twenty-four hours, and also a large flow of water. The well is 2,061 feet deep.

The Grant Street Well.—A well was commenced in February, 1892, by Jerome Haas at the corner of Fremont and Grant Streets, Stockton. When visited in May, 1892, this well had been bored to a depth of about 900 feet, and a small amount of gas was perceptible. Mr. Haas said that on April 28, 1892, when the casing was being forced down under a pressure of 100 pounds to the square inch, a slight earthquake occurred, and immediately thereafter it required a pressure of 800 pounds to the square inch to move the casing. The resistance gradually diminished until the former pressure of 100 pounds was sufficient to force the casing down.

The Central Well.—A well was commenced in 1891, on American Street and Miner Avenue, in Stockton, by a company organized under the name of the Central Natural Gas Company.

Other Gas Wells at and near Stockton.—A description of other gas-yielding wells, which have been sunk in Stockton and its immediate vicinity, can be found by referring to our VIIth, VIIIth, IXth, and Xth Reports.

Gas Well on Roberts Island.—The farthest west that natural gas has been obtained in San Joaquin County is on Roberts Island. On this island, at a point about 14 miles west of Stockton, a well, which yielded flowing water and gas, was sunk in 1883 by General Williams. This well is said to be 1,435 feet deep, and to be cased in the upper portion with 7-inch, and in the lower portion with 5-inch casing. The gas yielded by this well is said to have been sufficient to supply the ranch house with light and fuel. The water is saline, and it is said that the well was closed to prevent the water running on the land.

Natural Gas at Byron Springs.—Inflammable gas is found at Byron Springs, in the foothills of Contra Costa County. At this place the gas rises with thermal mineral water from springs and shallow borings. For a further description of these springs, see our VIIIth Report, p. 163.

At the Cutler Salmon Ranch, on the French Camp road, a well was bored in 1883 to the depth of 1,250 feet. At first a 7-inch pipe was put down to the depth of 1,250 feet, and inside of that a 4-inch pipe to the depth of 1,140 feet. The large pipe, which has no connection with the smaller one, yields a stream of fresh water and a small amount of inflammable gas. The 4-inch pipe yields brackish water and a larger amount of gas. The gas is used on the ranch for light and fuel.

In 1884 a well was bored to the depth of 1,404 feet at the *Pope Salmon Ranch*, about 9 miles southeast from Stockton. The well is cased with 7-inch pipe for the first 700 feet, and with 5-inch pipe from that depth to the bottom. The well yields sufficient gas for domestic purposes; the water is plentiful.

At Lathrop Junction an 8-inch well was bored in 1888 to a depth of 1,420 feet; this well yields flowing water and about 2,500 cubic feet of natural gas every twenty-four hours.

At the County Hospital, one mile east of Modesto, on the eastern side of the San Joaquin Valley, in Stanislaus County, a small quantity of gas rises from a well 1,070 feet deep. This well does not yield flowing water.

In Merced County inflammable gas has been struck, together with flowing water; and this is the case in more than one well a few miles southwest of Merced City, at a depth of about 600 feet. The formation penetrated is alternate strata of sand and clay. Thus, on the Oulds ranch, which is 6 miles south of the county seat, the gas from a well 600 feet deep is collected in a receiver 9 feet in height and 6 feet in diameter. This receiver is filled in less than twenty-four hours, although much gas goes to waste. The gas is used on this ranch for heating and lighting purposes, and gives great satisfaction. It is interesting to note, in this connection, that there are wells between the county seat of Merced County and the San Joaquin River, of greater depth than the one on the Oulds ranch, which yield flowing water but no gas.

At a point about 7 miles southeast of *White's Bridge, in Fresno County*, a well was bored in 1892 which yielded inflammable gas and flowing mineral water. The formation penetrated is sand and clay; flowing water was struck at a depth of 480 feet. Below a depth of 800 feet the sand became hard, "like sandstone"; at a depth of 1,050 feet it became black, with some gas rising through the water; at 1,100 feet there was enough gas to furnish fuel for the engines running the drill. Mineral water flowed from this well.

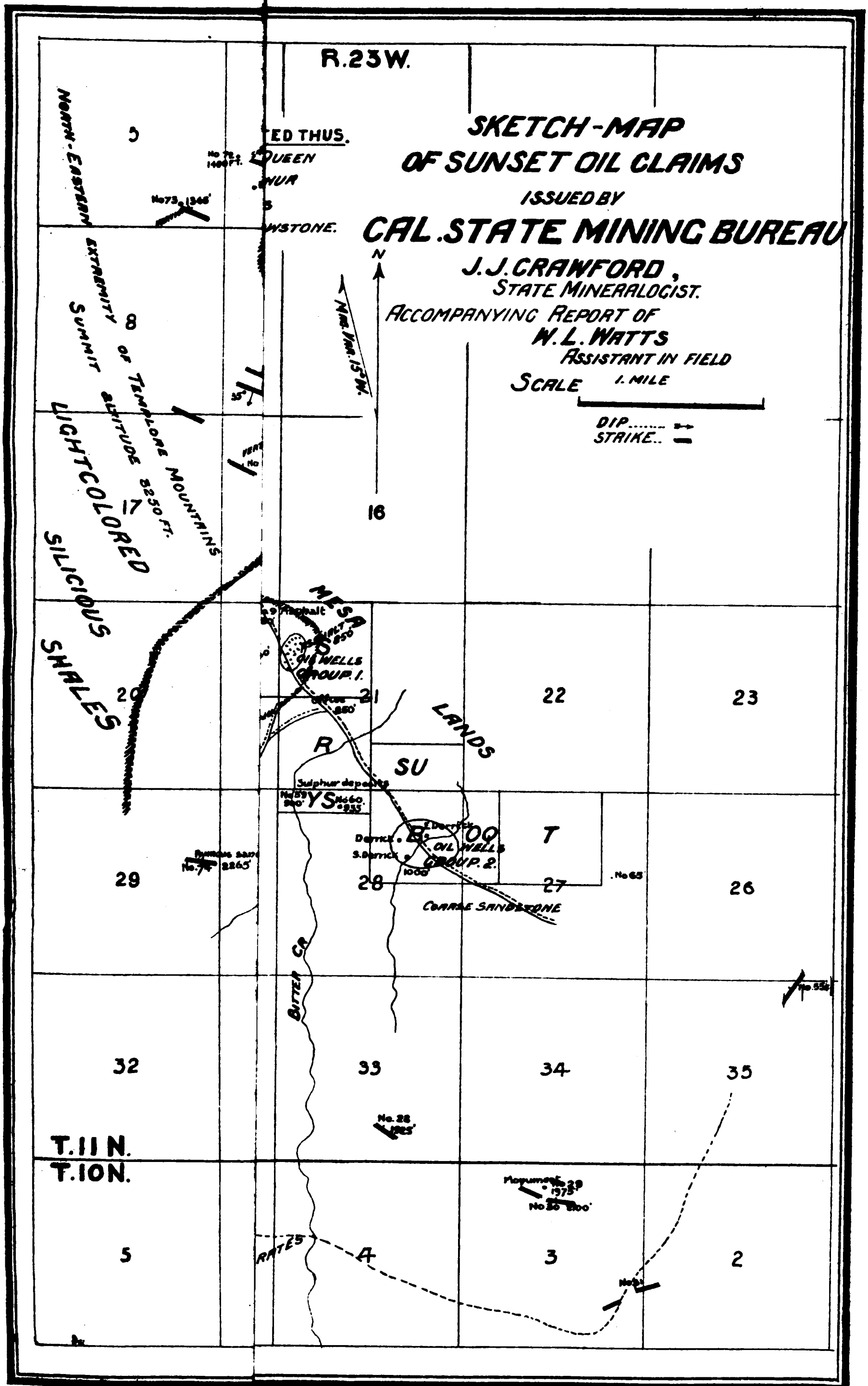
Near *Tulare Lake*, in Tulare County, several wells yield natural gas and flowing water. Thus, at the *Sevilla Colony*, 16 miles southwest of Pixley, there is a well 600 feet deep which yields sulphuretted water and a large quantity of gas. It is said that the yield of gas from this well amounts to several thousand feet a day; that the gas burns with a clear flame, and that it has been running to waste for more than five years.

At the *Lambertson Ranch*, also near Lake Tulare, a well was bored in 1889 to a depth of 1,058 feet, which yields both flowing water and natural gas; the formation is alternate strata of sand and clay, with much quicksand. The last 200 feet or more were nearly all through fine sand, which contains numerous shells. Some of these shells were examined by Dr. Cooper, who determined them to be *Amnicola turbiniformis* and *Sphærium dentatum*. The first named is a Pliocene, and the latter is a living fresh-water mollusk. From these shells it appears that the filling of the valley to a depth of 1,058 feet is, geologically speaking, very recent.

On the *Jacobs Ranch*, about 7 miles north of the Lambertson well, in July, 1889, a well was bored to the depth of 887 feet. Flowing water was struck between the depths of 508 and 514 feet. The formation was similar to that at the Lambertson well, but it contained less quicksand. At the depth of 190 feet a flow of gas was encountered which forced the water out of the casing. As the casing was nearly filled with water at the time, the gas must have been under a pressure of more than seven atmospheres—that is, more than 105 pounds to the square inch. The gas appeared to come from a stratum of blue sand about one foot in thickness, which was overlaid by a stratum of blue clay 50 feet thick. Fifteen different flows of water were observed in this well, and an increase of the amount of gas was observed as each flow of water was struck.

GENERAL REMARKS ON OIL, GAS, AND ASPHALTUM IN KERN COUNTY.

Petroleum and gas bearing formations are found on both sides of the San Joaquin Valley in Kern County. At the Sunset Oil District and at Asphalto, on the western side of the valley, the petroleum and gas yield-



SKETCH-MAP
OF SUNSET OIL CLAIMS
ISSUED BY
CAL. STATE MINING BUREAU
J. J. CRAWFORD,
STATE MINERALOGIST.
ACCOMPANYING REPORT OF
W. L. WATTS
ASSISTANT IN FIELD
SCALE
1. MILE
DIP
STRIKE
R. 23 W.
T. 11 N.
T. 10 N.
NORTH-EASTERN EXTREMITY OF TEMBLORE MOUNTAINS
SUMMIT ALTITUDE 3250 FT.
LIGHTCOLORED SILICIOUS SHALES
MESA
LANDS
OIL WELLS GROUP. 1.
OIL WELLS GROUP. 2.
Sulphur deposits
COARSE SANDSTONE
BITTER CR.
Mag. Var. 15° W.
N
5
8
16
17
20
21
22
23
29
28
27
26
32
33
34
35
5
3
2

ing rocks are extensively exposed, and oil and asphaltum industries are carried on. At 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., and T. 25 S., R. 18 E., M. D. M., as described in our VIIth Report, p. 67. Inflammable gas is found at the Barker ranch, in Sec. 5, T. 29 S., M. D. M., as recorded in this article. On the eastern side of the valley, however, the showing of hydrocarbons is insignificant compared with that on the western side. This may be partly accounted for by the fact that the geological disturbance of the Tertiary rocks on the western side is very great, while on the eastern side it is very slight. Moreover, it is not improbable that on the eastern side of the valley the formations contemporaneous with the rocks yielding oil on the western side are overlaid by more recent Tertiary strata, in which the hydrocarbons are not very abundant. On the eastern side of the valley, the Tertiary formation is well represented, as shown by fossils collected in the vicinity of the Rio Bravo ranch. The writer obtained a small collection of Tertiary 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.

As can be seen by examining the record of the strata penetrated by wells which have been sunk for water in the valley lands of Kern and Tulare Counties (see our XIth Report, pages 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. The petroleum and gas-yielding formations of Kern County will now be considered more closely, beginning with the Sunset Oil District, on the western side of the valley.

TOPOGRAPHY OF THE SUNSET OIL DISTRICT.

The territory comprising what is locally known as the Sunset Oil District (although no such mining district has been organized) is situated in the first two tiers of the northeastern foothills of the Coast Range, which rise to the southward of Buena Vista Lake, and stretches out a short distance into the mesa lands which form the southern border of the San Joaquin Valley in Kern County. The two tiers of foothills mentioned commence in the most northeasterly portion of the Templore Mountains, and extend in a southeasterly direction until they sink in the rolling mesa lands. A bird's-eye view of this locality from a suitable eminence on the mountains to the southward demonstrates the fact that these foothills are but a remnant of what was once a much more extensive formation. In the western portion of the territory under discussion a large gap, coinciding with the bed of Bitter Water Creek, has been eroded nearly at right angles to the prevailing strike of the country rock. Another valley, as shown on the sketch-map hereto appended, has been worn in a direction nearly parallel to the prevailing strike of the formation; this valley almost cuts off the first tier of hills, which are composed mainly of light-colored shale, from a second tier in which sandstone predominates.

At two other places, shown respectively on the sketch-map as "Cienega" Creek and Bitter Creek, ravines have been cut through the hills transversely to the prevailing strike of the country rock; and they are occupied by the dry beds of the creeks named. Opinions differ with regard to the correct name of Cienega Creek, hence it is marked "Cienega?" on the accompanying sketch-map.

The rocky strata throughout the foothills forming this portion of the Coast Range are greatly obscured by soil, upon which fair grazing is furnished during the spring. The continuity of this heavy mantle of alluvium no doubt results from the scarcity of rain. During the winter, violent storms occasionally send torrents down the channels, which in some places cut so deeply into the earth as to expose the rock beneath. For the rest of the year, these dry creek-beds are the embodiment of aridity, except when there is a cloud-burst in the mountains. These cloud-bursts occur during thunder storms, usually during the summer time, and they give rise to muddy debacles, which sweep with resistless force through the parched watercourses, tearing off huge masses of the softer formations, and strewing the mesa lands with blocks of harder rock from the higher portions of the Coast Range. Some of these creek-beds are white with effervescent salts, and in places they are moistened by saline springs. There is no potable water in the Sunset Oil District.

To the southward of the district, tier after tier of mountainous ridges rise toward the dominant ridge of the Tehachapi range, as this portion of the Coast Range is named upon the Kern County map. The northeastern slope and the greater portion of the summit slope of the Tehachapi range is covered with alluvium. On the summits of these mountains there are not only grazing, but agricultural lands. Potable water is found in springs, and also by digging in the bottom of ravines; and although the writer is informed that several dry wells are often dug before water is obtained, the water supply appears to be sufficient for the requirements of the inhabitants.

THE GEOLOGY OF THE SUNSET OIL DISTRICT AND ADJACENT TERRITORY.

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 Tehachapi range. These ridges are, for the most part, formed by flexures in the stratified rocks, which create, as it were, subsidiary anticlinals, some of which are very acute, their slopes frequently presenting an angle of more than 60°. The strike of this formation, in a general way, is southeasterly and northwesterly. These rocks yield springs of sulphuretted and saline water, and of potable water at a few places in the higher portions of the mountains. It is said that at one place in this formation there is a seepage of oil. 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 Cretaceous system; (*b*) Miocene fossils, also from thick sandstone strata.

The rocky formations of the Sunset Oil District will now be enumerated in what appears to be the order of their relative stratographical superposition. 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 Range, which are richer in palæontological evidence. The most ancient series of rocks exposed in the Sunset Oil District consist of sandstone, calcareo-silicious rocks and impure limestone, dark-colored earthy and sandy shales, massive light-colored shales which show 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.

These rocks are best exposed along what appears to be the axis of a flexure, which forms the second tier of foothills which rise to the southward of the mesa-land. A general view of the situation leads to the conclusion that this flexure has been modified, not only by erosion, but by faulting. This formation yields springs of sulphuretted brines, and in one place (Station 52; see sketch-map) a small quantity of greenish oil accompanies the brine; but no tufa nor any solid bituminous deposit is formed. No fossils were found in this formation. The most striking characteristic features of this formation are the earthy and sandy shales, and the sandstone containing rounded concretions. It may here be remarked that similar shales and sandstones constitute Late Cretaceous strata, which are found beneath light-colored silicious shales in the oil district 9 miles north of Coalinga, in Fresno County.

The next formation is composed mainly of light-colored silicious shales, and constitutes the first tier of foothills. These shales are frequently 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.

This light-colored silicious shale is by far the most characteristic rock of the bituminous formations; much of it is of low specific gravity, is porous, sticking readily to the tongue, and is easily scratched; some of this shale, 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. 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:

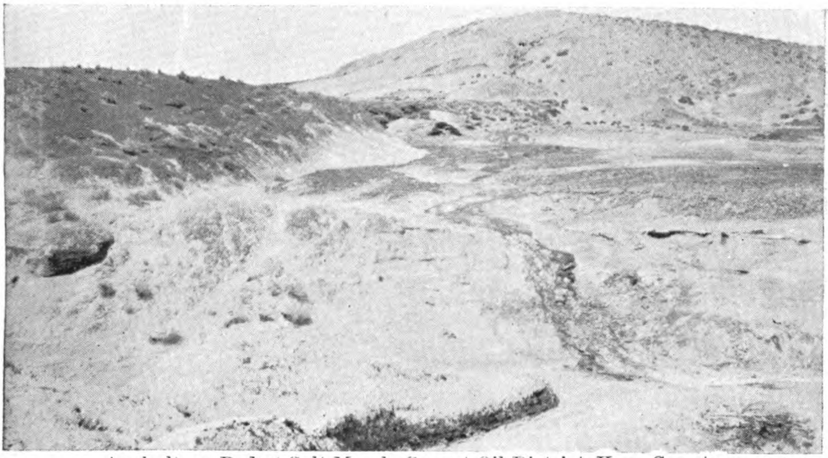
	Insoluble in Acid.	Silica Soluble in Sodium Carbonate.	Total Amount of Silica.
(*a*)	99 per cent.	12 per cent.	98 per cent.
(*b*)	91 per cent.	24 per cent.	89 per cent.

Only very small quantities of alumina were present in these specimens; indeed, one gramme of the shale did not yield a sufficient quantity of alumina for accurate estimation. The only other constituent of the portion of the shale which was insoluble in acid was a little iron. The constituents soluble in acid were not worked out; qualitatively (*a*) showed iron and a little lime; (*b*) showed iron, lime, and magnesia.

In some places these light-colored shales are interstratified with sandstone, and also with calcareo-silicious strata. The sandstone is seldom many feet in thickness, frequently only a few inches. The granules of which the sandstone is composed are usually individualized, although in some instances they appear to be metamorphosed and emerged in a silicious mass. There are also a few loosely coherent sandy strata, which are scarcely compact enough to be called sandstone; they are usually micaceous, and sometimes saturated with petroleum. The silicious rocks, as far as macroscopic inspection can determine, are amorphous, and they frequently possess a cleavage resembling the soft, silicious shales with which they are interstratified. Many of these silicious rocks are calcareous, varying from a flinty rock, which shows a slight reaction with hydrochloric acid, to a silicious limestone. These hard strata ("shells," as the well-borers call them) are usually either white or buff-colored, but occasionally they are reddish brown, at least such is their appearance where they crop out at the surface of the ground. These silicious strata, like the shales they interstratify, are darker colored at some distance beneath the surface. The reason of this change in color probably is that underground the rocky formation includes some moisture and bituminous matter, which evaporates when the rock is brought to the surface; also that the iron contained by rocks beneath the surface is in the ferrous condition, which changes to the ferric on exposure to the air.

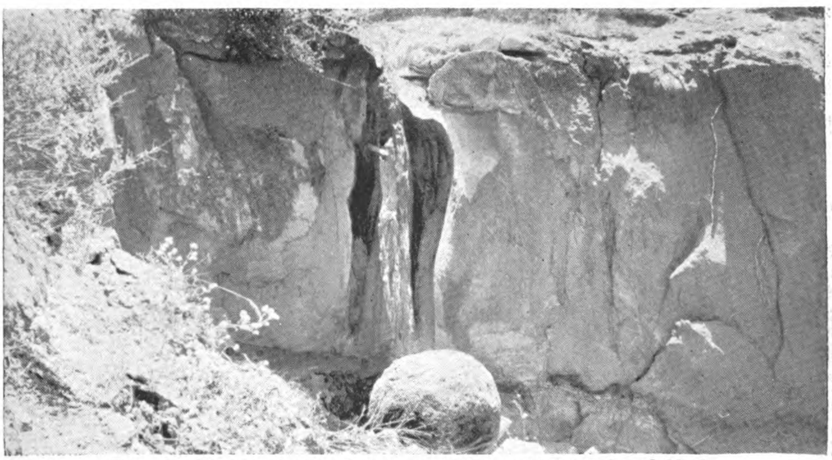
The light-colored shales are much less disturbed than the formation on which they rest. The direction of the dip of the light-colored shales in the Sunset Oil District varies from 5° to 35° east of north; and the angle of inclination is in some places as low as 20°, while in others it is as high as 80°. The northerly direction of the dip appears the most pronounced in the eastern portion of the district, and the angle of inclination increases toward the bottom of the formation. On the Santa Jaga Creek, however, in the eastern extremity of the district, the dip is southwesterly, and at an angle of less than 20°. At several places in this light-colored shale there are seepages of heavy, black oil, with springs of sulphuretted brine and saline water; and the heavy oil has formed beds of solid bitumen, as hereinafter described.

In the eastern extremity of the Templore Mountains, where the first tier of foothills which traverse the Sunset Oil District appears to culminate, the formation is almost entirely light-colored shale. The dip of this shale in these mountains warrants the belief that that formation has been thrown by flexure into two short anticlinals. It is no great



Asphaltum Bed at Salt Marsh, Sunset Oil District, Kern County.

Sulphur Deposits, Sunset Oil District, Kern County.



Peculiar Erosion in Sandstone underlying Light-Colored Shale.
Sunset Oil District, Kern County.

stretch of the imagination to suppose that if the strata forming such anticlinals were prolonged to the eastward, the northern slope of the southernmost anticlinal would correspond to the main body of the light-colored shales which yields the heavy oil and brine in the Sunset Oil District; and that the northern slope of the northern anticlinal would correspond to the strata which furnish the springs of heavy oil and brine at Salt Marsh, in the northern extremity of the district. These features can be further observed in the accompanying sketch-map by noting the direction of the arrows showing the dip of the light-colored shale; but the erosion which has taken place, and the alluvium with which the hills are covered, render the expression of opinion hazardous.

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 Range. In one instance a well was dug at an altitude of nearly 3,000 feet, in which light-colored shales similar in appearance to those found in the lower foothills were penetrated.

At two oil seepages in the northern edge of the light-colored shale formation, viz.: a short distance southwest of Flag No. 3, and at Station No. 66, as shown in the sketch-map, there are calcareous strata containing marine shells. Only three specimens, however, were obtained which were sufficiently perfect for identification. These were found by Dr. Cooper to be of the latest Tertiary epoch:

Tapes staleyi, Gabb	Pliocene.
Macoma inquinata, Desh	Living, Pliocene.
Mya arenaria, Linn	Living, Pliocene.

The fossiliferous strata are situated near the southern edge of sandstones which dip in a northerly direction. The remnant of this sandstone formation which is exposed in the district is insufficient to warrant much being said upon the subject.

Last in order come the formations which are but little disturbed, some of which are practically horizontal. With one exception the opportunities for examining these deposits in the Sunset Oil District are still more rare than in the case of the underlying Tertiary sandstones.

Briefly these horizontal formations are as follows:

(*a*) Hard, white, silicious sandstone, which appears to have been indurated by infiltering water. This rock is exposed about two miles northwest of the oil springs at Salt Marsh, where it shows a thickness of about 60 feet; also at the sulphur deposits near the Sunset Oil Well.

(*b*) A soft, white, gypseous rock, which rests uncomformably 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 upon the mesa-land. It can also be seen resting upon the upturned edges of older strata at an altitude of nearly 2,000 feet. A specimen of this white rock was examined in the laboratory of the California State Mining Bureau and was found to be composed of sulphate and a carbonate of lime and clayey matter.

(*c*) Soft, friable sandstones, which can be seen in the low hills adjacent to the oil springs at Salt Marsh.

(*d*) Travertine, calcareous tufa, and breccia, containing numerous fragments of light-colored shale. These rocks can be seen near the brine and oil springs, a short distance to the northwest of Flag No. 5.

MINERALS, OIL CLAIMS, AND BITUMINOUS DEPOSITS OF THE SUNSET OIL DISTRICT.

The mineral products of the rocky formations of the Sunset Oil District are inflammable gas, petroleum, asphaltum, mineral water, sulphur, and gypsum. Of these minerals, those to which this article is principally devoted are the hydrocarbon compounds. These occur as gas and oil, which are yielded by natural springs and by wells which have been bored, and also as superficial deposits of oil-soaked earth or rock, and as beds of asphaltum; the latter, no doubt, are caused by exudations of heavy oil from which the lighter naphthas have evaporated, and which have undergone a partial oxidization.

The group of oil and sulphur claims which constitute what is locally known as the Sunset Oil District are as follows: The Jewett and Blodgett claims, the Bakersfield, the Texas, the Oil Queen, the Ravena, and the Sulphur claims. As shown in the accompanying sketch-map, these claims extend diagonally about 6½ miles in a northwesterly and southeasterly direction, viz.: from Sec. 2, R. 24 W., T. 12 N., S. B. M., to Sec. 27, R. 23 W., T. 11 N., S. B. M.

In this district by far the greatest amount of development has been done by Messrs. Jewett and Blodgett, of Bakersfield, on the Sunset, the Jewett and Blodgett, and the Bakersfield claims.

The first mineral of the Sunset District placed upon the market by Messrs. Jewett and Blodgett was asphaltum, obtained principally in Section 20 from a bed of asphaltum through which most of the wells marked on the sketch-map as *Oil Wells, Group 1*, are sunk and from stations marked No. 9 and No. 10, respectively. When the mining of asphaltum was first commenced at *Oil Wells, Group 1*, there was a bed of asphaltum, which extended over several acres, varying in thickness from 3 to 25 feet or more. This asphaltum, which was of different degrees of purity, existed not only in exposed mounds, but was found by excavation to extend in some places beneath the superficial drift. In the asphaltum the bones of animals were discovered, as well as some stone mortars, the latter being found beneath 4 or 5 feet of asphaltum. The beds of asphaltum at Stations 9 and 10 present similar characteristics to the asphaltum at the oil wells, and trenches which have been cut through the asphaltum show it to be very similar, both as to quality and depth. The superficial asphaltum is of good quality, but beneath it the asphaltum is dry and pulverulent and mixed with earth. The dry asphaltum is used for fuel. In several places heavy oil oozes through the asphaltum. The asphaltum is principally black, pitch-like bitumen, varying from solid to viscous; some of it, however, is yellowish in color.

An asphaltum refinery was erected at the Sunset Oil Wells by Messrs. Jewett and Blodgett, the process employed for refining the asphaltum being similar to that hereinafter described as used at Asphalto. The raw material yielded from 50 to 75 per cent of refined asphaltum. About 1,200 tons of refined asphaltum were shipped from these works during 1892. The best quality of raw material in these beds has been worked up, and the refining of crude asphaltum was discontinued at the Sunset Oil Wells when the Southern Pacific Railroad Company extended its branch line to Asphalto, about 30 miles distant, where there are deposits of asphaltum near the railroad. The cost of producing refined asphaltum at the Sunset works was about $10 a ton, not including wear and tear of plant. The cost of transportation by wagon from the Sunset Oil Wells to Bakersfield was $6 a ton.

OIL WELLS OF JEWETT AND BLODGETT.

Messrs. Jewett and Blodgett bored two groups of wells in the mesa lands of the Sunset Oil District. One of these groups, which is marked "*Oil Wells, Group 1,*" on the sketch-map, is in Section 21; and the other, marked "*Group 2,*" is in Section 28. In Group 1 there are thirteen wells, one of these being 1,300 feet in depth, the remainder varying from 80 to 500 feet in depth. The 1,300-foot well yielded flowing water and much gas; the others yield a heavy oil by pumping. The twelve oil-producing wells are all situated within an area of about 400 feet in length and 30 feet in width. The 1,300-foot well was bored a short distance in a northeasterly direction from the most northerly of the oil-yielding wells. The twelve oil wells yield altogether about 15 barrels of oil every twenty-four hours. The specific gravity of this oil varies in the different wells from about 12° Baumé to a heavy liquid asphaltum that requires to be heated by steam, which is forced to the bottom of the well, before the heavy oil can be pumped. Six of these are dry wells, and are sunk to a depth of from 80 to 100 feet. The stratum yielding the greater portion of the heavy oil is about 35 feet in thickness. The other six are drilled wells varying from 150 to 500 feet in depth. All these wells are sunk to a sufficient depth to form reservoirs at the bottom capable of storing the oil which gathers during several days, for a few hours of pumping is sufficient to pump the oil accumulated during twenty-four hours. Each well is furnished with a pumping-jack, consisting of knee and frame, which is securely anchored to the ground or mud sills. All these wells are pumped with lift pumps, which have a 4-inch working barrel, pumping from the bottom. It is necessary to pump heavy oil at a very low rate of speed; indeed, the speed employed is only four strokes of two feet a minute. All the pumps are worked simultaneously by connecting rods which are attached to a large oscillating wheel, run by a 10-foot driving-wheel. (See illustration in our XIth Report, p. 233.) The power is supplied by a fifteen horse-power link-motion, single-action engine. This pumping plant, together with the engine and boiler, is run by one man.

This method of simultaneously pumping so many wells from one source of power, and at different angles, was devised by Mr. E. Youle, the Superintendent of the Sunset Oil Works, and of the works of the Standard Asphalt Company, at Asphalto. The oil is pumped by this method from the wells into two tanks, each of which is 12x20x2 feet in dimensions. In these tanks, the heavy oil, which is accompanied by more or less water, is heated by steam coils to a temperature of from 212° to 220° Fahr. This lessens the specific gravity of the oil, and allows it to rise to the surface of the water. As much water as possible is drawn from the bottom of the tanks, and the remainder, which is entangled in the oil, is expelled as steam, by increasing the temperature in the tanks. The oil is then conducted by a 3-inch pipe from the tanks to two refining kettles, each of which is 12 feet long, 5 feet wide, and 3 feet deep. These kettles are set in brick work, and in construction resemble those hereinafter described at Asphalto, the only difference being that the former are furnished with air-tight lids, fitted with goose-neck pipes connected by unions with a coil and condenser.

The process of refining the oil is as follows: As soon as a kettle is filled, the lid is left partially open, until the oil will stand a temperature of 300° Fahr. without foaming. During the early stage of this process the man in charge has constantly to watch the contents of the kettle, and so to regulate the heat as to prevent the oil from foaming. When the oil remains perfectly still, at a temperature of 300° Fahr., the cover is screwed down, and the temperature of the oil is gradually heated to 550° Fahr. The vapors given off are drawn into the condenser pipe by a suction produced by an air-compressor blast, and the expansion of the air, as it leaves the compressor, maintains the water in the condenser-box at a low temperature. During the entire process the oil is constantly stirred by a stirrer, consisting of paddles attached to a shaft which runs through the kettle. This stirrer is worked by a wire cable running from the oscillating wheel in the power-house, which also works the pumps, as previously described.

The crude oil yields about 50 per cent of distillates, which have an average specific gravity of 20° B. The heat is increased toward the end of the process to 700° Fahr., in order to expel the heavier distillates and make the refined asphaltum hard. It is the intention of the Sunset Company to treat these heavy distillates by fractional distillation; and at the time of the writer's visit these distillates were being stored in tanks for that purpose.

During the process of refining, the oil is from time to time drawn from stop-cocks in the kettles and tested. The process is considered completed when, on withdrawing a sample of the residue and pouring it into water, it forms a hard, black, lustrous substance, which bends slightly, and breaks under a moderate pressure of the hand. The residue, which consists of refined asphaltum, is then discharged into a kettle suspended on a carrier. This kettle is furnished with a swing-pipe, through which the refined asphaltum is drawn off into boxes in a manner hereinafter described when speaking of the process of refining asphaltum at Asphalto.

The fire-boxes under the kettles at the Sunset works, like those at Asphalto, are furnished with grate bars formed of iron pipe. The fuel is the dry crude asphaltum. The manager of the Sunset works states that the asphaltum made in these oil kettles is 100 fine, and that it is used in the manufacture of printing ink and varnish.

RECORD OF OIL WELLS, GROUP 1.

The following records show the character of the formation penetrated by the wells belonging to Group 1:

Well No. 1.

Bored in March, 1891. This well was commenced with 11-inch casing.

Surface drift, to a depth of	50 feet.
Light-colored shale, to a depth of	400 feet.
At this depth mineral water rose to within 40 feet of the top of the casing.	
Black sandy shale, to a depth of	559 feet.
At this depth the diameter of casing was reduced to 8⅝ inches.	
Black sandy shale, with black sulphur water, to a depth of	610 feet.
At this depth, casing reduced to 6⅝ inches.	

Black sandy shale, to a depth of	700 feet.
Gas from this depth burned with a flame 4 feet high from a 7-inch pipe.	
Black sandy shale, with oil in seams, to a depth of	900 feet.
At this depth, casing reduced to 5⅝ inches.	
Very light-colored shale, to a depth of	928 feet.
Gray sand rock, with flowing water, to a depth of	995 feet.
At this depth the well flowed 50 barrels of mineral water daily, and yielded much gas but little oil.	
Light-colored shale, to a depth of	1,235 feet.
Dark-colored shale, which caved badly, to a depth of	1,250 feet.
At this depth, casing reduced to 4⅞ inches.	
Dark-colored shale, to a depth of	1,290 feet.

The first gas was noticed at a depth of 600 feet, and two other distinct flows were struck at depths of 928 and 1,200 feet, respectively.

Well No. 2.

Asphaltum, to a depth of	30 feet.
Dark-colored shale, with a small amount of oil, to a depth of	60 feet.
Dark-colored shale, with more oil, to a depth of	130 feet.
Light blue shale, with either oil or water, to a depth of	500 feet.
In this shale a thin stratum of light blue sand was passed through.	

Well No. 3.

Asphaltum, to a depth of	40 feet.
Dark-colored shale, with some oil, to a depth of	110 feet.
Light blue sand, to a depth of	160 feet.

Well No. 4.

Asphaltum, to a depth of	50 feet.
Drift from the mountain, to a depth of	65 feet.
Shale, with some oil, to a depth of	70 feet.
Dark-colored shale and oil, to a depth of	130 feet.
Dark-colored shale, without oil, to a depth of	160 feet.
Light-colored shale, to a depth of	237 feet.

About 40 or 50 barrels of mineral water flowed from this well daily.

Well No. 5.

Asphaltum, to a depth of	25 feet.
Dark-colored shale, to a depth of	50 feet.
Dark-colored shale, with oil, to a depth of	121 feet.
Dark-colored shale, without oil, to a depth of	150 feet.
Light-colored shale, without oil, to a depth of	185 feet.

There was no water in this well.

Well No. 6.

Wash and drift, to a depth of	30 feet.
Dark shale and oil, to a depth of	75 feet.
Dark shale, without oil, to a depth of	120 feet.

The boring ended in light shale. There was no water in this well.

Well No. 7.

Light-colored shale, to a depth of	82 feet.
Dark-colored shale, with oil, to a depth of	175 feet.
Light-colored shale, to a depth of	215 feet.

There was no water in this well.

Well No. 8.

Yellow hardpan, to a depth of	15 feet.
Dark-brown wash and gravel, to a depth of	47 feet.
Dark-colored shale, with a slight showing of oil, to a depth of	110 feet.

Beneath the dark-colored shale a greenish shale was penetrated for a few feet. This greenish shale yielded brackish water, which filled the hole to within 15 feet of the top. After the well had been shut down for some days heavy asphaltum oil accumulated in the casing to the depth of about 60 feet. Mr. Youle, the Superintendent, is of the opinion that the stratum yielding the oil lies at the depth of about 110 feet.

Well No. 9.

White soil	20 feet.
Greenish soil and gravel	35 feet.
Hard "shell"	2 feet.
Dark-colored "mushy mud"	63 feet.
Brown shale, intercalated with sandy "shells" and streaks of green sand; "cavy" formation	42 feet.

Water was struck at the depth of 180 feet.

Well No. 10.

Earth and drift	40 feet.
Blue clay	30 feet.
Brown shale	130 feet.

There was no oil below the depth of 70 feet.

As will be seen from the accompanying sectional map, these wells are situated along a strip about 400 feet in length, which has a course of about 57° west of north. A large pile of material has been taken out of these wells, and the fragments of shale, of which it was principally composed, have become light-colored under the action of the atmosphere. No fossils were found amongst this material, but its physical appearance left no doubt but that it belongs to the light-colored shale formation previously described as constituting the first tier of foothills in the Sunset Oil District.

RECORD OF OIL WELLS, GROUP 2.

In 1892–93 Messrs. Jewett and Blodgett bored three wells on the mesa lands in Section 28, at a point a little more than a mile distant from Oil Wells, Group 1, and in a southeasterly direction therefrom. These last bored wells are marked on the sketch-map as Oil Wells, Group 2. The following records show the character of the formation penetrated:

Well No. 1.

This well was commenced with a 11⅝-inch casing.

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

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

Well No. 2.

This well is situated about 200 paces a little south of west from Well No. 1.

Earth and gravel	60 feet.
Blue sandstone with some very hard streaks	175 feet.
Gray and bluish sandstone	430 feet.
This stratum yielded daily about one barrel of oil mixed with water.	
Sandstone, first soft then hard (more oil and water)	535 feet.
Soft sandstone, passing into hard sandstone with streaks of mud (more water, oil, and gas)	660 feet.
Sand, with a little oil and much water	820 feet.

This well was cased with 8⅝-inch casing for the first 245 feet, and below that depth with 6⅝-inch casing. The writer is informed that about 150 barrels of sulphuretted mineral water and 4 barrels of oil were pumped from this well in twenty-four hours.

Well No. 3.

This well is situated about 150 paces a little east of south from Well No. 2.

For the first 300 feet a similar formation was penetrated to that passed through in Wells No. 1 and 2	300 feet.
Bluish gray sandstone, with an occasional streak of darker colored and sharper sand	755 feet.
At this depth there was much gas and a little oil. At the depth of 540 feet the water was shut off with 6⅝-inch casing.	
Brown sand, with considerable oil	815 feet.

Barren sandstone	940 feet.
Oil-bearing sandstone	950 feet.
Light-blue sand	1,030 feet.
At this depth a blue clay impeded drilling.	
Dark-blue sandstone, with more gas	1,060 feet.
Light-blue sandstone, with more gas	1,180 feet.
At this depth there was an increase in the amount of gas and oil.	
Sandstone	1,210 feet.
Black shale	1,215 feet.
Sandstone	1,220 feet.
Close-grained shale, with more oil	1,270 feet.
Oil sand	1,295 feet.
Coarse sand	1,350 feet.

It is the gas from this well which was used in the experiments on the fuel value of the gas at Sunset, as hereinafter recorded.

The oil yielded by the oil wells of Group 2 is a dark green oil, and possesses a lower specific gravity than that yielded by the oil wells of Group 1.

OTHER OIL SEEPAGES AND OIL WELLS.

At Station 64, in what is known as Robber's Gulch, there is a seepage of heavy oil, and a small amount of asphaltum has been formed. (See sketch-map.) The upper portion of the oil-yielding formation at this point is a fossiliferous sandy limestone, in which the fossils are very poorly preserved. Beneath the fossiliferous stratum is a soft, gray sandstone, about 100 feet in thickness; and beneath the soft, gray sandstone is an oil-soaked stratum of sandstone, which rests upon light-colored shale, interstratified with thin courses of sandstone. The outcropping shale shows a thickness of about 100 feet; this formation dips 13° west of north at an angle of about 55°. The shale exhibits considerable flexure.

In the cañon to the west of Flag No. 3, there is another bed of asphaltum, which extends up the cañon for about 200 yards. In these asphaltum beds there are several springs of heavy oil, which flow feebly during hot weather. At the base of the hill on which Flag No. 3 is situated, fossiliferous strata are exposed. The strata containing the fossils, and the soft, sandy strata composing the hill to the northeast of the fossiliferous formation, appear to dip in a more easterly direction and at a less angle than is the case with the light-colored shales on which they rest.

A short distance farther southward, at Station 6, light-colored shale crops out, which is intercalated with bituminous sandstone. This formation pitches about 30° east of north, and at an angle of about 54°.

In the mouth of the cañon about half a mile westward from Flag No. 3, there is another irregular deposit of asphaltum; and at point C a well was bored, it is said, to the depth of 1,300 feet. This well flows about 500 barrels of salt water daily. A little oil and some gas accompany the salt water, which flows with spasmodic energy. A small amount of oil also oozes up around the outside of the casing.

A hundred yards or so in a southeasterly direction from the flowing well, another well was bored to the depth of 70 feet. This well must be nearly full of oil, for a heavy black oil could be easily pumped with what was said to be an ordinary suction-pump, which was fixed in the casing.

Near the mouth of the cañon to the westward of the flowing well, there is another small bed of asphaltum. At the entrance to this cañon there is a series of ledges of travertine, which are practically horizontal. In some places this travertine contains fragments of light-colored shale; some of the travertine is vesicular, and the vesicles are filled with petroleum. Here and there asphaltum has flowed over the travertine, but its source is obscured by drift from the mountain. The formation to the southward is principally light-colored shale, which at Flag No. 5 is interstratified with whitish sandstone, and at one point contained sections of what appear to be fish vertebræ. At this point a thin stratum of gypseous material rests unconformably on the upturned edges of the shale and sandstone strata, which dip 45° east of north at an angle of about 40°. To the southward of Flag No. 5, light-colored shales and silicious shales predominate. The abraided edges of these shaly strata are worn off level with the surface of the ground and form broad bands, which traverse the barren country, with a strike of about 60° east of south. In some places slight flexures in these strata are very distinctly marked on the slopes of the bare hills.

Extending in a northwesterly direction from Flag No. 5 are a series of springs, which yield sulphuretted and saline water, and a small amount of heavy oil. Two of the principal springs, which yield sulphuretted water are situated at Stations 21 and 22, and between them are several other seepages of mineral water. (See water analyses at end of bulletin.) These springs have deposited a large amount of tufaceous matter, some of which is calcareous. The springs give off a large amount of sulphuretted hydrogen. In their vicinity there is a saline crust on the surface of the ground. Beneath this crust the soil is pulverulent, and sustains a growth of bright-green plants, which flourish in the saline soil, and they show a marked contrast to the faded whity-green of the sagebrush. Specimens of these plants were examined in the herbarium of the California Academy of Sciences, and found to be *Spirostachys occidentalis*, *Nitrophila occidentalis*, and *Distichlis maritima* (salt grass).

In the hills which rise to the northwest of these springs the formation is much obscured by alluvium. In some places light-colored shales crop out, but the strata are flattened or undulating, and in two places near Flag No. 7 they dip to the southward, as shown on the sketch-map. The physical appearance of the shale forming these flattened strata is somewhat different from that of the light-colored shale yielding heavy oil.

At Salt Marsh there are several springs of sulphuretted brine, some of which deposit tufa. The course of the salt formation to the westward is marked by bright-green plants similar to those previously mentioned. At Salt Marsh there is an asphaltum bed of about five acres in extent (see illustration), but it appears to be a comparatively thin layer. This asphaltum bed is nearly surrounded by low hills. Most of these hills are covered with alluvium, but in the principal hill there are a few outcropping ledges of light-colored shale and sandstone, which show an average dip of about 30° east of north, at an angle of about 60°. From one of the sandstone strata a few specimens of very small pectens were obtained, but they were too imperfect for identification. These peculiar features of soil and vegetable growth are also characteristic of other localities in the oil-bearing formations of the Coast Range, where the ground is moistened by the waters of saline springs.

A few hundred yards to the eastward of Flag No. 8 what appears to be a more recent formation than the light-colored shales has been cut through to make a roadway. This formation consists of friable sandstone and sandy shales, containing fragments of light-colored silicious shale. The dip is to the east of north at an angle of not more than 30°. A short distance to the northeast of Flag No. 8, a well was bored to the depth of 325 feet. This well yields a small stream of sulphuretted brine, which is accompanied by inflammable gas and a small amount of oil.

OIL CLAIMS EAST OF SECTION 28, T. 11 N., R. 23 W., S. B. M.

In the mesa lands and low foothills which lie to the eastward of the Oil Wells, Group 2, there are several oil and sulphur claims. The writer, however, made only a brief reconnoisance of this portion of the Sunset Oil District, and for the following reasons: (1) Because it was obvious that the geological formation is so obscured by alluvium and drift that much work might be done and a great deal of time spent in vainly searching for outcropping rocks. (2) Because very little development had been made on these claims. (3) Because the geological formation was evidently similar to that of the portion of the Sunset Oil District herein described, where extensive developments have been made, and where there are rock exposures by which the oil-yielding strata may be examined.

The principal developments that have been made in this portion of the Sunset Oil District are two wells on the Texas claim, owned by Hambleton and others. One of these wells is 18 feet in depth, the material passed through being earthy decomposed sandstone. The man who dug the well says that the strata of sandstone which he penetrated are standing nearly vertical, and that oil and gas were blown through crevices in the bottom of the well. The other well is situated about 100 yards south of the first, and at a slightly higher elevation. The formation passed through is sandstone. This well yields less oil, but more water and gas than the first one. At the time of the writer's visit these wells were partly filled with salt water, and with oil which floated on the surface of the water.

THE SULPHUR DEPOSITS OF THE SUNSET OIL DISTRICT.

Sulphur appears to be a concomitant of the oil-bearing formations, or rather of the more recent formations overlying them. The deposits of sulphur in Sunset Oil District and vicinity are found under the following conditions: (*a*) As drift cemented with sulphur; (*b*) as irregular masses of sulphur in the drift; (*c*) as sulphur encrusting or filling fissures in the rocks which underlie the drift and appear to rest unconformably on the oil-yielding formations; (*d*) as sulphurous earth; (*e*) as sulphurous precipitate in the waters of mineral springs.

Deposits of sulphur and sulphurous rocks and earth were observed at the following places in Sunset District:

At Station 27, as previously mentioned, there is a series of light-colored sandstones, some of which are very silicious and brecciated; they are practically horizontal, and taken together show a thickness of about 75 feet. Some of the lower strata of sandstone are impregnated with sulphuric acid or acid sulphur salts.

At Station 27*x*, which is situated about 150 yards west of Station 27, and at a slightly greater elevation, there is an outcrop of white, brecciated, clayey sandstone. Beneath the sandstone is a black, earthy, decomposed rock, containing sulphur; this rock is impregnated with acid, and has a fetid odor, which appears to result from the action of sulphuric acid on bituminous matter.

In the vicinity of the springs at Stations 21 and 22 there are acid, sulphurous earths, some of the latter being black and having a fetid odor. The waters of some of these springs are turbid with precipitated sulphur.

At Station 14 there are outcroppings of a light-colored sandstone, which is very acid to the taste.

At Station 58 the surface soil is pulverulent, and is apparently formed from a decomposed tufaceous material, while here and there some undecomposed fragments of the silicious rock protrude. Associated with the harder rocks is a soft, dark-colored, sulphurous formation, possessing a fetid odor. These sulphurous deposits extend for some distance, and have a trend of 80° east of north.

At Station 59 much sulphur is associated with partially decomposed sandstone, which has a strongly astringent taste. This rock is interstratified with a darker colored rock of similar structure. The whole deposit has the appearance of having undergone metamorphism from mineral springs or solfataric action.

The surface of the low hills on which Station 59 is situated shows sulphurous earth and sulphurous rock throughout an area of several acres. These sulphur deposits have been prospected by excavation to a depth of 10 or 12 feet, and have been found to consist of drift cemented with sulphur and acid decomposed rocks containing sulphur.

The sulphur-bearing formation evidently extends from Station 59 to Station 60. At the latter place an excavation shows a sulphurous deposit very similar to that at Station 59. At Station 60 there is an excavation which exposes a fissure varying from 2 to 6 inches or more in width, and having a direction of 65° west of north and east of south. The sides of this fissure are lined with high-grade sulphur ore, which extends for a distance of a foot or more on both sides of the fissure. The sulphur ore appears to be fine drift cemented with much sulphur.

On the eastern slopes of the low hills on which the principal sulphur deposits are situated, are several excavations, about 4 feet in depth, which show rich sulphur ore. These workings, which have been made in light-colored sulphurous rock and earth, also expose fissures from which "chimneys" of sulphur extend nearly to the surface of the ground. A man who dug some of these holes states that when the fissures were first opened they gave forth a strong flow of acid pungent gas. In these excavations the air is redolent with acid sulphurous gases, and the peculiar fetid odor before mentioned is perceptible in most places. (In the illustration of "sulphur deposit," the hammer and drill are placed upon a chimney of sulphur. The walls of the excavation shown are formed of sulphurous earth.)

A few hundred yards eastward from Station 60 there is an excavation about 10 feet in depth. This has been made all the way in high-grade sulphur ore, interstratified with dark-colored and acid sulphurous earth. Lateral extensions of this excavation have been made to the depth of 4 or 5 feet; in some of them solid sulphur has been struck, and in all the earth is acid and sulphurous. The massive sulphur exposed in this pit is of a grayish color, and some lying on the dump was coated with lemon-colored crystals of sulphur. From this excavation a decomposed sulphurous formation extends in a northeasterly direction, and prospect workings encountered an acid-tasting sandstone at a depth of about 5 feet. In many places what appears to be a tufaceous deposit is exposed, which, on weathering, forms a white silicious rock. Still farther eastward there is a recent formation containing numerous small fragments of light-colored shale. In some places these fragments form a breccia. This superficial formation pitches to the southward.

Deposits of sulphur and sulphurous earth, similar in character to those already mentioned but of less extent, are exposed at intervals in an easterly direction across the mesa lands between Stations 60 and 67. Thus a line of sulphurous deposits extends in an easterly direction for more than a mile between Stations 59 and 67. There are, as already mentioned, numerous springs in the Sunset Oil District which yield sulphuretted water.

Since so many have evinced an interest in the history of these deposits, a few remarks on their probable genesis may not be out of place. If we turn to our chemical text-books, we find that when a solution of sulphuretted hydrogen is exposed to the air it soon becomes turbid, owing to the oxidization of the hydrogen and the consequent precipitation of the sulphur, the reaction that takes place being $(2H_2S+aq)+O_2=(2H_2O+aq)+S_2$. Also, that if the chemical action is assisted by the sulphurous vapors or solutions being absorbed by porous solids, the oxidization is more complete, and that the chemical reaction that then takes place can be expressed by the equation: $(H_2S+aq)+2O_2=H_2SO_4+aq$.

This view as to the formation of these sulphur deposits is strengthened by finding that many of the rocks in contact with the sulphur are acid with free sulphuric acid or acid sulphur salts, and that gypsum and alum usually accompany the sulphur.

With regard to the primordial source of the sulphuretted hydrogen, the probability is that it originated in the decomposition of the tissues of organisms, the carbonaceous constituents of which composed the petroleum and the hydrocarbon gases found in the Sunset Oil District. It is probable that such was the origin of the sulphur deposit referred to, and that the fissures through which the sulphur gases rise in the territory under discussion, allow the escape of such gases from the stratified rocks in which they were formed by chemical processes; not, as popularly supposed, that the fissures conduct the sulphurous gases from a volcanic source.

There are other deposits of sulphur and sulphurous earth in the southeastern borders of the Sunset Oil District, but they present similar characteristics to those already described.

GYPSUM.

The principal deposit of gypsum in the Sunset Oil District is situated in its southeastern borders. The gypsum forms a stratum of rather soft, chalky-looking rock, which in some places attains a thickness of several feet. Much impure gypsum is also found at and near the sulphur deposits previously described. A ravine, which is situated immediately to the east and southeast of Oil Wells, Group 2, cuts through a bank of this material to the depth of about 30 feet. This bank is composed of sedimentary strata, which appear to have been metamorphosed by the waters of mineral springs. The exposed rocks have the appearance of a friable white sandstone, containing much gypsum and kaolinized matter. In some places there are streaks and pockets of nearly pure kaolin and small masses of pure gypsum.

MINERAL WATER.

[See analyses of water at the end of this bulletin.]

REMARKS ON THE SUNSET OIL DISTRICT.

A review of the foregoing description of this territory, when taken in conjunction with investigations made in the oil district 9 miles north of Coalinga, in Fresno County, leads to the conclusion that there are two oil-yielding formations in the Sunset Oil District; but the paucity of palæontological evidence in this territory demands that such a conclusion be accepted tentatively. The most recent of formations, geologically speaking, consists principally of light-colored silicious shales, which practically compose the first tier of foothills. A line drawn across the sketch-map, in such a manner as to pass through the principal oil springs and asphaltum beds, shows that these oil seepages and asphaltum deposits are distributed along a line which corresponds very nearly with the prevailing trend of the light-colored shales, *i. e.*, about 70° east of south. It is also to be noticed that the different places where such oil springs and asphaltum beds are found in this formation have nearly the same altitude. These facts suggest that the principal oil-bearing strata are situated near the northern limit of the light-colored shales which are exposed at the Sunset Oil District, although it by no means necessarily follows that the rest of that formation is barren. The slight deviation of such oil seepages from a line coinciding with the prevailing strike of the formation is fully accounted for by local disturbances of the strata at many places in the territory under discussion.

The occurrence of these oil springs may be referred to two causes: (1) The cutting through of oil-yielding strata by erosion. In this connection the fact is recalled that many of the oil springs and beds of asphaltum are situated where cañons cut through the formation nearly at right angles to its strike. (2) In some instances the immediate cause of the oil springs may be referred to fracture of oil-bearing strata, by which means fissures are formed, which extend to the surface of the earth. As heretofore described, such fissures can be seen at the sulphur deposits in the mesa lands of the district.

The wells marked Oil Wells, Group 1, show what might be expected from wells penetrating the oil-yielding formations in the light-colored shales; and we should naturally expect that wells piercing the oil-yielding strata where there are no seepages of oil would yield better results than wells situated in localities where seepage has for ages been exhausting the contiguous oil-bearing rocks. That which is here assumed to be the second oil-yielding formation, immediately underlies the light-colored shales.

The wells marked on the sketch-map as Oil Wells, Group 2, appear to have been bored to prospect this formation. As previously mentioned, this lower formation is characterized by two things; namely, the absence of the peculiar light-colored shales such as compose the formation lying next in the order of upward vertical range, and the presence of dark-colored, argillaceous, earthy or sandy shales, which resemble certain shales found beneath the light-colored shales in the oil district nine miles north of Coalinga. These argillaceous, earthy shales can be seen near Station 52, where sulphuretted brine, accompanied by a little dark-green oil, issues from a soft sandstone. At Stations 49 and 49*a* there are also springs of sulphuretted and saline water, and earthy and sandy shales are exposed. Dark-colored shales can also be seen in the bed of the Cienega Creek, between Stations 32 and 33. If we journey in a southeasterly direction from the points named (which, notwithstanding much contortion of strata, appears to be the prevailing strike of this lower formation), we shall come out on the mesa lands in the vicinity of "Oil Wells, Group 2." Unfortunately, the heavy mantle of alluvium with which the hills are covered, and the disturbed character of this lower formation, prevent one from being able to speak with any degree of confidence concerning the stratigraphical position of the rocks penetrated by these wells. The writer searched diligently for geological evidence which would throw light on this subject, but the results are meager. Neither do the records of the strata penetrated during the process of boring "Oil Wells, Group 2," nor the character of the oil yielded by these wells when they were completed, solve this problem.

As will be seen by reference to the table of oil analyses at the end of this bulletin, the oils yielded by Wells Nos. 1, 2, and 3, both in their specific gravity and the character of their distillation products, resemble the samples of oil obtained from Tertiary strata, rather than the sample obtained from the Cretaceous formation at Coalinga. Moreover, whatever evidence might be deduced by a comparison of the oil yielded by "Oil Wells, Group 2," with oil obtained from strata of known geological age, is vitiated by the existence of such fissures as those found in the sulphur deposits of the Sunset Oil District. These rifts may penetrate formations of more than one geologic age, and occasion a blending of such oils as the strata contain. Moreover, deep-seated fissures are quite likely to induce an unusual oxidization of the hydrocarbons contained in the fractured rocks.

It is possible that a careful geological examination commenced at Mud Creek, and extended in a northwesterly direction, might tell something about the geologic age of the bench of sandstone in which "Oil Wells, Group 2," are bored. The brief reconnoisance in the vicinity of Mud Creek suggests that the Tertiary sandstones overlying the light-colored shales extend farther to the westward in that locality than they were observed to do in the Sunset District. Moreover, the heavy deposit of impure gypsum seen to the south of the Sunset Oil District resembles similar deposits on the eastern side of the San Joaquin Valley, which were probably formed during the Pliocene age.

The greatest drawback to a successful prosecution of the oil business in the Sunset District appears to be the large amount of water which accompanies the oil. In this connection, the fact must be borne in mind that the Sunset Oil Wells are bored at an altitude of something less than 1,000 feet, and that the maximum altitude of the anticlinal prospected by them does not exceed 2,000 feet. It is probable that there are portions of the Coast Range adjoining the Sunset District' where the oil-bearing formations extend to a much higher altitude than the anticlinal which has hitherto been prospected by boring; and that there may be extensive oil-bearing territory on the northeastern slope of the Coast Range, where no difficulty would be experienced from water. A partial analysis of the water obtained from Wells Nos. 2 and 3, Group 2, is given at the end of this bulletin.

THE SAN EMIDIO GRANT.

A hasty visit was paid to Muddy Creek and the San Emidio Grant. At the former place the formation is principally sandstone, and many fragments of gypsum are scattered on the slope of the hills. A spring of strong sulphur water is situated on the southern bank of the creek. The surface of the water in this spring is covered with sulphur, and the air is redolent with sulphuretted hydrogen. The taste of the water is nauseating in the extreme, and is said to act with severity on the bowels.

At the San Emidio Grant the writer followed the outcrop of a thin stratum of fossiliferous limestone from Muddy Creek in a southwesterly direction, and obtained several fossils, which were submitted to Dr. J. G. Cooper for examination, who classified them as follows:

Fossils Collected on San Emidio Grant between the Muddy and Lobos Creeks.

Crassatella collina, Con.	Pliocene, Miocene.
Glycimeris generosa, Gould	Living, Quaternary, Pliocene, Miocene.
Macoma secta, Con.	Living, Quaternary, Pliocene.
Neverita recluziana, Pet.	Living, Quaternary, Pliocene, Miocene.
Dosinia mathewsoni, Gabb	Miocene.
Macoma, n. sp.	
Tapes staleyi, Gabb	Pliocene.
Tapes, n. sp.	
Cryptomya californica, Gabb	Living, Quaternary, Pliocene, Miocene.

At Lobos Creek, on the San Emidio Grant, was observed a stratum of shells about 2 feet in thickness, and it appeared to be composed entirely of *Crassatella collina*. The formation dipped to the east of north, and at an angle of about 70°. The fossiliferous stratum rested on a light-colored shale, which was exposed higher up the creek. A large amount of bituminous matter had issued from the shale, accumulated in the creek, and, flowing down the creek-bed, had formed a layer of brea overlying the shelly stratum.

NATURAL GAS AND FOSSILIFEROUS FORMATIONS ON THE EASTERN SIDE OF THE SAN JOAQUIN VALLEY.

The wagon road from Sumner to the Rio Bravo ranch traverses a series of alluvial bluffs, which form the first bench of the eastern foothills. These foothills, where the Kern River enters the valley, are formed for the most part of soft Tertiary strata, which abut the granitic rocks of the Greenhorn Mountains. The Tertiary formation here is mainly friable sandstone, traversed by a few thin strata of sandy limestones and fossiliferous rock. The characteristic features of the formation are a large amount of quicksand and some beds of impure gypsum. In many of the bluffs beds of cobblestones and bowlders are exposed. From a bluff on the west side of Kern River, about 2 miles down the stream from the Rio Bravo ranch, is found a ledge of fossiliferous sandstone. On the south line of Kern River, a few miles eastward from the Rio Bravo ranch, near the contact of the Tertiary and the granitic rocks, several thin fossiliferous strata were noted. The surface of the hills is in some places covered with impure gypsum. From the top of what is locally known as Pyramid Mountain, at an elevation of 2,800 feet, is an extended view showing the line of contact between the granite and the sedimentary strata, the eastern margin of the latter being in places strewn with fragments of granite, which protrudes here and there through the softer formations. To the west and south nothing but sedimentary formations appear to be in sight. Near the top of Pyramid Mountain a ledge of fossiliferous rock crops out. This ledge also forms the summit of a neighboring elevation farther eastward, which is about 150 feet lower than Pyramid Mountain. Both these eminences are situated on the divide between Poso Creek and Kern River.

In 1891, Mr. J. Barker, who resided at the Rio Bravo ranch, discovered natural gas in a spring on his property in the center of Sec. 5, T. 29 S., R. 29 E., M. D. M., and he erected a small receiver in order to utilize the gas for illuminating purposes. He bored a 10-inch well about 300 yards east of the above-mentioned spring, which is situated on the south bank of the river, and probably 15 feet above the water's edge. The formation penetrated is a fossiliferous clayey sand. At a depth of 26 feet a flow of 8 miner's inches of mineral water, and some gas, was obtained. The temperature of the water was found to be 80° Fahr. The well was continued through a similar formation to a depth of 48 feet. Casing was then pushed down, and the water to the depth of 26 feet was shut off. When this was done, the gas and water forced their way up outside of the casing. A stream of not less than 2 miner's inches then flowed from the casing, and the well yielded a greater volume of gas than the spring in which the gas was first observed. At a depth of 48 feet a stratum of limestone was struck, a fragment of which contained a good specimen of *Solen rosaceus* of unusually large size. A partial analysis of the water from this well, made by Prof. E. W. Hilgard, was as follows:

	Grains to the gallon.
Sodium and potassium sulphate (Na_2SO_4 and K_2SO_4)	22.99
Common salt (Sodium chloride) ($NaCl$)	197.00
Sodium carbonate (Na_2CO_3)	22.52
Calcium and magnesium sulphate ($CaSO_4$ and $MgSO_4$)	5.55
Silica (SiO_2)	5.21
Total	253.27

The following fossils were obtained by the writer from the Tertiary formation in the vicinity of the Rio Bravo ranch, and they were afterwards submitted to Dr. J. G. Cooper for classification:

From Bluff on North Side of Kern River about Two Miles down the Stream from Rio Bravo Ranch.

Conus californicus, Hinds	Living, Quaternary, Pliocene.
Neverita callosa, Gabb	Miocene.
Dosinia mathewsoni, Gabb	Miocene.
Pecten discus, Con.	Miocene.
Cerithium, n. sp.	
Tapes staleyi, Gabb	Pliocene.
Axinæa patula, Con.	Pliocene, Miocene.
Cancellaria, n. sp.	
Lunatia lewisi, Gould	Living, Quaternary, Pliocene.
Nassa californica, Con.	

Meretrix tularana, Con.	Miocene.
Solen rosaceus, Cpr.	Living, Quaternary, Pliocene, Miocene.
Teeth of *Oxyrhina tumula*, Agassiz	
Teeth of *Oxyrhina plana*, Agassiz	
Vertebræ of some reptile's tail bones	

From Ravine near the Contact of the Granite and Tertiary Formation.

Tellina ocoyana, Con.	Miocene.
Dentalium, n. sp.	
Myorella, n. sp.	
Neverita callosa, Gabb	Miocene.
Arca microdonta, Con.	Pliocene, Miocene.

From various places on the South Side of Kern River on the Barker Ranch.

Solen rosaceus, Cpr.	Living, Quaternary, Pliocene, Miocene.
Tooth of *Oxyrhina plana*, Agassiz	
Cypricardia (?), n. sp.	
Agasoma (?), n. sp.	
Arca microdonta, Con.	Pliocene, Miocene.
Neverita callosa, Gabb	Living, Quaternary, Pliocene, Miocene.
Tellina ocoyona, Con.	Miocene.
Yoldia impressa, Con.	Living, Quaternary, Pliocene, Miocene.
Acila, n. sp.	
Leda, n. sp.	

From North Side of the Kern River on the Barker Ranch.

Pinna alamedensis, Yates	Miocene.

From Pyramid Mountain, about Five Miles North of the Rio Bravo Ranch.

Dentalium, n. sp.	
Axinæa patula, Con.	Pliocene, Miocene.
Pecten discus, Con.	Miocene.
Chione pertenuis, Gabb.	Miocene.
Crepidula grandis, Midd.	Quaternary, Pliocene, Miocene.

From Bluff near Pyramid Mountain.

Ostrea heermanni, Con.	Pliocene.

The specimens of marine mollusca collected by the writer near Kern River and at the San Emidio ranch, when classified by Dr. J. G. Cooper, were found to represent the following palæontological periods:

Thirty-three Species from Eastern Side of the San Joaquin Valley, near Kern River.

	No. of Species.	
Miocene	10	19 Miocene.
Miocene, Pliocene	4	
Quaternary, Pliocene, Miocene	1	
Living, Quaternary, Pliocene, Miocene	4	
Pliocene	2	5 Pliocene.
Living, Quaternary, Pliocene	3	
N. sp.		9

Nine Species from San Emidio Ranch on the Western Side of the San Joaquin Valley.

	No. of Species.	
Miocene	1	5 Miocene.
Pliocene, Miocene	1	
Living, Quaternary, Pliocene, Miocene	3	
Pliocene	1	2 Pliocene.
Living, Quaternary, Pliocene	1	
N. sp.		2

Dr. J. G. Cooper says: "It should be remarked that the proportions of species here given as extending downward to the Pliocene or Miocene strata are based on what was hitherto known of their vertical ranges, and cannot be always considered decisive, especially when only a few species are given. Late explorations tend to show that they are not always separable in California, and they have therefore been lately combined under the name of Neocene. There is, however, good evidence, obtainable from large numbers of species, to show the relative age of the Tertiary strata, and good ones can always be separated from the Cretaceous or Eocene, here called Cret. B."

There are other places on the eastern side of the San Joaquin Valley, in Kern County, where natural gas has been found, notably in T. 29 S., R. 28 E., M. D. M.; and in the township named bituminous sandstone is exposed on the northern bank of Kern River. For further description of these localities the reader is referred to our VIIth Report, p. 67.

THE BUENA VISTA OIL AND ASPHALTUM DISTRICT.

The Buena Vista Oil and Asphaltum District is situated about 26 miles in a northwesterly direction from the Sunset Oil Wells. The Buena Vista oil territory comprises oil claims which are owned by the Standard Asphalt Company, the Buena Vista Oil Company, and others.

The Standard Asphalt Company.—The Standard Asphalt Company was incorporated in Bakersfield in 1892. This company has leased certain oil and asphaltum claims belonging to the Union Land and Oil Company of Georgia, the Columbian Oil Company, and J. Quirolo. The territory thus leased comprises about 1,480 acres in T. 30 S., R. 22 E.; also, 160 acres in T. 30 S., R. 21 E., and 240 acres in T. 31 S., R. 22 E., M. D. M. The company has also located thirty-seven or more oil and asphaltum claims in the vicinity of Asphalto. The territory leased by this company and the claims located by them are all situated within a radius of about 4 miles from the western terminus of the branch line of the Southern Pacific Railroad between Bakersfield and Asphalto. The property of the company at Asphalto consists of the oil and asphaltum claims located by them, the lease above mentioned, a plant for refining asphaltum, which is furnished with twenty-one kettles; also a boarding-house capable of accommodating about forty men, and a store-house of four rooms. The railroad track extends to the refinery.

The Buena Vista Company.—The property of this company consists of about 720 acres, in addition to territory leased from them by the Standard Asphalt Company, all in T. 30 S., R. 22 E., M. D. M. In May, 1893, the improvements of the Buena Vista Oil Company consisted of a boarding-house capable of accommodating about 20 men; an oil well 410 feet deep; another 92 feet deep; two dry wells, one of which is 204 and the other 202 feet deep. All these wells were bored by E. Rowe, of Stockton, in 1892. At one time 22 barrels of oil were daily pumped from the deepest well. In this well oil was struck at a depth of 392 feet, but it is said to have been shut off when the casing was lowered to a greater depth. This well was drilled "snug" to the casing, leaving the casing to cut its way for about half an inch. The well is cased with 5⅝-inch casing, consisting of ¼-inch screw pipe. The formation penetrated is said to be sand. The writer was informed that 23 feet of asphaltum was bored through at a depth of 345 feet. The 92-foot well was sunk in July, 1892. This is an 8-inch well, and is cased with No. 16 iron, single casing. This well yields three barrels of oil daily by baling. (See table of oil analyses at the end of this bulletin.) The Buena Vista Company store their oil in a 250-barrel tank. There are also some smaller tanks on the property of this company. A record of wells which were bored in this district prior to those herein mentioned will be found by referring to our VIIth Report.

Topography of the Buena Vista Oil District.—The oil claims of the Standard Asphalt Company and the Union Oil Company commence on the northern side of the railroad at Asphalto. From the railroad the ground slopes in a northerly direction toward a tier of low rolling hills, which stretch out into the San Joaquin Valley. Between the railroad and the rolling hills several prospect holes have been sunk in the drift to a depth of from 8 to 12 feet. Some of these holes show pulverulent, carbonaceous material, which is no doubt decomposed asphaltum. In a few of the holes asphaltum has been struck which is similar in appearance to that composing the extensive asphaltum beds lying to the south of the railroad track, as hereinafter described. The hills to the north of the railroad track are covered with alluvium, and no rocky strata are exposed. In one of the ravines which cut through these hills there are exudations of asphaltum of limited extent.

The asphaltum beds leased by the Standard Asphalt Company and those owned by the Buena Vista Company extend up the hillside in a southerly direction from the railroad track; amid these asphaltum beds there are seepages of heavy oil, which collects in shallow pits that have been dug in the asphaltum for that purpose. The tier of hills on which the asphaltum beds are situated are the foothills of the main chain of the Coast Range lying to the south of Asphalto. These hills are for the most part covered with alluvial soil, which sustains a scanty herbage during the spring; but in many places there is an abundant growth of greasewood and sagebrush. Although many plants grow in a mixture of asphaltum and sand, the *Eriogonum inflatum* appears to be the only one which flourishes while its roots actually penetrate the asphaltum.

Rocky Formations of Buena Vista Oil and Asphaltum District.—The formation most extensively exposed in this district consists principally of light-colored silicious shales, similar to those seen in the Sunset Oil District. The outcropping rocks, which represent the formations resting on the light-colored shales, are scanty and irregular; they consist mainly of a peculiar, porous, silicious rock of low specific gravity, bituminous sandstones, silicified sandstones, and clayey and sandy strata. The porous silicious rock contains marine diatoms. In some places these infusorial rocks are impregnated with bitumen, and in other places with salt, the exposed surface being frequently found to be whitened, apparently by the action of the weather. These diatomaceous rocks, like the light-colored shales on which they rest, contain a large amount of silica. Samples of these silicious rocks examined showed as follows:

Description of Specimen.	Percentage Insoluble in Acid.	Percentage of Silica Contained in Specimen.	Percentage of Silica Soluble in Sodium Carbonate.
Light-colored shale from Asphalto	97.7	92.0	17.5
Porous, bituminous rock, containing diatoms	78.0	~~98.0~~ 78.0	39.0
Diatomaceous rocks impregnated with salt (after ignition, 37 per cent of this specimen was soluble in water)	62.0	60.0	20.0

In these estimations small fractions are disregarded. A good exposure of these saline rocks can be seen in the northwest corner of Section 33, where a cañon extends in a northeast and southwest direction. In this cañon a crust forms on the surface of the saline rocks, and this crust appears to be composed principally of salt (NaCl). A short distance from the outcrop of the saline rock the side of the cañon is formed of decomposed soft sandstone, but no rock-exposures are to be seen which throw much light on the relation of the sandy and clayey formations. The loose sandy surface is in some places strewn with quartzose pebbles, fragments of silicious rock, and a few marine shells. These shells were examined by Dr. Cooper, who determined them to be:

Pecten deserti, Con. .... Pliocene.
Ostrea attwoodi, Gabb .... Pliocene.

About half a mile from Asphalto by trail, and much less in a straight line, there is a spring of warm mineral water (see table of water analyses) which yields inflammable gas and a little oil. The gas smells strongly of sulphuretted hydrogen. A short distance eastward from the spring there is an outcrop of bituminous sandstone, which is much eroded and weatherworn. The greater portion of the hills in this vicinity is covered with what appears to be decomposed sandstones, through which the winter rains have cut deep ravines. In many places there are seepages of bituminous matter and outcropping ledges of asphaltum. In Section 27, as hereinafter described, the exposed formation is traversed by numerous veins of pure asphaltum. To the northwest of the boarding-house of the Buena Vista Oil Company, asphaltum has flowed down the hillside, but it is so eroded and weatherworn that it appears like the ruins of a lava stream. A few outcropping rocks of coarse sandstone show a strike of west of north by east of south; their dip is indeterminable, but they evidently stand at a great angle. A short distance farther westward, light-colored porous rocks make their appearance. Following the strike of the formation, the character of the debris covering the hills and an occasional outcropping ledge of rock evidence the proximity of the sandstone and the porous diatomaceous rocks. The sandstones are frequently oil-soaked, and seepages of maltha can be seen in almost 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 light-colored porous rocks. In one place a coarse sandstone and fine conglomerate can be seen in contact with the light-colored porous rock. The strike is east of south by north of west.

About 1½ miles west of Asphalto, in the northwestern portion of Section 20, there is an escarpment of light-colored sedimentary strata, some of which are bituminous. This escarpment rises abruptly for about 100 feet; the dip of the strata appears to be east of south and at an angle of about 25°. Some of these strata are interspersed with fragments of silicious shale, which resembles the silicious shale seen farther to the westward. It appears, therefore, that the whole cliff is of more recent formation than are the light-colored silicious shales. At the base of the cliff a vein of very pure asphaltum is exposed. To the southward of the strata forming this cliff, porous silicious shales are seen, but as investigation is made in a southerly direction across the strike of the formation, light-colored shales are found to lose their porous character, and appear to be indurated with silica.

The average strike of these silicious shales is N.W.W. by S.E.E. No exposures were found where the dip could be determined in a satisfactory manner, but the formation evidently stands at a great angle. In a few places there are weatherworn masses of impure limestone, but they do not appear to be in place. Still farther to the southward the light-colored shale is covered with alluvial soil, which affords excellent pasture during the spring. These rolling grazing lands extend to the Santa Maria Mountains, as the dominant ridge of this portion of the Coast Range is called. These mountains appear to be composed of metamorphosed sedimentary strata; at least, the writer saw no other rock exposed at the point where he ascended the divide, and one specimen obtained from this locality was bituminous. The dip of this formation is a little east of south, and at an angle of 25°.

THE SUPERFICIAL ASPHALTUM BEDS AT ASPHALTO.

The asphaltum deposits at Asphalto are found under two conditions: First, as superficial beds of impure asphaltum; secondly, as veins of asphaltum in the country rock.

As before mentioned, the superficial beds are situated to the south of the railroad track at Asphalto. The first bed examined covers an area of probably seven acres, and extends from the store of the Standard Asphalt Company to the white heap at the northern base of the hill, seen in the accompanying photograph. The asphaltum rests partly on sandy and clayey drift, and partly on a white calcareous sand, which has been struck in some pits that have been sunk through the asphaltum to a depth of about 12 feet. This bed of asphaltum constitutes the northern portion of a much larger bed, the southern portion of which was still reserved by the Buena Vista Oil Company in May, 1893. From the asphaltum bed which has been leased by the Standard Asphalt Company, large quantities of crude asphaltum have evidently been removed. The crude asphaltum varies in quality; some of it is brownish in color, and resembles ironite; it is frequently pulverulent and more or less mixed with earthy matter. 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 about two feet or more. This stratum principally consists 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.

About 200 paces south of their store, the Standard Asphalt Company have dug a trench across the asphaltum bed leased from the Buena Vista Oil Company. This trench, which is a little more than 100 yards in length, has been dug to the depth of from 6 to 12 feet, in order to test the thickness and quality of the asphaltum. This prospect work has shown that the best asphaltum is near the surface, where it varies from 6 inches to 2 feet in thickness. Beneath this upper stratum, it is very impure and rotten, and is intercalated with wash from the mountain. In some places the trench cuts through small veins of asphaltum, which penetrate the earthy material and give evidence of the fluidity of the asphaltum at the time of its deposition. At its eastern end, this trench cuts into the hillside and shows a sandy formation, which is not hard enough to be classed as sandstone; some of the sand is fine and some coarse, and contains small pebbles; no stratification is to be seen. In some places the sand is cemented with petroleum. A short distance to the eastward of the white heap shown in the photograph of Asphalto, a series of irregular pits have been sunk. These pits show a superficial stratum, about 2 feet in thickness, of fairly good asphaltum, beneath which, to the depth of about 20 feet, the formation is similar to that in the lower portions of the trench previously described. The greater part of the superficial asphaltum has been removed from the surface of the bed which is leased by the Standard Asphalt Company. At the time of the writer's visit there were heaped up or strewn on the surface of this bed 100 tons or more of fairly good asphaltum. The holes caused by mining were filled with heavy oil, or with water, the surface of which was covered with floating oil. The asphaltum beds, which in May, 1893, were still reserved by the Buena Vista Oil Company, commence a little more than 1,000 feet to the southward of the store belonging to the Standard Asphalt Company.

At that date the superficial asphaltum had not been removed from these beds, and a pit, in which much heavy oil had collected, showed a superficial stratum of about 4 feet in thickness, of fairly good asphaltum. Beneath it is sand, impregnated with heavy oil. Southward from the tank seen in the photograph a trench, which has a northerly and southerly direction, has been cut to a depth of from 3 to 12 feet. This trench is about 250 feet in length and penetrates asphaltum and sand soaked with heavy oil. The oil accumulates in the bottom of this trench and sluggishly flows through a pipe into a tank. Another ditch branches off in a southeasterly direction from the one last described, and shows that the asphaltum at that point is about 2 feet in thickness, and that it rests on oil-soaked sand. This plot of asphaltum, which has been reserved by the Buena Vista Oil Company, probably covers an area of about six acres. Other asphaltum beds extend to the westward of the roadway, which runs in a southerly direction from Asphalto, and to the westward of the boarding-house of the Buena Vista Oil Company.

These asphaltum beds are evidently much more ancient than those farther down the hill, and much of the asphaltum is of poor quality. The general trend of these ancient asphaltum beds is northwesterly and southeasterly, and they appear to extend along the contact of the sandstone and light-colored shale. The shale has a general strike of north of west by south of east, and evidently stands at a great angle. In some places these asphaltum beds show evidence of having been on fire, and masses of clinker have been formed. This clinker is locally called "coked asphaltum," a sample of which showed 39.1 per cent of carbonaceous matter. There must be more than ten acres covered with this ancient asphaltum on the land of the Buena Vista Oil Company, all of which is situated on the hills overlooking Asphalto.

Attempts to Refine Asphaltum.—Several years ago an experimental attempt to refine asphaltum was made by the Buena Vista Oil Company. What remains of their plant consists of three kettles, 3x8 feet, by 20 inches deep; a tank, and four kettles not set up. In May, 1893, the tank and three of the kettles were full of oil, and piled up near the kettles were many boxes of refined asphaltum. The asphaltum appeared to contain much oil, for it had partly melted under the heat of the sun.

Although there is a large amount of impure, crude asphaltum in these beds, only a small portion is sufficiently pure to pay for mining and refining by the methods now employed. It is possible, however, that the impure, crude asphaltum may be of value as bituminous rock.

THE ASPHALTUM VEINS IN THE BUENA VISTA DISTRICT.

The principal working from which asphalt was being mined at the time of the writer's visit to this district, is near the N.W. corner of the S.W. ¼ of Sec. 27, T. 30 S., R. 22 E., M. D. M., and is marked as Flag No. 1 in the accompanying sketch-map. It consists of a shaft, with drifts connected therewith. This shaft is about 40 feet deep, and has been sunk on a vein of asphaltum which shows a thickness of 8 feet, and dips about 15° west of north. The asphaltum is of a high grade, is black, lustrous, and breaks with a ready cleavage. At the depth of 15 feet the vein widened and was drifted on for 15 feet 20° east of north, 45 feet 70° east of north, and 18 feet 70° west of south. At the end of the 18-foot drift the vein pinched, and an inclined shaft was sunk thereon 6 feet. At the bottom of the inclined shaft the vein again widened, and was drifted on for about 7 feet in a northwesterly direction along its strike, the foot wall being light-colored clay, and the hanging wall a light-colored, friable sandstone. The course of the vein then turned until it showed a strike of 44° east of south, and the foot wall changed from clay to coarse sand. At the end of this drift the angle of the dip greatly increases, the vein pinches to a width of about 4 inches, and the light-colored clay comes in again as a foot wall. A short distance from the end of the drift the vein has been stoped out to the depth of about 12 feet below the floor. In the bottom of the stope the vein widens to about 4 feet, showing about 2 feet of pure black asphaltum, which is separated from the walls by about a foot of dull and somewhat pulverulent asphaltum.

Passing to the bottom of the shaft, a lower vein of asphaltum about 2½ feet thick is seen dipping about 5° west of north, at an angle of about 45°. The foot wall is light-colored clay with streaks of gypsum, and the hanging wall is sandy clay. The drift penetrates the hanging wall, and the following strata are passed through:

Sandy clay	7 feet.
Hard and calcareous stratum	6 inches.
Sandy clay	7 feet.
Loose sand	4 inches.
Sandy clay	2 feet.
Asphaltum	6 inches.

The drift terminates in light-colored, friable sandstone. This 6-inch vein is, no doubt, the same vein which is mined in the upper level; in the lower level the vein dips 25° east of north.

In mining this asphaltum, holes are bored in the clay to the depth of 2½ feet, with augers. Each hole is charged with a stick of No. 2 giant powder. Three such charges usually move or loosen a block of clay 4 feet wide, 6 feet high, and 2 feet thick. The sand is mined with picks, but the hard streaks sometimes require drilling. When the work can be so adjusted as to allow time for the smoke to clear, a good effect is obtained with two holes and the use of Judson powder. When this powder is used, one hole is bored in the top and the other in the bottom of the face of the drift. The bottom hole is sprung with half a stick of giant powder, and is then loaded with from one to two quarts of Judson

powder; the top hole is loaded with a stick of giant powder. The fuse used for the bottom charge is a little shorter than that used for the upper charge, so that the Judson powder is exploded first.

In the formation hitherto encountered, which is about half clay and half sand, two men can drift from 5 to 6 feet a day, if the wheeling and hoisting are done by others. The clay is dry and stands without timbering, but the sand is timbered and lagged on the roof and sides of the drift. As may be supposed, mining in such a formation is not very destructive to tools. Two men picking in the sand will dull four or five picks daily, but in the clay one pick will last a man a week or more. The asphalt splits with ready cleavage, and is easily mined. At the time of the writer's visit a second shaft was being sunk about 35 feet from the one described.

About 200 yards north of the main shaft a broad band of light-colored clay stretches across the country, and has a strike of 53° west of north (see sketch-map). Extending eastward from this shaft toward Station 2 are shallow workings and prospect holes. These appear to have been sunk on the outcropping edge of the lower vein of asphaltum which was mined in Shaft No. 2. In these workings the stratum of asphaltum is well exposed, and dips somewhat irregularly between 15° and 25° east of north, at an angle of from 45° to 55°. The average width of the vein is from 3 to 4 feet, and much of it is good, bright, black asphaltum. In one of these excavations a tunnel has been run into the hill for about 40 feet in a northeasterly direction. The formation penetrated is light-colored clay and soft friable sandstone, dipping 25° east of north, at an angle of about 50°. It is probable that this excavation has been made on a fold in the strata, for although, as above noted, the tunnel which runs into the hill from the northeast side of the excavation shows a dip to the east of north, the strata on the south side of the excavation dip 2° west of north, at an angle of 50°. About 65 feet to west of Shaft No. 2, outcroppings of the vein are found. The vein at this point shows a strike of 68° west of north and dips 22° east of north, at an angle of about 70°. At Station 2 there is a good exposure of a vein of asphaltum, dipping 23° east of north, at an angle of 50°. The strike of this vein would, if extended in a southwesterly direction, carry it across the ravine in which the already described workings are situated; and following along the strike of the vein for a short distance in a northwesterly direction across the ravine, a shaft about 10 feet deep is reached, which shows a vein of asphaltum about 3 feet in thickness. Crossing the roadway and a ravine which leads in a southeasterly direction, superficial excavations are found showing asphaltum mixed with sand and clay. On the eastern side of the ravine there are three tunnels, which are marked, respectively, on the accompanying sketch-map as tunnels *a*, *b*, *c*.

Tunnel *a*, which is situated about 20 feet above the bottom of the ravine, has been run in a southwesterly direction. The formation penetrated dips 20° west of south, at an angle of about 20°, and is as follows:

Light-colored clay	20 paces.
Asphaltum	2 feet.
This asphaltum is partly a pure black variety, and partly light and powdery and mixed with clay.	
Fine, light-colored sand	7 paces.
Light-colored clay and sandy clay traversed with streaks and pockets of asphaltum	15 paces.
One of these pockets was 2 feet thick, 4 feet wide, and extended from the floor to the roof of the tunnel.	

Reddish-brown sand	20 paces.
Light colored, clayey sand, with streaks and pockets of reddish asphaltum	20 paces.
Light-colored sand, some of which was saturated with oil	2 paces.

At the end of the tunnel there is a seepage of heavy oil.

Tunnel *b* was commenced about 20 feet farther down the side of the ravine than tunnel *a*, and is about 20 paces distant therefrom in a northwesterly direction. This tunnel has been run into the hill for about 50 paces in a southwesterly direction. The formation is similar to that observed in the upper tunnel, but the dip is a little more westerly. At the mouth of the tunnel there appears to be an irregular vein of asphaltum, but a winze sunk thereon about 7 feet shows only a few seams of asphaltum of no great width traversing a light-colored clay.

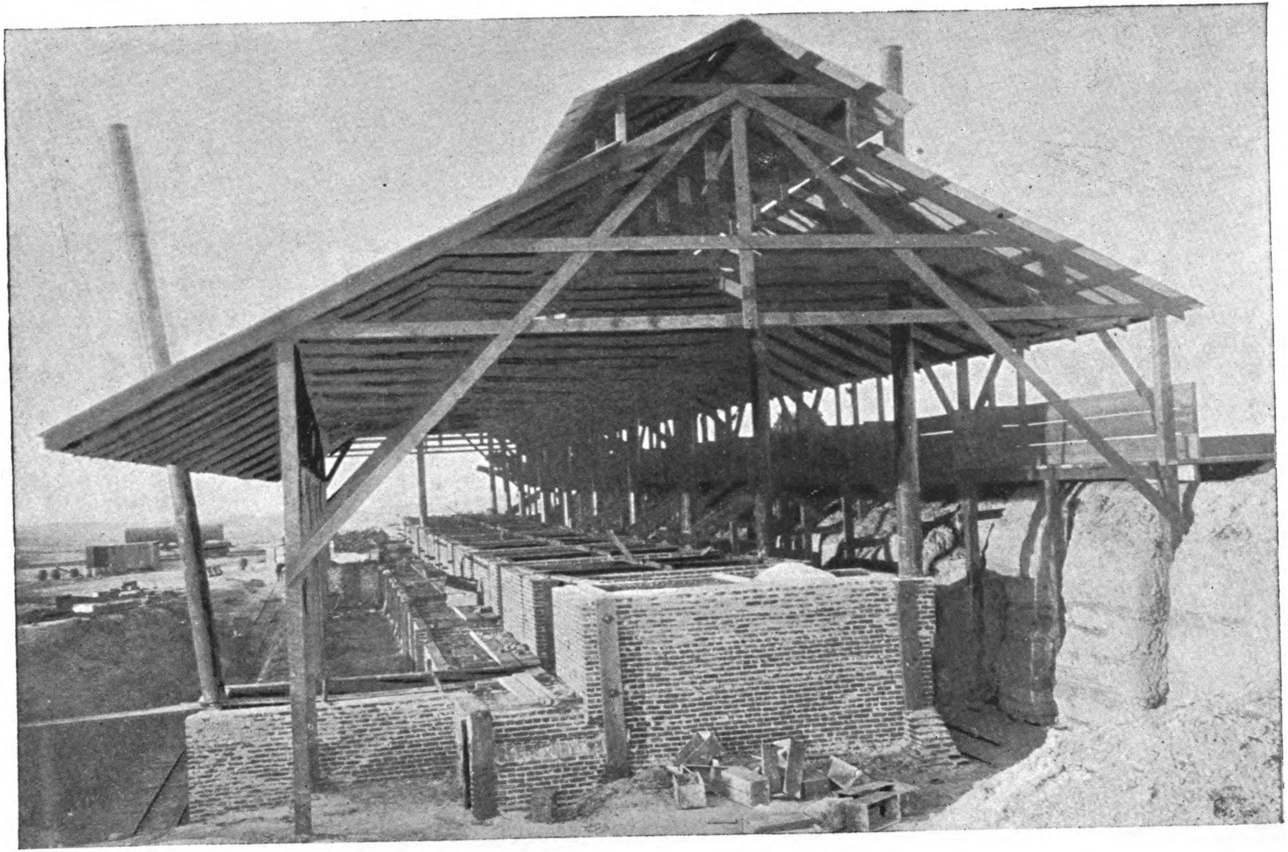
A short distance southeast of tunnel *b* an open cut shows a disturbed vein of asphaltum about 2 feet in width, and irregular masses of asphaltum spreading out therefrom. The inclosing rocks, which dip 30° east of south, at an angle of about 40°, are light-colored, sandy clay. This formation is penetrated by tunnel *c*, which has been run nearly in the direction of the dip, and is as follows:

Light-colored sandy clay, with asphalt	7 paces.
Reddish-brown sand	15 paces.
Light-colored clay, with seams of gypsum	7 paces.

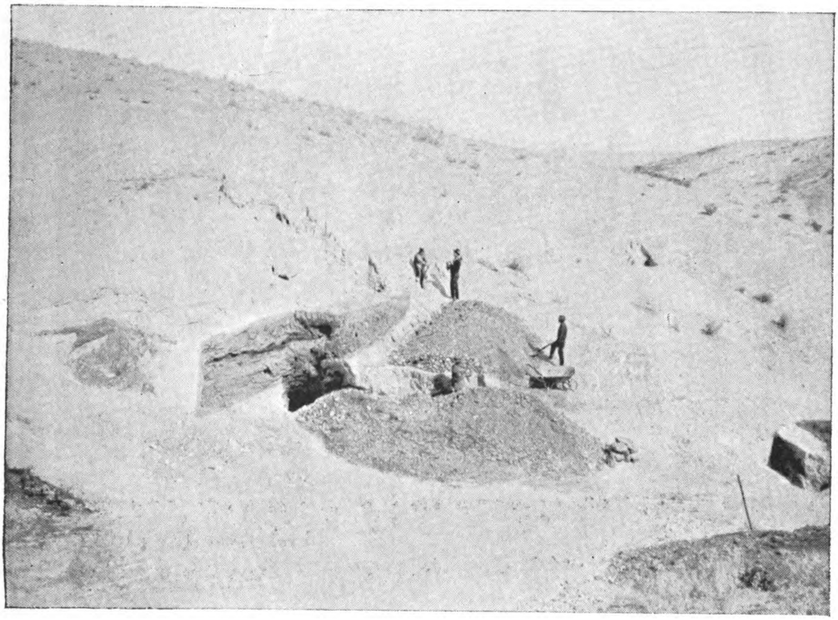
About 35° west of south from tunnel *c* an open cut shows an irregular-shaped mass of asphaltum, inclosed in soft brown sandstone, which is faulted in places, and a fissure occasioned thereby is filled with asphaltum. This is somewhat softer than that obtained from the shafts, and the heat of the summer's sun had evidently been sufficient to melt it. At Station 5 the dip of the soft brown sandstone is 60° east of north, and a fissure, having a direction of 55° east of north, has been filled with very pure asphaltum, forming a vein from 4 to 5 feet in width. The fissure is nearly vertical, and the vein has a slight pitch to the northwest.

A few yards east of south from Station 5 there are open cuts in a soft bituminous sandstone, which show straggling veins of asphaltum of no great thickness. On the western side of the principal ravine, at Station 6, the formation dips 35° west of south, at an angle of about 60°. A vein of high-grade asphaltum of about one foot in width is here exposed in an open cut. Both the head walls and foot walls are formed of light-colored clay, which is seamed with gypsum. About 20 yards west of Flag B a soft, dark-brown sandstone is exposed, which becomes grayish on the outside by exposure to the air. At Station 7 are bituminous shales, which become almost white by exposure; these shales dip 85° west of south, at an angle of about 80°. Between these shales and the soft brown sandstone is a soft silicious stratum, containing marine diatoms, and saturated with bituminous matter. The surface of this silicious stratum is white, and appears to have been bleached by exposure. Both the soft silicious stratum and the sandstone have suffered greatly by erosion, especially along the contact of the shales and the soft silicious rock, where a gulch has been formed, which has a course of from 20° to 40° west of north and east of south. The dark color of the material forming these shales, silicious rocks, and sandstones is evidently occasioned by bituminous matter.

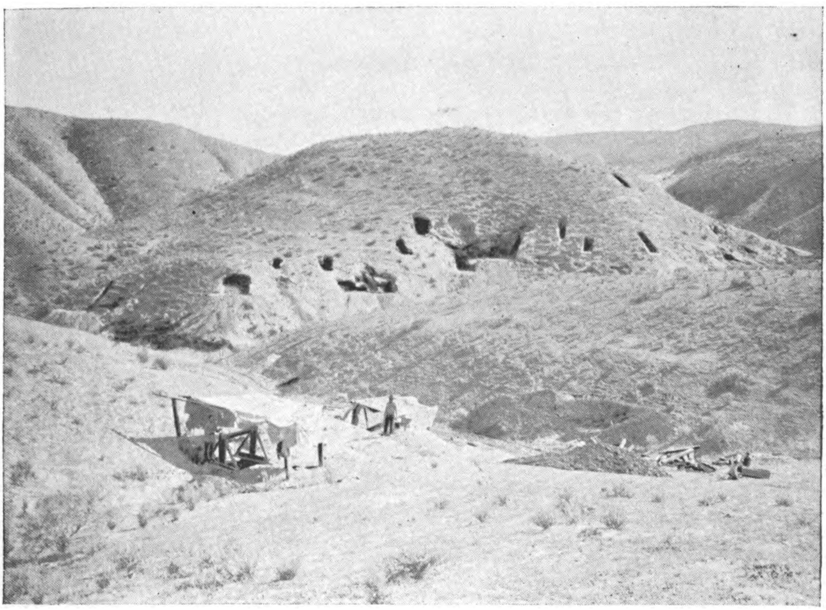
At Station 8, an open cut about 6 feet deep shows the dip of the



Interior of Asphalt Refinery at Asphalto, Kern County.



Asphalt Mine, showing Vein of Asphalt. Buena Vista District, Kern County.



Asphalt Mines in Buena Vista District, Kern County.

formation to be 40° east of south, and shallow cuttings between Stations 8 and 9 show asphaltum "prospects"; but the exposures are not sufficient to determine either the dip or strike.

At Station 9, a soft, dark-colored sandstone, similar to that near Station 7, is exposed, having a strike of 60° west of north, and dipping southwesterly at an angle of about 70°. At Station 10, an open cut shows a body of asphaltum about 4 feet across, which has been bent upward and folded on itself, apparently by a flexure in the formation.

At Station 11, a pit about 8 feet deep shows a disturbed formation of sandy clay and asphaltum. The probable strike is 75° west of north, dip northeasterly, and at a great angle.

At Station 12, an open cut about 12 feet deep shows several strata of impure asphaltum, which vary in thickness from 1 inch to about 1 foot. The asphaltum is intercalated by 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. The pitch of the fossiliferous stratum is 80° east of north, and at an angle of about 50°; the fossiliferous stratum rests upon impure, sandy asphaltum, on sand impregnated with bituminous matter. Specimens of these fresh-water shells were submitted to Dr. Cooper, who found them to be:

Anodonta nuttaliana, Lea	Living.
Carinifex newberryi, Lea	Living.
Pomatiopsis intermedia, Tryon	Living.

At Station 13 a 25-foot tunnel has been run into the hill, and cuts a vein of powdery asphaltum, more or less mixed with clay and sand. There are also several open cuts and shallow workings between Flags D and C, which show the strike of the formation to be 65° east of south, and the dip 25° east of north, at an angle of about 40°. In two of these cuts a stratum of calcareous clayey sandstone is exposed, which contains numerous small fresh-water shells similar to those seen at Station 12. In one of these openings the bones of mammals were found beneath the impure asphaltum which underlies the fossiliferous stratum in this locality.

A few yards westward from these workings a line of open cuts shows a vein of asphaltum similar to the one already noted between Flags D and C, but the dip is 35° west of south at an angle of 65°. At Station 15, about 250 yards to the southwest of Station 13, and in the same ravine, there is a tunnel a few feet in length and a shaft about 12 feet deep. The formation penetrated is dark-colored, soft sandstone and sandy clay. In the tunnel a vein of high-grade asphaltum is exposed, standing nearly vertical and having a strike of 10° east of south. At Station 16, between Flags B and E, two open cuts show a mass of asphaltum about 2 feet in thickness, and some heavy oil. At three places between Stations 16 and B, open cuts show irregular veins of asphaltum, which vary in thickness from that of a few inches to about 2 feet. The asphaltum is more or less mixed with clay and sand.

Remarks on the Asphaltum Veins.—The asphaltum veins herein described may be divided into two orders: those having a strike and dip dissimilar to that of the rocks inclosing them, and those having a strike and dip similar to that of the inclosing rocks. The asphaltum veins of the first order are no doubt dikes of asphaltum, which occupy fissures in what appear to be rocks of late Tertiary formation. The genesis of the asphaltum veins of the second order is more dubious; some of the veins may be dikes filling fissures formed between the contact planes of upheaved strata, or they may have been formed as subaqueous exudations. The asphaltum has a specific gravity of about 1.10, and even if it were less, assuming that it exuded beneath water, its viscosity would tend to keep it submerged. An interesting feature of this locality is the diversity in the direction of the dip of asphaltum-bearing strata within comparatively small areas, although the prevailing dip appears to be northeasterly. As the purport of this article is merely to describe the geological conditions under which these asphaltum veins occur, it is unnecessary to theorize.

This recent discovery of veins of asphaltum appears the more important when we remember that formations of similar geologic age to those at Asphalto can be traced along the foothills on the western side of the San Joaquin Valley, and it is hardly likely that these veins of asphaltum are confined to the vicinity of Asphalto. The heavy mantle of alluvium covering the western foothills of the San Joaquin renders prospecting in these formations difficult, but the rapid erosion which takes place during the rainy season will probably, from time to time, expose outcropping veins of asphaltum, which, in view of the recent discoveries at Asphalto, it would be well to investigate.

THE REFINERY OF THE STANDARD ASPHALT COMPANY.

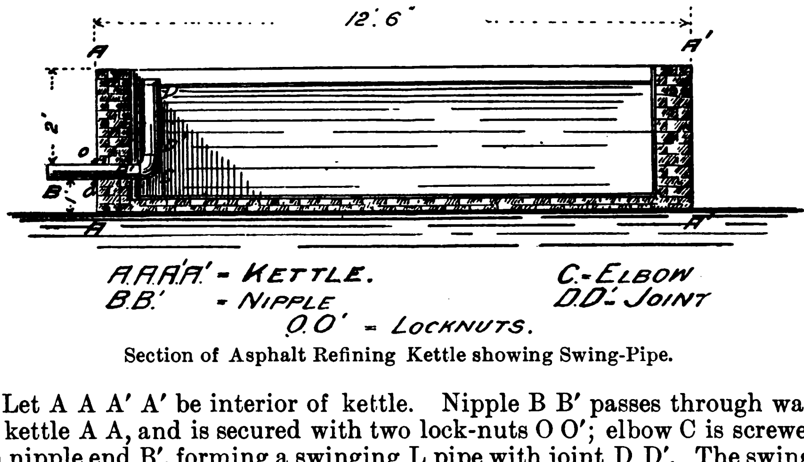
As before mentioned the refinery belonging to this company is situated at Asphalto, and consists of a plant furnished with twenty-one refining kettles. The refining kettles, as shown in the accompanying photograph, are set nineteen in a row, and each is about 12½ feet long, 5 feet wide, and 3 feet deep. They are made of steel, and are surrounded by brickwork; they are suspended by angle-iron flanges, which are riveted to the kettles, the free limbs of the angle-irons resting on the brickwork. The fireplaces are situated below the level of the kettles, and about 5 feet in front of them. Dry, crude asphaltum and asphaltum refuse are used as fuel, and the flames therefrom pass over a fire-arch before reaching the bottom of the kettles. Iron pipes are used as grate-bars, the ends being left open so as to permit the air to circulate through them, and by this means the bars resist the heat, which is very great, for the melted fuel runs through between the bars, and burns in the ash-pit. The refining kettles are arranged in pairs, and each pair is furnished with a separate smokestack. The refining kettles are connected with kettles for receiving the refined asphaltum, and each of the receiving kettles is furnished with a smokestack.

The crude asphaltum is stacked up on a charging floor, which is situated 4 or 5 feet above the level of the refining kettles and a few feet distant therefrom. From this floor the asphaltum is fed into the kettles by chutes. A little heavy oil is then added to the asphaltum to assist its liquefaction. When 90 per cent asphaltum is refined, a kettle is charged, boiled, and emptied in twenty-four hours. The asphaltum is considered sufficiently refined when it cools and sets quickly as a hard, brittle substance possessing a high luster. The quality of hardness is only required to enable the asphaltum to be shipped, for it has to be fluxed with liquid petroleum previous to use. This refinery is said to have a capacity of 20 tons every twenty-four hours, when 90 per cent asphaltum is refined. The time consumed by the operation of refining naturally varies according to the richness of the crude material. The lower the grade of the crude asphaltum, the longer it takes to refine it.

Samples containing sandy impurities are the most easy to refine, and those containing clayey matter are the most difficult. In refining a low-grade asphaltum, as soon as the crude material becomes sufficiently liquid to allow the heavier impurities to settle, the liquid asphaltum is transferred to a clean kettle, wherein the process is continued. The refined material is drawn off through tap pipes ("swing pipes"), and it is conducted by a gutter into large receiving kettles.

The receiving kettles are 17 feet long, 6 feet wide, and 4 feet deep; and each of them hold about 15 tons of asphaltum. In these the asphaltum is kept at such a temperature that it will flow readily when poured. From the receiving kettles the asphaltum is drawn off into a swinging kettle, which holds about 65 gallons. This is set on wheels, and is pushed along a track, by the side of which wooden boxes destined to hold about 110 pounds of asphaltum, are arranged. The boxes are filled by pouring from the swinging kettle.

The "swing pipe" before referred to, which is used to draw off the refined asphaltum, is constructed according to the accompanying drawing.



Section of Asphalt Refining Kettle showing Swing-Pipe.

Let A A A′ A′ be interior of kettle. Nipple B B′ passes through wall of kettle A A, and is secured with two lock-nuts O O′; elbow C is screwed on nipple end B′, forming a swinging L pipe with joint D D′. The swinging L pipe C D′ D is just so as to be long enough, when standing perpendicular, to protrude above the surface of the liquid asphaltum. The purpose of this pipe is to avoid the use of stop-cocks, which would get clogged and cause trouble.

In the process of refining it is found best to commence with a slow fire and gradually increase the heat until a temperature of from 250° to 300° Fahr. is attained. Constant stirring is needed to prevent the sediment from burning, which would soon destroy the kettle. Before "tapping" the asphaltum the fire is drawn and the liquid asphaltum is allowed to stand for an hour or more so the impurities may settle. The "swing pipe" is then lowered and the liquid asphaltum is run out. The refuse is valuable as fuel, and could also be utilized as bituminous rock. It is used with good effect to line tanks and reservoirs. When twenty kettles are in operation ten men are required for each shift. This refinery was completed March 1, 1893. The first run was made on 300 tons of crude asphaltum from the superficial asphaltum beds leased by the Standard Asphalt Company, and about 100 tons of refined asphaltum were produced.

The higher grades of crude asphaltum are not only the most easily refined, but they are the most easy to mine and handle. They fracture readily, and can be "blocked off" with drift bars and picks. The tough, oily varieties of asphaltum have to be mined with a hot spade, and cut with ax-shaped mattocks and picks; heavy charges of powder are also required.

The cost of working 60 per cent crude asphaltum is figured at about $10 a ton, inclusive of mining and all expenses. When the impurities are of a sandy nature it is said that 30 per cent crude asphaltum can profitably be worked, and with clayey impurities 40 per cent. With regard to the grade of asphaltum which could be worked with profit, the limit would be controlled by the market price of refined asphaltum. The writer is informed that during 1893 the market price for refined asphaltum averaged $25 a ton f. o. b. at Asphalto.

The following extracts from the records of the Standard Asphalt Company have been courteously placed at the disposal of the California State Mining Bureau:

Comparative Analyses of Trinidad Pitch Lake Asphalt and Standard Asphalt from Bakersfield, California.

	California. Sample H, Crude from Mine.	California. Sample H, Refined.	Pitch Lake. Average.	Pitch Lake. Best.
Specific gravity	1.132	1.240	1.3857	1.3771
Softening temperature, F.	180 degrees.	150 degrees.	190 degrees.	183 degrees.
Flowing temperature, F.	220 degrees.	180 degrees.	205 degrees.	198 degrees.
Inorganic matter	9.57 per cent.	9.77 per cent.	35.66 per cent.	35.48 per cent.
Bitumen soluble in CS.	85.49 per cent.	90.16 per cent.	56.29 per cent.	57.47 per cent.
Bitumen soluble in ether	69.98 per cent.	86.45 per cent.	41.43 per cent.	41.59 per cent.
Percentage of total bitumen soluble in ether	81.85 per cent.	95.88 per cent.	73.60 per cent.	72.37 per cent.

"The above analyses of California asphalt were made by G. Q. Simmons, Sedalia, November 8, 1893. Those of Pitch Lake asphalt were made by Clifford Richardson, Washington, D. C., and the results are to be found in his report of 1892, page 114. In the case of the Pitch Lake petroleum, naphtha was used instead of ether."

The following tests were made by H. Stillman, Engineer of Tests to the Motive Power and Machine Department at Sacramento (S. P. Co.):

Asphalt.	Ash.	Soluble.	Insoluble.
Trinidad	1.5 per cent.	46.30 per cent.	52.20 per cent.
Cuban	2.8 per cent.	44.25 per cent.	52.85 per cent.
Asphalto	6.5 per cent.	59.55 per cent.	33.95 per cent.

"In the above, the Trinidad represents the imported asphaltum. The proportion of ash shows the amount of foreign matter, dirt, and sand contained. Of the organic matter, the proportion insoluble in petroleum spirit may be considered as pigment in a paint or varnish made from the same, while the proportion soluble in spirit express the pure asphaltum together with hydrocarbon oils or petroleum existing in the rock.

"The nature of paint made from the product (especially as to drying properties) will depend to a certain extent on the quantities of petroleum oil present. This could only be determined by continued process, requiring more of sample than at hand.

"Some idea of this may be obtained from the results of combustion:

	Soluble Hydrocarbon.	Fixed Carbon.	Ash.
Trinidad	77.15 per cent.	22.7 per cent.	0.15 per cent.
Cuban	70.20 per cent.	27.0 per cent.	2.80 per cent.
Asphalto	81.40 per cent.	12.1 per cent.	6.50 per cent.

"Proportion of volatile to fixed carbon would express their value as referred to in the above." * * *

Two samples analyzed by W. B. Potter, of the St. Louis Sampling and Testing Works, showed:

Asphalt from Asphalto.	Percentage of Asphaltum.
No. 1	88.90 per cent.
No. 2	85.32 per cent.

The manager of the Standard Asphalt Company informed the writer that the crude asphaltum, as it is mined from the asphaltum veins now being worked at Asphalto, averages 75 per cent of asphaltum.

BITUMINOUS FORMATIONS IN KINGS COUNTY.

After leaving Asphalto the writer visited Tar Cañon, in Kings County. It is said that bituminous formations extend through the foothills between Asphalto and Tar Cañon for a distance of more than 100 miles. The northern entrance to Tar Cañon is at an altitude of 1,000 feet. In this cañon there are seepages of heavy tarry oil, which in one place has formed a small quantity of asphaltum. The strata yielding the oil are somewhat metamorphosed shales and sandstones, and constitute a ridge, which rises, in one place, to an altitude of more than 2,000 feet. The shales exposed on the northern slope of this ridge are grayish, and become light colored on exposure; but they exhibit a different physical appearance to that shown by the light-colored shales which yield the heavy oil north of Coalinga. They appear to be unfossiliferous, and dip 10° east of north, at an angle of about 75°. The rock exposures on the northern slope and summit of this ridge show that these shales rest conformably on thick strata of sandstone and calcareous conglomerate.

From the upper strata of the sandstone the writer obtained a few fossils, which were classified by Dr. J. G. Cooper, as follows:

Dosinia conradi, Gabb	Miocene.
Ostrea titan, Con.	Miocene.
Ostrea bourgeoisi, Remond	Pliocene.
Pecten discus, Con.	Miocene.

As this collection contained a preponderance of Miocene fossils, Dr. Cooper referred the strata containing them to the Miocene group. Some of the strata of sandstone and conglomerate underlying the strata from which these fossils were obtained must at one time have been highly fossiliferous, but the metamorphism to which they have been subjected prevents the identification of the fossils they contained.

The ridge referred to appears to be separated from the main Coast Range by faulting and erosion. On following in an easterly direction the prevailing dip seems to be more easterly, and at a somewhat less angle than that in Tar Cañon. In some places in the eastern portion of the ridge, the strata appear to have been subject to contortion. This appearance, however, as seen at a distance, may, perhaps, be exaggerated by the manner in which the strata have been eroded. The formation exposed on the southern slope of this ridge shows strata of soft sandstone and sandy shales, aggregating a thickness of about 700 feet. To the northward and at the foot of this ridge, the formation is soft blue sandstone, the dip of which appears to be rather more easterly and at a somewhat less angle than that of the strata forming the ridge. From the blue sandstone the following fossils were obtained:

Chione gnidia, Sowby	Living, Pliocene.
Crepidula grandis, Midd.	Quaternary, Pliocene, Miocene.
Macoma edulis, Nutt.	Pliocene, Miocene.
Pinna venturensis, Yates	Pliocene.
Arca microdonta, Con.	Pliocene, Miocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.

It is apparent that the fossils obtained from the blue sandstone show a more recent age than that indicated by the fossils collected at Tar Cañon.

The Kettleman Plain.—The Kettleman Plain is really a valley lying between the ridge of hills among which Tar Cañon is situated and a range of low hills which, on the northward and eastward, separate the plain from the main valley of the San Joaquin. The center of the Kettleman Plain is at an altitude of 500 feet. A reconnoisance of these hills showed that their more elevated portions are formed of soft blue sandstone, and their summits rise to an altitude of about 1,000 feet. The summits of these hills present a rounded, undulating appearance, while their sides are furrowed by narrow gulches and ravines deeply cut into the comparatively recent formations. At the summit of these hills the strata dip from 10° to 35° west of south and at an angle of something less than 30°. In the cañons leading to the westward, the direction of the dip of the formation averages about 25° west of south, and the angle of inclination varies from 25° to 35°. Near the summit of these hills, the blue sandstone on which the formations rest is interstratified with a few calcareous and fossiliferous strata. The following fossils were obtained therefrom:

Acila castrensis, Hinds	Living, Pliocene, Miocene.
Arca microdonta, Con.	Pliocene, Miocene.
Cardium meekianum, Gabb	Pliocene, Miocene.
Galerus diegoanus, Con.	Living, Pliocene, Miocene.
Galerus filosus, Gabb	Pliocene, Miocene.
Lutricola alta, Con.	Living, Pliocene, Miocene.
Macoma inquinata, Desh.	Living, Pliocene.
Mya arenaria, Linn.	Living, Pliocene.
Ostrea bourgeoisi, Remond	Pliocene.
Pseudocardium gabbi, Remond	Pliocene, Miocene.
Solen rosaceus, Carp.	Living, Pliocene, Miocene.
Standella falcata, Gould	Living, Pliocene.
Tapes staleyi, Gabb	Pliocene.
Balanus estrellanus, Con.	Miocene.
Scutella gibbsi, Remond	Pliocene, Miocene.

This collection may be classified in the order of their upward vertical range, as follows:

Miocene	1	10 ranging back to the Miocene epoch.
Pliocene, Miocene	5	
Living, Pliocene, Miocene	4	
Pliocene	2	5 Pliocene.
Living, Pliocene	3	

As these hills seemed to offer a chance of obtaining some information as to the character of the more recent strata, which may reasonably be supposed to underlie the San Joaquin Valley, a cañon was selected and observations were made from which the sketch marked "Section of Tertiary strata in Kettleman Hills," and which accompanies this article, was drawn. The most interesting formation exposed in the Kettleman Hills is a sandy calcareous stratum, which is marked on the accompanying sectional sketch as Station No. 4, and contains fresh-water shells; but the fossiliferous portion is of no great thickness. The specimens of fresh-water shells obtained from this locality were classified by Dr. J. G. Cooper, as follows:

Anodonta decurtata, Con.	Pliocene.
Anodonta nuttaliana, Lea	Living, Quaternary, Pliocene.
Amnicola turbiniformis, Tryon	Living, Quaternary, Pliocene.
Carinifex newberryi, Lea	Living, Quaternary, Pliocene.
Goniobasis occata, Hinds	Living, Quaternary, Pliocene.
Margaritana subangulata, Cooper	Quaternary, Pliocene.
Physa costata, Newcomb.	Living, Quaternary, Pliocene.
Planorbis tumens, Carp.	Living, Quaternary, Pliocene.
Sphærium dentatum, Hald.	Living, Quaternary, Pliocene.

BITUMINOUS FORMATIONS IN FRESNO COUNTY.

There is a seepage of heavy oil in Canours Cañon, in Sec. 28, T. 22 S., R. 16 E., on the Kreyenhagen ranch. The formation yielding the oil is similar to that in Tar Cañon, and is well exposed where the South Fork of the Zapato Chino Creek breaks through the first tier of higher mountains to the west of the foothills. This gap has been worn almost at right angles to the strike of the formation. The first stratum seen on entering the gap is shale, and is very similar in appearance to the shale seen at the entrance to Tar Cañon; it has a strike of 75° west of north. These shales rest on strata of fossiliferous sandstone, from which the following species were obtained:

Ostrea titan, Con.	Miocene.
Ostrea bourgeoisi, Remond	Pliocene.
Pecten discus, Con.	Miocene.
Trophon ponderosus, Gabb	Pliocene, Miocene.
Turritella hoffmanni, Gabb.	Miocene.
Balanus estrellanus, Con.	Miocene.
Astrodapsis antiselli, Con.	Miocene.

Some of the lower fossiliferous strata, like those seen at Tar Cañon, must at one time have contained many shells, but the metamorphic action which they have undergone has nearly obliterated the fossils. The sandstone strata show a dip of from 10° to 20° east of north, the first mentioned direction predominating; the dip is at an angle of about 50°.

As the South Fork of the Zapato Chino Creek is ascended, the sandstone shows increased metamorphism. About one half mile westward from the gap previously mentioned, the mountains are timbered with white oak, cottonwood, and cedar.

A short distance north of the gap through which the Zapato Chino Creek enters the lower foothills, the formation is soft, reddish-brown sandstone. The direction of the dip of this sandstone is 20° east of north, and at an angle of from 35° to 40°. Only three fossils were obtained in this sandstone, viz:

Liropecten estrellanus, Con.	Pliocene, Miocene.
Balanus estrellanus, Con.	Miocene.
Solen rosaceus, Carp.	Living, Pliocene, Miocene.

At the junction of the north and south forks of the Zapato Chino Creek, soft bluish Tertiary sandstone is encountered. The direction of the dip of this sandstone is 25° or 30° east of north, and at an angle of about 35°. At this point the following fossils were obtained:

Balanus estrellanus, Gabb	Miocene.
Cardium meekianum, Con.	Pliocene, Miocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.
Arca microdonta, Con.	Pliocene, Miocene.

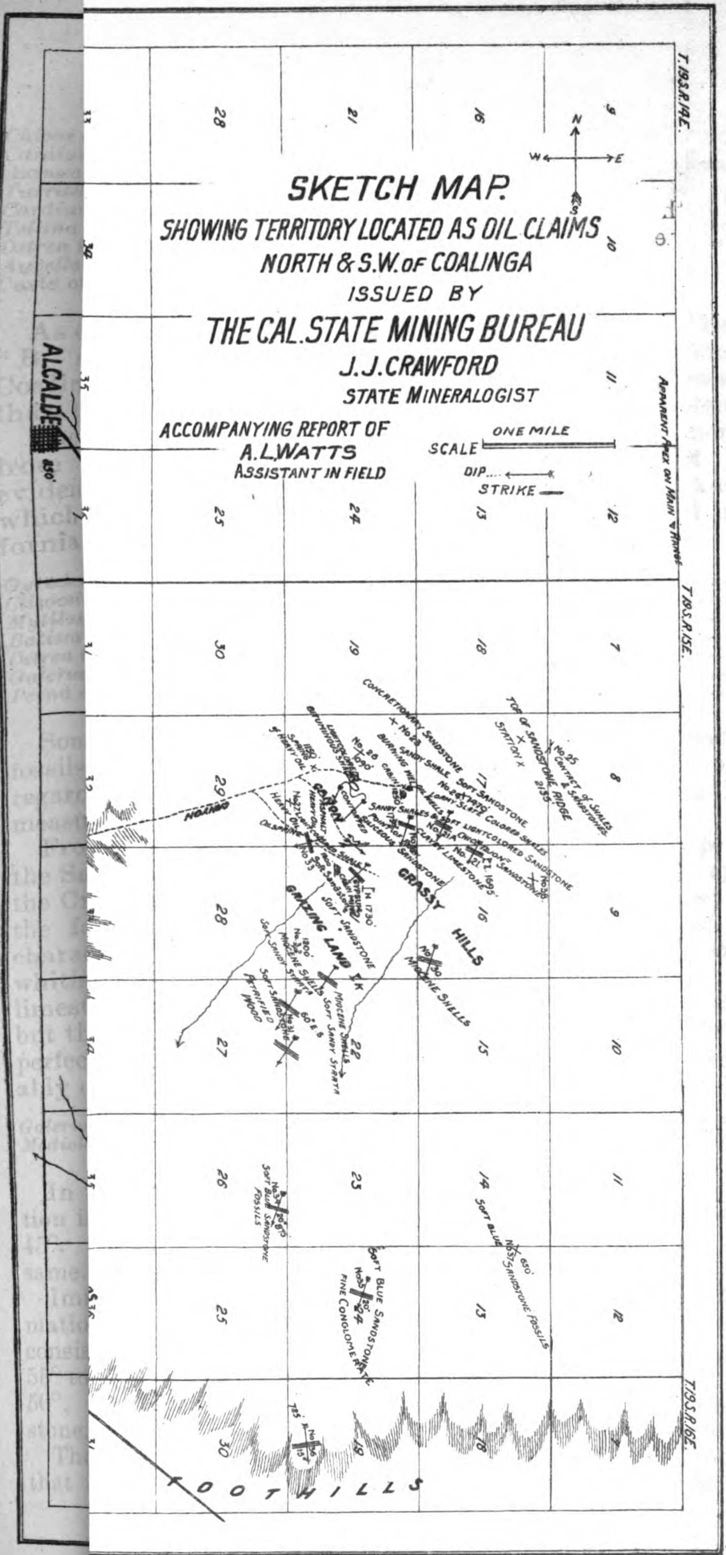
Remarks on the Geology of Tar Cañon and Kreyenhagen Ranch.—The preponderance of Miocene fossils in the rocks yielding the heavy oil, both in Tar Cañon and at the Kreyenhagen ranch, warrants the assumption that the bituminous formations exposed in these localities belong to the Miocene group. The preponderance of Pliocene fossils in the blue sandstone which forms the lower foothills, and which overlies the bituminous formations, is probably sufficient to indicate that the blue sandstone belongs to the Pliocene group. The direction in which the blue sandstone strata dip does not appear to differ very much from that of the Miocene rocks on which they rest, but the angle of inclination is much greater in the latter formation. In the places where the observations herein recorded were made the friable nature of the soft sandstone renders it impossible to estimate the direction of the dip very closely by surface inspection. The average of several observations is therefore given.

OIL CLAIMS IN FRESNO COUNTY.

As will be seen by reference to the accompanying sketch-map, there are two groups of oil claims near Coalinga, in Fresno County. One of these groups is situated a little more than 3 miles in a westerly direction from Coalinga, and the other is about 9 miles distant in a northerly direction from the same place.

The oil claims west of Coalinga cover a territory which lies immediately to the south of the San Joaquin and the California Coal Mines. In order rightly to comprehend the situation, it is necessary to refer to these mines. In the slope last sunk in the San Joaquin Coal Mine, a small quantity of oil was struck in a fossiliferous stratum; and in this mine inflammable gas is frequently encountered. Fossils from a calcareous sandstone in one of the upper tunnels of this mine were classified by Dr. Cooper, as follows:

Modiola cylindrica, Gabb	Cretaceous.
Rimella macilenta, White	Cretaceous B.
Tellina ovoides, Gabb	Cretaceous.
Tapes conradiana, Gabb	Cretaceous B.
Tellina ashburneri, Gabb	Cretaceous.



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Chione varians, Gabb	Cretaceous.
Cardium breweri, Gabb	Cretaceous B.
Axinæa veatchi, Gabb	Cretaceous A and B.
Turritella uvasana, Gabb	Cretaceous.
Cardium linteum, Gabb	Cretaceous B.
Tellina hoffmanniana, Gabb	Cretaceous.
Ostrea idriaensis, Gabb	Cretaceous B.
Aucella piochii, Gabb	Cretaceous.
Casts of *Galerus excentricus*, Gabb	Cretaceous.

As only about one third of the species in this collection belong to the "B" series of Cretaceous species, Dr. Cooper is of the opinion that the Coalinga coal measures occupy a lower position in the Cretaceous system than that to which the coal measures of Mount Diablo belong.

The California Coal Mine is about one mile distant, northwesterly, from the San Joaquin Coal Mine, and the workings of both mines evidently penetrate the same coal measures. From a dark-colored clay which forms the hanging wall near the end of the tunnel in the California Coal Mine, the following fossils were secured:

Gyrodes dowelli, White	Cretaceous B.
Cliocolus dubius, Gabb	Cretaceous.
Mytilus quadratus, Gabb	Cretaceous.
Batissa dubia, White	Cretaceous B.
Ostrea idriaensis, Gabb	Cretaceous.
Galerus excentricus, Gabb	Cretaceous.
Perna excavata, White	Cretaceous.

Some new species were also obtained. Dr. Cooper states that the fossils from the California Coal Mine tend to confirm his opinion with regard to the relative age of the Coalinga and Mount Diablo coal measures.

From these fossils Dr. Cooper refers the coal measures penetrated by the San Joaquin and California Coal Mines to the Chico Tejon group of the Cretaceous system. In several places between the two coal mines the formations overlying the coal measures are exposed. The most characteristic rocks that can be seen between the two mines are a peculiar whitish, fine-grained, soft sandstone, and a decomposed, fossiliferous limestone. This limestone is exposed at Station 17 (see sketch-map), but the writer was able to obtain only two fossils which were sufficiently perfect for identification. These were classified by Dr. Cooper as probably of Pliocene age:

Galerus diegoanus, Con	Living, Pliocene, Miocene.
Modiola capax, Gould	Living, Pliocene.

In the San Joaquin Coal Mine the direction of the dip of the formation is 65° east of north, and the angle of inclination is between 30° and 45°. In the California Coal Mine the direction of the dip is about the same.

Immediately to the westward of the San Joaquin Coal Mine, the formations which appear to underlie the coal measures are exposed, and consist of sandy shale and soft sandstone. The direction of their dip is 55° to 60° east of north, and the angle of inclination appears to be about 50°. These sandy strata appear to rest conformably on hard, gray sandstone, which becomes dark-colored, on the outside, by exposure.

The most characteristic features of this hard, gray sandstone are, that it splits into slabs on weathering, and the plane of cleavage appears to coincide with the lines of sedimentation which mark the original plane of bedding.

This gray sandstone is well exposed at Station 9, and can be traced thence for more than a mile both to the northward and to the southward in the direction of its strike. It is apparently unfossiliferous, and seems to rest conformably on a sandstone of lighter color, which is remarkable for the numerous concretions which it contains. These concretions, which stud the weathered faces of the inclosing rock, are for the most part round in form, and are harder than their sandstone matrix. There is a good exposure of this sandstone at the point marked "Stratified Peak," where these eccentric concretions look like bowlders embedded in the sandstone. A short distance south of Stratified Peak, a stratum of coarse conglomerate extends from Station 6*a* to Station 6. The pebbles forming this conglomerate are quartzose or metamorphic, and are cemented with calcareous material. The ridge of hills on which the conglomerate crops out can be traced as far south as Flag B. Southward from Station 6 the conglomerate disappears beneath the alluvium, but outcroppings of grayish concretionary sandstone can be followed between Station 6 and Flag B. At Station 10, similar sandstone shows a course of 50° west of north. A short distance north of Flag A, a white sandstone, similar in appearance to that seen between the California and San Joaquin Coal Mines, is exposed. This sandstone has a striking resemblance to that found south of the cabin near the gypsum mine, in T. 19 S., R. 15 E. (see sketch-map); also at Station 27 north of Salt Marsh, near the Sunset Oil Wells, in Kern County. South of Flag A, the soft sandstones and sandy shales extend much farther to the westward; and it is this portion of the foothills (*i. e.*, the portion lying southeast of Flag A and north of the railroad between Coalinga and Alcalde) which has been taken up as oil-bearing territory. At Station 1 there is a soft, iron-stained sandstone, traversed by seams of gypsum, and overlaid by a stratum of clayey limestone, from which were obtained the following fossils:

Galerus filosus, Gabb	Pliocene, Miocene.
Saxidomus gibbosus, Gabb	Pliocene.
Tapes staleyi, Gabb	Pliocene.

South of Station 1 the formation is soft sandstone, dipping apparently about 70° east of north. If the dip of this formation is 70° or thereabouts, it does not conform to what seems to be the dip of the stratum from which the fossils were obtained at Station 1. It is impossible, however, to determine exactly the dip of these formations from surface observation, on account of their incoherent nature and the broken character of the outcropping rocks.

At Station 2 a fossiliferous stratum is exposed; but the specimens obtained therefrom were not sufficiently perfect for identification.

At Station 3 there is a spring of tar-like oil, which is accompanied by a small quantity of brine. Farther down the cañon in which Station 3 is situated, there are several brine and sulphur springs; and the formation changes to sandy and earthy shales, which are interstratified with soft sandstone and impure limestone. At Station 4 the direction of the dip of these shales is 80° east of north, and the angle of inclination is about 40°.

In the cañon farther to the northwest (see sketch-map) similar earthy and sandy shales are exposed. In this cañon observations were made at two places, and the direction of the dip of the formation was found to be 65° east of north, and the angle of inclination about 50°. These shales are interstratified with thin strata of concretionary sandstone, impure limestone, and coarse conglomerate; and in one place a stratum containing numerous small fragments of shells was observed. The country in this direction consists of grazing lands, and the superficial deposit of alluvium is very deep. At Station 11, massive strata of concretionary sandstone are exposed.

In traveling eastward to the station marked Little Peak, it was found that the soft shales and sandstones gave place to a fine conglomerate. The direction of the dip of this conglomerate is 70° east of south. The writer is informed that there are seepages of oil and outcroppings of coal in the cañon which extends from the station marked Little Peak toward the cabin.

At Little Peak a fossiliferous stratum of sandy limestone dips 70° east of south, from which the following fossils were obtained:

Arca microdonta, Con.	Pliocene, Miocene.
Axinæa patula, Con.	Miocene.
Cardium quadragenarium, Con.	Living, Quaternary, Pliocene.
Dosinia conradi, Gabb.	Pliocene.
Galerus diegoanus, Con.	Living, Pliocene, Miocene.
Galerus filosus, Gabb.	Pliocene, Miocene.
Lutricola alta, Con.	Living, Pliocene, Miocene.
Macoma inquinata, Desh.	Living, Pliocene.
Neptunea recurva, Gabb	Miocene.
Pholadidea penita, Con.	Living, Pliocene.
Saxidomus gibbosus, Gabb.	Pliocene.
Solen rosaceus, Carp.	Living, Pliocene, Miocene.
Standella falcata, Gould	Living, Pliocene.
Tapes staleyi, Gabb.	Pliocene.

At Station 20, in the railroad cutting, strata of sandstone and conglomerate are exposed, from which specimens of *Mytilus mathewsoni* were obtained. At Station 13, in the first tier of foothills bordering the valley lands, there are outcroppings of pulverulent gypsum. In this ridge the following fossils were obtained:

Mya arenaria, Linn.	Living, Pliocene.
Mytilus mathewsoni, Gabb.	Miocene.
Pecten nevadanus, Con.	Miocene.
Pseudocardium gabbi, Rem.	Pliocene, Miocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.

Remarks on the Geology of the Hills in which the Coal Mines and the Oil Claims West of Coalinga are Situated.—From the foregoing it is apparent that two geological systems are represented in the territory described. To the first are strata belonging to the Cretaceous system, to which the coal measures penetrated by the San Joaquin and the California Coal Mines belong. It is probable that the sandy and earthy shales which are exposed at Station 4, and in the cañon westward therefrom, are of the same geologic age. To the second belong the Tertiary strata, which constitute the foothills immediately bordering the valley lands, and which are also found resting on Cretaceous rocks. A review of the collection of fossils made in this locality shows that they may be classified according to the vertical range of their species, as follows:

Miocene	3	10 species ranging backward to the Miocene.
Pliocene, Miocene	4	
Living, Quaternary, Pliocene	2	
Living, Quaternary, Pliocene, Miocene	1	
Pliocene	2	7 Pliocene.
Living, Pliocene	5	

The preponderance of Miocene forms indicates that the Tertiary formations of the district under consideration belong to that group.

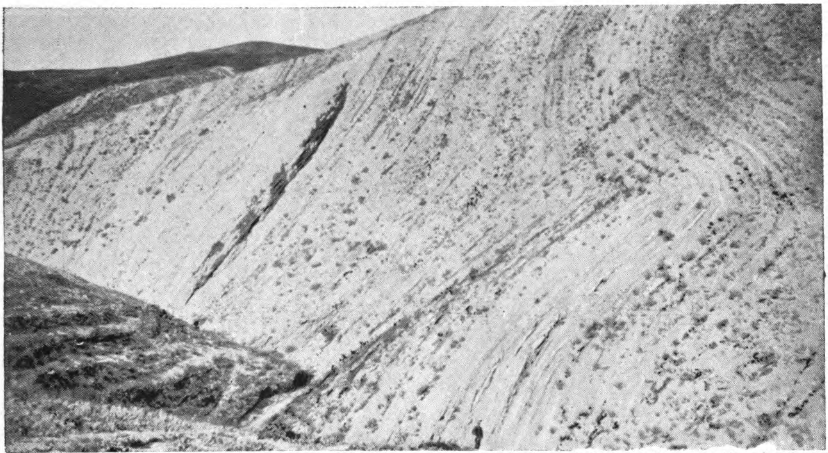
OIL CLAIMS NINE MILES NORTH OF COALINGA.

This oil territory is subdivided by oil claims throughout an area of about 12 square miles. To the westward of this area a ridge of reddish-brown, compact sandstone (Station X; see sketch-map) runs nearly north and south, and is separated from the main Coast Range by a valley which is a few hundred feet in depth. The surface of this ridge is covered with protruding weatherworn crags of sandstone, many of which split into slabs, and the plane in which the sandstone cleaves is apparently coincident with the lines of sedimentation which mark the plane of its original bedding. The summit of this ridge has an altitude of about 2,300 feet. Although this ridge was carefully inspected, no strata were found sufficiently well defined to enable one to estimate the dip and strike of the formation. The sandstone composing this ridge contains rounded concretions, and resembles that found to the westward of the San Joaquin and the California Coal Mines, which is probably Cretaceous.

Between this ridge and the San Joaquin Valley are tier after tier of foothills. Their surface is covered with alluvium, and deeply furrowed with gulches and ravines, and here and there patches of the underlying rocks are exposed. First in order are seen drab and slate-colored patches and slopes, marking the formation in which the oil wells are bored. This formation consists, for the most part, of sandy or earthy shales and soft sandstones.

The oil obtained from these wells is of a remarkably low specific gravity. (See table of oil analyses.) Farther eastward are whitish hills, which are composed of light-colored shale yielding a heavy, tar-like oil. These light-colored shales appear to have been subject to considerable geological disturbance, and wavy lines, caused by the curious contortions of their strata, are noticeable through the scanty herbage with which the hills are covered. Still farther in the eastern distance are seen drab-colored and whitish escarpments, which expose Tertiary strata dipping in an easterly direction toward the San Joaquin Valley. This latter formation, in the lower strata of which the gypsum mine hereinafter described is situated, appears to rest unconformably on the light-colored shales. (See illustration.) The last tier of hills seen to the eastward consists of grassy slopes; and these subside into the mesa lands which form the western boundary of the San Joaquin Valley. The most easterly outlying foothills are principally formed of soft bluish sandstone, similar to that found at the Kettleman Hills and the Krayenhagen ranch. Turning to the westward the eye falls on the more lofty elevations of the Coast Range, which culminate at the point marked "Apparent apex of main range" in the sketch-map.

Descending from the sandstone ridge to the head of a cañon leading to the oil wells, a point is reached where a tunnel has been run into the


Light-Colored Shales, showing Contortions of Strata. Nine miles north of Coalinga, Fresno County.


Contact, showing Non-Conformity of Light-Colored Bituminous Shales and Miocene Strata which rest upon them. Nine miles north of Coalinga, Fresno County.


Gypsum Mine, nine miles north of Coalinga, Fresno County.

sandstone for water. At the time of the writer's visit this tunnel could not be explored, as the water it yielded had been dammed up in the tunnel, forming a reservoir to supply sheep-troughs erected near by. The water is very hard. At Station 25 the slate-colored shales can be seen in contact with the sandstone, but the exposure is a poor one.

In the cañon which leads in a southeasterly direction from the sheep-troughs, the formation is dark-colored shale and soft sandstone. These rocks are interstratified with a few thin courses of impure limestone; and in some places the shale exhibits a variety of strike and dip within a small area. At one point, however, a sandy shale, which appears to be in place, shows a dip of 50° east of south, and an angle of inclination of about 35°. It is probable that these figures approximately represent the prevailing dip of the dark-colored shales. Farther to the northward, slopes of slate-colored shale are exposed, in which there are several springs of sulphuretted water. This bluish shale extends to the ridge of hard, concretionary sandstone previously mentioned. Shortly before reaching the hard sandstone ridge, this shale is traversed by a few strata of soft sandstone; it is so at Station 24, and in one place a thin stratum of magnesian limestone crops out. It is in these dark-colored shales that the oil wells have been bored. The wells marked "oil wells" in the accompanying sketch-map are situated in a depression in the hills. There are five of these wells, namely:

One 4-inch well, in which an oil of low specific gravity stands within 32 feet of the surface, and inflammable gas bubbles freely through the oil. (See table of oil analyses.)

One 4-inch well, plugged.

One 7-inch well, plugged.

One 14-inch well, from which oil and water flow, and inflammable gas rises. In November, 1893, this well was burning fiercely, and a small stream of mineral water and a little oil flowed from the top of the casing. (See table of water analyses.)

One 10-inch well, plugged.

The formations immediately overlying the strata pierced by the oil wells are exposed along the road leading to Coalinga, which runs through a cañon to the eastward of the oil wells. First, a dark-colored shale is seen, the laminæ of which are separated by an ocherous material. Overlying this shale are thin strata of fissile sandstones and impure limestones; and overlying these are light-colored bituminous shales, resembling the light-colored bituminous shales seen at Asphalto, and at the Sunset Oil District, in Kern County. The light-colored shales of Coalinga, like those of Kern County, are very silicious, and vary in color from drab to almost white. Two specimens were examined, which, in round figures, showed as follows:

	Percentage of Specimens Insoluble in Acid.	Percentage of Silica Contained in Specimen, which was Soluble in Sodium Carbonate.	Total Amount of Silica Contained in Specimen.
(*a*)	90	Not determined.	80
(*b*)	91	27	86

Sample *a* was a drab-colored shale; it also contained 7.5 per cent of iron and aluminum (weighed together as sesqui-oxides). The specimen showed quantitatively calcium and magnesium.

Sample *b* was a soft, white shale containing marine diatoms. It showed qualitatively similar constituents to sample *a*, but alumina was only present in traces.

In this formation the scales of fish and a few bones of small fish were found; also several casts of *Pecten peckhami* (Gabb), Mioc.

As shown in the sketch-map, there is a spring of heavy oil in this cañon (see table of oil analyses); and immediately above the spring a bituminous sandstone is exposed. The prevailing direction of the dip of the formations cut through by this cañon appears to be approximately 15° east of south.

Returning to the oil wells the writer explored the little cañons leading up the side of the hills which rise immediately to the southeast of the oil wells. The formation exposed in these cañons is principally earthy and sandy shales containing crystallized gypsum. At Station 22 a stratum of clayey limestone shows a dip of 70° east of south, and the angle of inclination is about 35°. From this clayey limestone the following fossils were obtained:

Discohelix leana, Gabb	Cretaceous A.
Turritella saffordi, Gabb	Cretaceous A.

At Stations 21 and 21*a*, a stratum of calcareous sandstone is exposed, which dips in the same direction as the clayey limestone noted at Station 22. From this calcareous sandstone several fossils were secured, which were determined by Dr. Cooper to be:

Axinæa sagittata, Gabb	Cretaceous B.
Ficopsis cooperi, Gabb	Cretaceous B.
Turritella uvasana, Gabb	Cretaceous A.
Tritonium californicum, Gabb	Cretaceous B.

Farther eastward the formation changes to the light-colored, porous, silicious shales previously described. These shales may be seen cropping out near the summits of some of the hills. The best opportunity for examining them, however, is in a little cañon which leads off in a northeasterly direction from the cañon traversed by the road running between the oil wells and Coalinga. In this subsidiary cañon the light-colored shales are well exposed; a heavy, tar-like oil and sulphuretted water ooze from the shale in several places, and a small amount of asphaltum has been formed. This light-colored shale is much contorted and shows a huge fold, which extends across the little cañon. (See illustration.) At this point the dip of the shale varies from 15° east of south to 25° west of south. In the northern extremity of this cañon the strike of the shale is 50° east of south, and the dip northerly.

On the summit of the adjacent hills the shale is bent and flattened. About 1¼ miles southeast of the burning well another cañon extends in a northeasterly and southwesterly direction. It is in this cañon that the gypsum mine, hereinafter described, is situated. Shortly before reaching the cabin belonging to the owners of the gypsum mine, the light-colored shale is cut through by a road leading to the mine. At Station 33 there is a spring of sulphuretted water and tar-like oil. The shale shows a dip of 85° west of north, and an angle of inclination of about 40°. Following up the bed of this cañon the light-colored shales show evidence of great disturbance; the direction of its dip varies from 15° to 70° east of south, and the angle of inclination varies from 35° to more than 80°. Near the upper end of the cañon the dip of the shale is 10° east of north, at an angle of 70°, and a little farther northward it is 5° west of north, at an angle of 80°. At the upper extremity of the cañon the dip is 35° east of north, and the angle of inclination is 60°. Toward the upper end of this cañon there are two or three seepages of sulphuretted water, and the shale is indurated with silica. These shales are overlaid by strata of soft sandstone and conglomerate, which have a dip of 50° east of south, at an angle of apparently not more than 25°. (See illustration.) Immediately to the eastward of the cabin belonging to the Gypsum Company are bluffs of soft friable sandstone. The upper portion of this sandstone is light-colored, but the lower portion is black, weathering to gray on the outside. This sandstone resembles sandstone seen near the asphaltum mines in Kern County. It is in the formation immediately overlying the contorted shales, and about 50 feet above the bottom of the above-mentioned cañon, that the gypsum mine, which at the date of visit was being worked, is situated.

THE COALINGA GYPSUM MINE.

This mine was opened in November, 1892, and is owned by Hall, Doverall & Lavelle, of Visalia, who erected a mill at Coalinga for grinding the rock. The workings at this mine consist of two open cuts. At one of these cuts, which has been made for a distance of about 60 feet in the hillside, the stratum which is being mined is about 10 feet in thickness. The foot wall is soft sandstone, and the hanging wall, light-colored shale. The formation dips from 45° to 50° east of south at an angle of not more than 20°, perhaps not so much. At the other open cut, which is probably 100 yards south of and 25 feet below the cut already described, there are two distinct strata from which the gypseous material is obtained. These strata are separated by light-colored, sandy shale and clayey and calcareous matter. The writer is informed that about 500 tons of material have been taken from these mines, and that it finds ready sale as land-plaster in Tulare and Fresno Counties. The summit of the hill in which the gypsum mine is situated is marked Flag H in the accompanying sketch-map. Near the top of the hill there are outcroppings of rock very similar in appearance to that which is being taken out of the gypsum mine.

A short distance below this summit, the hillside is traversed by fossiliferous strata, principally calcareous sandstone. Fossils obtained from these strata proved principally to consist of Miocene species, as follows:

Axinæa patula, Con.	Pliocene, Miocene.
Dosinia conradi, Gabb	Miocene.
Mytilus mathewsoni, Gabb	Miocene.
Ostrea titan, Con.	Miocene.
Ostrea bourgeoisi, Remond	Pliocene.
Pecten nevadanus, Con.	Pliocene, Miocene.
Balanus estrellanus, Con.	Miocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.

It is said that gypsum was also formerly mined at the point marked Station 27; but the writer is informed that so much material which was not gypsum was shipped, that the work had to be abandoned. An old sled road marks the scene of former mining. There are several openings not very far away, around which a white rock, which may contain gypsum, is piled up. The formations which rest unconformably on the light-colored shales in this locality, are composed of soft sandstones and calcareous and gypseous strata, some of which are fossiliferous, as previously noted. Conspicuous amongst the sandstones is a peculiar, white sandstone similar to that observed near Station 1, in the oil district southwest of Coalinga, and at Salt Marsh, in Kern County.

About half a mile in a northeasterly direction from the gypsum mines a deep cañon leads in an easterly direction, and at one point therein contorted silicious shales are exposed. In this cañon there is also a spring of mineral water, from which sheep-troughs are supplied. This cañon cuts through a ridge of sandstone and calcareous strata, which dip in an easterly direction, and appear to rest somewhat unconformably on the formation in which the gypsum mine is situated; but the strike and dip of these soft, sandy rocks are very difficult to determine with accuracy, especially when they are much eroded. The strata forming the ridge are very regular, and lie conformably on one another with no signs of folding or contortion. The formation comprising this ridge was examined at points marked Flag K and Stations 30 and 32. From the calcareous sandy strata at the points named the following fossils were obtained:

Ostrea titan, Con.	Miocene.
Liropecten crassicardo, Con.	Miocene.
Liropecten estrellanus, Con.	Miocene.
Balanus estrellanus, Con.	Miocene.
Tamiosoma gregaria, Con.	Miocene.
Pecten discus, Con.	Pliocene, Miocene.

In some places these shell-beds are composed almost entirely of the species named. It is said that these fossiliferous formations can be traced for a distance of more than two miles. The writer was informed that there is a seepage of oil in a cañon to the northeast of Flag K, but he could not find it.

At Station 31 an escarpment of soft sandstone is exposed, forming a cliff of about 200 feet in height. This sand is brownish, and is interstratified with black sand, and contains seams of gypsum; some of the strata of black sand are quite thick. The only organic remains which could be found in this formation are logs of silicified wood. Some portions of the cliff show numerous concretions in the process of formation. A spherical shell of gypsum or oxide of iron forms around a mass of sand, the inclosed mass appearing to grow harder and harder by the action of infiltering water, until a nodule is formed. This formation rests on strata of light-colored, sandy clays and strata of fine conglomerate; it dips 60° east of south, at an angle of about 20°.

After crossing about 1½ miles of grazing land in an easterly direction, a low range of hills is reached at Station 34. The formation is soft, grayish-blue sandstone; the dip appears to be 80° east of north, and at an angle of about 20°. At this station the following fossils were obtained:

Cardium corbis, Martyn	Living, Pliocene.
Cardium meekianum, Gabb	Pliocene, Miocene.
Columbella richthofeni, Gabb	Pliocene.
Macoma edulis, Nut.	Living, Pliocene, Miocene.
Margarita pupilla, Gould	Living, Quaternary.
Mytilus mathewsoni, Gabb	Miocene.
Nassa californica, Con.	Living, Pliocene, Miocene.
Pecten islandicus, Müll.	Living, Pliocene.

Saxidomus gibbosus, Gould	Pliocene.
Schizothœrus nuttali, Con.	Living, Pliocene.
Balanus estrellanus, Con.	Miocene.

At Station 37 soft blue sandstone is again exposed, but the only fossils found at this point were:

Galerus diegoanus, Con.	Living, Pliocene, Miocene.
Modiola capax, Gould	Living, Pliocene.
Scutella gibbsi, Rem.	Pliocene, Miocene.
Balanus estrellanus, Con.	Miocene.

The soft bluish sandstone is again seen at Station 35, where it is interstratified with fine pebbles. The dip of the formation appears to be very slightly north of east, and at a very low angle. The last tier of foothills is reached at Station 16, at an altitude of about 825 feet.

Remarks on the Geological Formations of the Oil District Nine Miles North of Coalinga.—From the foregoing it is obvious that the formations exposed in this oil district represent several epochs in the geological history of the Coast Range, and may be enumerated in what appears to be the order of their superposition, as follows:

Cretaceous:

1. Concretionary sandstone, unfossiliferous.
2. Slate-colored shales passing into earthy or sandy shales, with strata of soft sandstone. This formation contains oil of low specific gravity, and in the uppermost strata of it late Cretaceous shells are found.

Miocene:

3. Light-colored porous silicious shales, which yield heavy, tar-like oil and asphaltum. The only fossils found in these shales were *Pecten peckhami* (a Miocene fossil), a few fish bones, and marine diatoms.
4. Soft sandstones and calcareous and gypseous strata, containing Miocene fossils. These rocks appear to rest unconformably on the light-colored silicious shales, but their slight angle of inclination raises a suspicion that they may belong to a series of strata which are higher in the order of upward vertical range than their position with regard to the light-colored shales might lead one to suppose.
5. Sandy formations containing immense numbers of *Ostrea titan*, *Liropecten*, and *Tamiosoma*.
6. Soft brown and black sands, containing numerous logs of petrified wood.

Pliocene:

7. Soft bluish-gray sandstone and fine conglomerate, containing Tertiary fossils. The fossils collected in these sandstones show a preponderance of species which have a vertical range extending upward from the Miocene group. Some idea as to the thickness of the Tertiary formations overlying the light-colored shales may be gathered from the accompanying sectional sketch, which represents a cross-section from Station 36, in the foothills, to the concretionary sandstone beneath the dark-colored shales in which the oil wells are bored.

Records of Wells which have been Bored in the Oil District Nine Miles North of Coalinga.—Opinions differ as to the results which have been attained by boring in this district, and various reasons are given for the wells being plugged or abandoned. The following is all the data concerning these wells which it has been possible to gather:

The first well of which any record is extant, was sunk several years ago by the Coast Range Oil Company, of Los Angeles. This well is one of the group marked on the sketch-map. The formation penetrated is as follows:

Dark-colored shale, containing a small amount of green oil and inflammable gas	65 feet.
Soft, light-colored sandstone, and a thin stratum of limestone; altogether	50 feet.
At this depth there was a great increase in the amount of gas.	
Dark-colored shale	163 feet.
This shale contained a little green oil and much gas.	

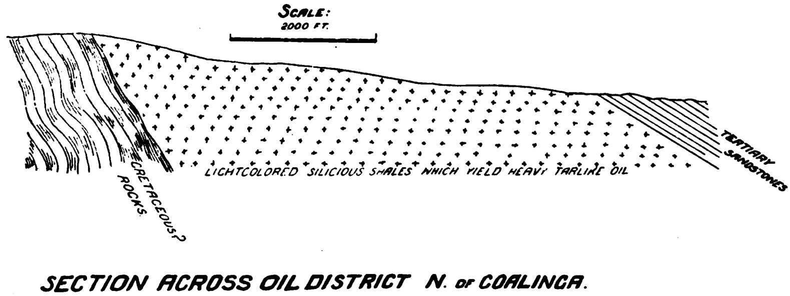
Beneath the shale a dark-colored sandstone was struck, from which a greenish oil of light specific gravity rose to the surface and flowed slightly. A windmill pump was attached to this well, and 10 barrels of oil were pumped from it daily for two days. The third day, the well yielded 7 barrels of oil.

Another gentleman, who bored one of the 4-inch wells, has been kind enough to supply the following record:

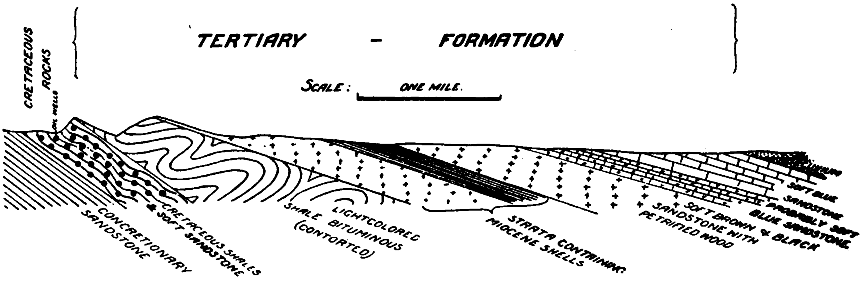
Alluvial soil	30 feet.
Black shale	100 feet.
Soft sandrock	20 feet.
Black shale	45 feet.
Sandstone	15 feet.
Shale	50 feet.
Oil sand	10 feet.
Black shale	105 feet.
Total depth of well	400 feet.

This well was tested by pumping, and was found to yield from 8 to 10 barrels daily. The gentleman who tested the 4-inch well states that the 10-inch well previously mentioned is about 650 feet in depth, and that he thinks it yielded about 40 barrels of oil a day. He also says that one of the other wells is 500 feet deep, but that it was never pumped.

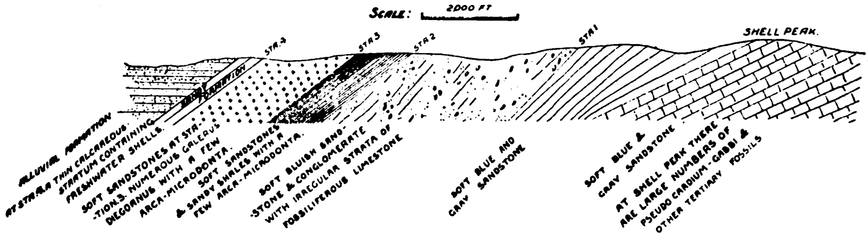
SECTION SHOWING APPROXIMATELY THE MAXIMUM THICKNESS OF LIGHTCOLORED SHALES EXPOSED IN THE SUNSET OIL DISTRICT. KERN COUNTY.



SECTION ACROSS OIL DISTRICT N. OF COALINGA.



SECTION OF TERTIARY STRATA IN KETTLEMAN HILLS.



REMARKS ON THE OIL-YIELDING AND GAS-YIELDING FORMATIONS IN THE CENTRAL VALLEY OF CALIFORNIA.

We have now traced the occurrence of oil and gas in both the Sacramento and the San Joaquin Valleys, and can see how the geological conditions under which the gas is found in the Sacramento Valley compare with the geological conditions under which it is found in the valley of the San Joaquin. In the foothills of the Sacramento Valley, gas and oil are found in Cretaceous formations, and gas is noted issuing from deep wells which penetrate the Quaternary filling of the valley. In the foothills of the San Joaquin Valley, gas and oil are found in formations of both Cretaceous and Tertiary age; and inflammable gas is observed issuing in quantities of commercial value from deep wells penetrating the Quaternary filling of the valley. We have seen that wells penetrating the Upper Cretaceous strata north of Coalinga yielded inflammable gas and an oil of a peculiarly low specific gravity. The Cretaceous formation no doubt underlies the whole of the Central Valley of California. As previously stated, rocks of this age can be traced on both sides of the Sacramento Valley. In the San Joaquin Valley, Cretaceous rocks have been observed as far south as the Tejon Pass. The writer has found fossils of this age in San Emidio Cañon, in the foothills near Coalinga, and near Merced Falls in Merced County. At the latter place (see our XIth Report p. 257), there is a range of low hills of sandstone, from which specimens of *Cardita planicosta* were obtained, showing the formation to belong to the Cretaceous B (Chico Tejon) series.

The principal showing of Tertiary hydrocarbons on the western side of the San Joaquin Valley is found in what appears to be the lowest formation belonging to the Tertiary system. As previously noted, these lower Tertiary strata consist of a peculiar, porous, silicious shale, which yields a heavy, tar-like oil. Heavy oils are also found in some of the sandy strata, which appear to be of more recent origin than the light-colored shales. Thus, seepages of tar-like oil exude from Tertiary sandstone at the Krayenhagen ranch, at Tar Cañon, and at Asphalto; and bituminous sands, which are probably of this age, are found on the banks of Kern River on the eastern side of the San Joaquin Valley. There are also many other places in the foothills on the western side of the San Joaquin Valley where bituminous Tertiary sandstones are exposed.

The bituminous shales exposed in the Sunset Oil District show a maximum thickness which may be approximately estimated at 2,700 feet, but exposures of this formation seen north of Coalinga and near the Vallecitos Creek, in San Benito County, convey the idea that it becomes thinner as it extends northward. The thickness of the Tertiary formations overlying the light-colored shales (as calculated from observations made in the oil district nine miles north of Coalinga) may be taken at not less than one mile.

From these estimates, other things being equal, the aggregate thickness of the Tertiary formation underlying the San Joaquin Valley may be tentatively put down at not less than 8,000 feet; but observations similar to those herein recorded should be made at many places in the foothills before expressing a definite opinion as to the thickness. By the sectional sketches accompanying this article, the aggregate thickness of the Tertiary formation is approximately shown; but the relative thickness of the different strata overlying the light-colored shales is largely a matter of conjecture.

The greater portion of the Tertiary rocks are sufficiently porous to afford a good storage for gas under suitable conditions. It is probable that the gas wells in the valley lands derive their immediate supply from formations similar to the sandstones composing the Kettleman Hills, and from porous Quaternary strata, which lie practically horizontal on the older rocks forming the slopes of the valley. It may be here remarked that one of the strongest evidences of the existence of a large supply of gas is the great uniformity in the fuel value of the gas yielded by the various Stockton wells.

The approximate thickness of the blue sandstone and more recent formations exposed in the cañon investigated in the Kettleman Hills may be tentatively reckoned as probably more than 5,000 feet. It is quite likely that further explorations in the Kettleman Hills, especially on their eastern side, would materially add to our knowledge concerning the strata which immediately underlie the filling of the San Joaquin Valley, for on the eastern side of those hills the rocky formations are said to be less obscured by alluvium than they are in the cañon explored by the writer. The character and the thickness of the filling of the valley can only be inferred from the material brought to the surface during the process of well-boring. Hitherto the borings at Stockton have not thrown much light on the geological age of the strata they penetrate. The only organic remains identified which have been brought up by the sand-pump are the following: The leg bone of a small rodent, from a depth of 600 feet; a horse's incisor, a much worn tooth of some carnivorous animal, and two small pieces of jaw bone, from a depth of 1,058 feet. There is also some lithological evidence, for lava pebbles have been brought up from a depth of about 1,500 feet. From these organic remains, and from the fact that the lava pebbles probably came from lava streams of late Tertiary origin, it appears a reasonable conclusion that the first 1,500 feet, and probably more, of the strata thus far penetrated at Stockton are of the Quaternary age. This opinion is strengthened by finding Pliocene and recent fresh-water shells at a depth of more than 1,000 feet in the Lambertson well, near Lake Tulare.

Two of the most important things shown by the record of wells which have been bored in the San Joaquin Valley are: (1) The clayey nature of many of the strata which overlie the gas-holding formations. (2) The great increase in the number and thickness of the gas-yielding strata as a great depth is reached. By referring to the records of wells which have been sunk in the San Joaquin Valley, to obtain gas or water (see our VIIIth, Xth, XIth Reports and this bulletin), it will be seen that sheets of clay, which are encountered at no great depth beneath the surface, extend throughout the Central Valley of California. These clayey strata aggregate several hundred feet in thickness, and are of comparatively recent geologic age. It is in the porous formations which lie beneath these sheets of clay that the natural gas which has been obtained by wells bored in the valley lands is stored. There has not as yet been sufficient evidence forthcoming to determine the extent of the area occupied by the more recent porous gas-holding strata in the San Joaquin Valley; but investigation warrants a belief that they are coextensive with the central portions of the valley, and that the alluvial formations on the sides of the valley are either connected with the gas-holding rocks or isolated therefrom, according as the intervening strata are either sand or clay.

In reviewing the history of the Stockton gas wells, it is interesting to compare the records of the relative depth and character of the strata from which gas was obtained.

Gas-Yielding Strata in the Court-house Well.

Character of Strata.	Thickness of Strata, in Feet.	Depth of Well, in Feet.
Bituminous shale or clay, with gas	30	1,070 to 1,100
Fine, friable, soft sandstone, with gas	20	1,280 to 1,300
Sandy cement, with gas	40	1,410 to 1,450
Clayey sandstone, with gas	40	1,560 to 1,600
Light-colored, clayey sandstone, with gas	30	1,630 to 1,660
Cement gravel, with gas	40	1,660 to 1,700
Indurated clay, with gas	100	1,700 to 1,800
Soft, friable sandstone, with gas	70	1,800 to 1,870
Coarse sandstone, with gas	27	1,890 to 1,917
Total thickness of gas-yielding strata	397	

It will be observed that after striking the gas, a thickness of 590 feet showed only 160 feet of gas-holding formation, while the 275 feet penetrated below a depth of 1,660 feet showed a thickness of 237 feet which yielded gas. The gas furnished by this well has been estimated at 30,000 cubic feet every twenty-four hours; a large amount of water accompanies the gas, but the strata in which the flows were struck are not recorded.

Gas-Yielding Strata in the Northern Well.

Character of Strata.	Thickness of Strata, in Feet.	Depth of Well, in Feet.
Soft clay, with small flow of water	- - ------	830 to 834
Blue clay, and a little gas	5	963 to 968
Sand, and a little gas	6	1,185 to 1,191
Sand	1	1,210 to 1,211
Soft clay, with good flow of water and gas	15	1,215 to 1,230
Hard blue clay, with more water and gas	38	1,270 to 1,308
Sand, packed very hard; small flow of water and gas	8	1,330 to 1,338
Sand, with good flow of water and gas	15	1,385 to 1,400
Loose, black sand, with more water and gas	8	1,434 to 1,442
Packed sand, with water and gas	2	1,468 to 1,470
Coarse black sand, with water and gas	6	1,543 to 1,549
Fine black sand, with water and gas	4	1,583 to 1,587
Gravel and cement, with gas and water	5	1,624 to 1,629
Total thickness of gas-yielding strata	113	

Gas-Yielding Strata in the Jackson Well No. 2.

Character of Strata.	Thickness of Strata, in Feet.	Depth of Well, in Feet.
Soft sand-rock	34	746 to 800
Coarse sand, with good flow of water and gas	10	870 to 880
Porous cement, with good flow of water and gas	16	880 to 896
Porous, sandy cement, with gas	30	1,000 to 1,030
Sand, with water and gas	10	1,170 to 1,180
Sand, with water and gas	10	1,260 to 1,270
Sand, with large flow of water and gas	15	1,445 to 1,460
Porous, sandy stratum, yielding much gas	10	1,630 to 1,640
Sand, with large flow of water and gas	5	1,650 to 1,655
Total thickness of gas-yielding formations	140	

It appears from the records of Jackson Well No. 2, the Court-house well, and the Northern well, that the average thickness of gas-yielding strata for wells 1,600 to 1,700 feet deep may be put down approximately at 150 feet. Below that depth, the proportion of gas-yielding strata greatly increases, and it is the opinion of those who have bored deeper wells at Stockton, that below a depth of 1,700 feet all the porous strata yield gas.

Concerning the tension of the gas in the gas-yielding strata, the problem is complicated by the presence of flowing water which has been struck in nearly all the gas wells hitherto bored in the valley lands. The flowing water is, however, a qualified misfortune, for not only is it in itself of great service to the community, but it is a safeguard against waste, such as was occasioned in the Eastern States by an unimpeded flow of gas. If the water could be kept out of the casing without obstructing the flow of gas, there is no doubt but that the amount of gas yielded by the wells would be greatly increased. The only information that could be obtained on this important subject is as follows:

In the Jackson Well No. 2 some gas was obtained before flowing water was struck. In the St. Agnes Well No. 1, only about a mile distant from the Jackson wells, when the water ceased to flow the well ceased to yield gas. In the Haas well, which is probably a mile and a half from the Jackson well, the force of the gas, when the well was virtually capped by the boring tools, drove the water out of the hollow boring-rod, and burst the fire hose attached to it. Mr. Haas is of the opinion that the pressure equaled 200 pounds to the square inch. In this connection we call to mind the fact that the gas which blew the water out of the casing of the Jacobs well in Tulare County must have been under a pressure of more than 105 pounds to the square inch.

It is impossible to determine to what extent the Tertiary rocks may have been eroded in central portions of the valley, but it is quite likely that Tertiary strata several thousand feet in thickness underlie the Quaternary filling of the valley. If such strata should contain gas, its tension would be much greater than in strata near the surface, and the amount of water might be much less.

A great increase in the depth of wells is limited by questions of cost and practicability; but all circumstances connected with the question of "natural gas" in the San Joaquin point to the fact that deep wells produce the best results.

There is one point on which the reader will probably wish to know something, and that is the cost of well-boring in the Central Valley of California. Concerning the cost of well-boring, the writer has not yet sufficient data to give very satisfactory information, but he is informed that the Court-house well at Stockton, which is said to yield 30,000 cubic feet of gas daily, cost about $12,000, including the cost of gasometer and the necessary plant.

THE LEADING GEOLOGICAL FEATURES OF THE OIL-BEARING FORMATIONS OF THE SAN JOAQUIN VALLEY.

The most characteristic rock of the bituminous formations of the Coast Range is the light-colored, silicious, bituminous shale. These shales are described by Professor J. D. Whitney in Geology of California, vol. 1, and more recently in a bulletin published by the University of California, entitled "The Geology of Carmelo Bay," by Dr. A. C. Lawson, assisted in chemical analysis and field-work by Juan de la Posada. It is impossible to read the descriptions of this shale in the works referred to, and then to examine the light-colored shale mentioned in the foregoing pages, without at once recognizing the probability of the formations being identical. Dr. Lawson has described the samples of shale which he found in Monterey County somewhat exhaustively from a lithological point of view; he regards the rock as being indirectly of volcanic origin, and states that it is probably made up of a very silicious volcanic ash. In comparing the samples of light-colored shale obtained near Coalinga with samples from Kern County, the writer spent no more time in laboratory work than was required to bring out the leading features necessary to demonstrate a similarity in the composition of the light-colored shales seen in Kern and Fresno Counties.

The facts here relied on to establish the identity of the light-colored shale formation exposed in both counties, are as follows: Both at the San Emidio Grant, in Kern County, and in the oil district nine miles north of Coalinga, these shales are found beneath strata containing Miocene fossils. The physical appearance of the light-colored shales both in Kern and Fresno Counties is very similar, not only when studied as a formation, but also when hand specimens are subjected to macroscopic examination. After these shales have been treated with acid to remove soluble infiltrations, they are found to be largely composed of silica, and a notable percentage of this silica is soluble in a solution of sodium carbonate. These shales, both in Kern and Fresno Counties, yield a heavy, tar-like oil, and contain marine diatoms. Samples of light-colored shale from the oil district nine miles north of Coalinga, the Sunset Oil District, and Asphalto, were examined by Mr. D. C. Booth, of the San Francisco Microscopical Society, who makes the following statement: "The sample of light-colored shale from the oil district nine miles north of Coalinga contained numerous diatoms, and some specimens contained the spicula of sponge. The species of diatoms most abundant in the specimen furnished me are: *Actinoptychus*, *Raphoneis*, *Actinocyclus*, *Coscinodiscus* (3 var.), *Navicula* (2 var.), and *Hyalodiscus*—all marine species. The specimens of light-colored shale from the Sunset Oil District do not contain many diatoms, but what appears to be the silicious epidermis of algæ is abundant. In some specimens from this locality I found the spicula of sponge and foraminifera. The soft silicious rock from Asphalto contains numerous *Coscinodiscus*, and a few

Raphoneis; and both these diatoms appear to be of the same varieties as the *Coscinodiscus* and *Raphoneis* in the sample of light-colored shale from Coalinga."

The necessity of producing the aforementioned evidence to establish the identity of the light-colored shale exposed in the oil district nine miles north of Coalinga and that seen in the Sunset Oil District, arises from the impossibility of tracing the formation continuously between the two places. This disappearance of the light-colored shales ceases to be surprising when we find sandy Miocene formations resting unconformably on the light-colored shales in the oil district nine miles north of Coalinga. Another interesting geological feature is the contortion which the light-colored shales have undergone in some places. This contortion, as suggested by Dr. Cooper, may be due not only to the folding incidental to orographic movement, but to an irregular subsidence caused by the escape of gas, oil, or other matter once contained by the light-colored shales, or by strata on which they rest. It will, no doubt, be observed by the reader that only scanty exposures of what are believed to be earthy Cretaceous shales were noticed in the Sunset Oil District, and that no mention is made of them at Asphalto, although the light-colored shales are well exposed at both places. This awakens a suspicion that the light-colored shales rest unconformably on the Cretaceous strata. This, however, is not established by the observations herein recorded. The most that can be safely said on the subject is, that at Sunset the light-colored shales appear to be less disturbed than the strata on which they rest, and that in the oil district north of Coalinga the reverse seems to be the case. But formations which are conformable in one locality may be unconformable in another.

An interesting line of inquiry presents itself in the gradual increase in the easterly direction of the dip exhibited by the strata composing some of the formations herein described, when they are examined in the order of their upward vertical range. It is to be hoped that these investigations will be supplemented by the work of others who have both the means and the time for exhaustive scientific research.

ESTIMATION OF FUEL VALUE OF NATURAL GAS AT STOCKTON.

Having dwelt somewhat largely on the geological features attending the occurrence of natural gas, in both the San Joaquin and the Sacramento Valleys, it is now in order to consider the value of the gas as fuel. It has for some time been the endeavor of the State Mining Bureau to obtain reliable information upon this subject from the experience of those who have used the gas. A review of the information collected under this head shows a wide difference of experience and opinion; this, however, is by no means surprising when we consider the lack of uniformity in the conditions under which the gas has been burned. It was concluded that under the circumstances the best results in this investigation could be obtained by physical experiment. The plan chosen was the comparison of work done by burning measured quantities of hydrogen with work done by measured quantities of natural gas burned under practically similar conditions. To this end a cylindrical boiler was made capable of holding 6,700 cubic centimeters of water, the tare of the boiler for purposes of calormetric estimation having an equivalence of 270 cubic centimeters of water. The height of the boiler was 20 inches, and its diameter 6 inches. A funnel-shaped fire-box formed the base of the boiler and connected with an air-chamber, from which a flue for the escape of the products of combustion extended through the upper portion of the boiler and protruded from its top. The air-chamber was so constructed that it would retain any water that might be condensed from the products of combustion. It was found that, although several cubic centimeters of water were condensed during short experiments, only an insignificant amount remained at the close of the experiments herein recorded. The outer portion of the boiler was of tinned iron, and the fire-box, air-chamber, and flue were made of copper. When this instrument was in use it was surrounded by a screen of thick asbestos paper, and the boiler was insulated by asbestos, as much as possible, from the iron ring-stand upon which it stood. Bunsen burners were employed. The test-meter used was manufactured by the American Meter Company. Repeated experiments with hydrogen showed that the best results were obtained with a five-jet burner, in which the air passages at the base of the jets were about two-thirds closed. The hydrogen was prevented from "snapping back" by the insertion of platinum gauze in the tips of the burners. Under these conditions very uniform results were obtained.

Repeated experiments with the natural gas showed that the best results were secured by using a Bunsen burner in which three jets fed an Argand nozzle, while a single jet, the tip of which formed a center to the base of the nozzle, supplied an independent flame; this flame in its passage upward superheated, to some extent, the gas passing through the Argand nozzle. A series of experiments showed that the most heat was obtained from the natural gas by regulating the flow so that a flame was produced blue at the base, and passing through various shades of dull red to a yellow color at the edges and in the upper portions of the luminous cone. In the experiments with both the hydrogen and natural gas the tips of the burners were on a level with the base of the boiler. By carefully noting the color of the flame, and instantly repressing any tendency to roar or flicker, very uniform results were derived from experiments made with the same bagful of natural gas. At Stockton, the natural gas was conveyed in a rubber bag directly from the wells to a room wherein the experiments were conducted; and as the tabular statement hereto annexed shows, the conditions were as uniform as the circumstances would allow.

Gas was taken from the following wells: St. Agnes, Court-house, Asylum, Northern, Jackson, Citizens, and Haas. In this article these wells are referred to by numbers and not by names, nor are the numbers in the order in which the wells have just been mentioned. The only exception made is in the case of the Asylum well.

As the following table of results shows, only in one instance was any noteworthy difference observed in fuel value of the gas yielded by the various wells:

Table recording the Experiments with Natural Gas and Hydrogen, and showing the Conditions under which they were Conducted.

Wells.	Barometric Pressure Approximated by a Pocket Aneroid.	Amount of Gas Burned	Temperature of Gas	Open Pressure of Gas in Meter	Temperature of Air	Temperature of Water at Beginning of Experiment	Temperature of Water at End of Experiment	Number of Degrees Water was Raised	Number of Degrees for Each Foot of Gas Burned	Duration of Experiment	Average Temperature at which Products of Combustion were Lost
		Cubic Feet.		Inch of Water.						Minutes.	
The Asylum	29.50 in.	3	17.60° C.	.6	13.00° C.	14.00° C.	67.00° C.	53.00° C.	17.66° C.	36.00	37.00° C.
Well No. 1		3	15.40	.6	18.00	16.00	68.75	52.75	17.58	31.00	36.00
Well No. 2		3	13.20	.6	17.00	15.75	64.75	49.00	16.33	42.00	35.00
Well No. 3		3	15.40	.6	15.40	17.00	70.75	53.75	17.91	48.00	35.60
Well No. 4		3	16.50	.6	16.50	16.00	70.25	54.25	18.08	46.00	36.40
Well No. 5		3	17.60	.6	17.60	17.00	70.25	53.25	17.75	40.00	35.60
Well No. 6		3	17.60	.6	17.60	16.50	70.00	53.50	17.83	46.00	37.10
		3	113.30	.6	115.10	112.25	481.75	369.50	123.14	289.00	252.70
Average for natural gas		3	16.18	.6	16.44	16.03	68.82	52.78	17.59	41.30	36.10
Experiment with hydrogen	29.65 in.	7	15.00	.6	15.00	16.20	72.20	56.00	8.00	44.00	34.00

Another sample taken from the Asylum Well and from Well No. 2 showed as follows:

Asylum.										
Second sample taken 3 days after first sample	3	13.75° C.	.6	14.90° C.	16.00° C.	68.00° C.	52.00° C.	17.50° C.	32.00	39.00° C.
No. 2.										
Second sample taken 2 days after first sample	3	13.20	.6	13.75	15.00	63.50	48.50	16.25	41.00	38.00

If the temperature of the gases had been reduced to 0° C., disregarding fractional differences resulting from a slightly increased loss by radiation and conduction, the work performed by the three feet of natural gas and the seven feet of hydrogen, respectively, would have been practically as follows:

Average sample of natural gas	3	0.00° C.	.6	16.44° C.	16.00° C.	72.90° C.	55.90° C. 56.90	18.63° C. 18.96	43.74	38.23° C.
Experiment with hydrogen	7	0.00	.6	15.00	16.20	76.16	59.07	8.44	46.40	35.86

As hereinafter described, the loss of heat by radiation and conduction under the conditions attending the experiment with hydrogen was approximated experimentally and found to be 2.17° C.

In the foregoing experiments the temperatures at which the products of combustion were lost increased as additional gas was consumed and the temperature of the water in the boiler rose. In the subsequent estimates as to the value of the gases at 0° C., a rise in the temperature at which the products of combustion would have been lost is therefore calculated corresponding to the increased calorific value of the gases at 0° C. Moreover, as the density of the gases would be increased by reduction to zero, the time representing the duration of the experiment is also proportionately lengthened.

The experiments are thus placed on as equal a footing as the conditions will permit. It was found that the work done by 1 foot of hydrogen, its temperature being 0° C., was to raise the temperature of the water in the boiler 8.44° C., while an average foot of natural gas at a temperature of 0° C. raised the water in the boiler 18.63° C.

By comparing the work done it was found that 1 foot of natural gas performed as much work as 2.207 cubic feet of hydrogen. Taking the weight of 1 cubic foot of hydrogen at 0° C. as 2.537 grammes, the available calorific value of hydrogen as 29,629 kilogramme calories, and that of carbon as 8,080 kilogramme calories, it is evident that the practical fuel values of hydrogen and natural gas as compared with carbon are respectively as follows: 1 cubic foot of hydrogen equals, practically, 9.30 grammes of carbon; 1 cubic foot of natural gas equals, practically, 20.525 grammes of carbon; therefore, 1,000 cubic feet of natural gas equal 20,525 grammes, or 45.3 pounds of carbon, which is practically equal to 50 pounds of coke carrying 10 per cent of ash.

As the temperature of the natural gas when burned was 16.18° C. instead of 0° C., it is necessary to adjust the value by calculation. This being done it is found that 1,000 cubic feet of natural gas at 16.18° C. have a fuel value of, practically, 47 pounds of coke. Therefore, a ton of coke carrying 10 per cent of ash has a fuel value of, practically, 42,500 cubic feet of an average sample of Stockton natural gas.

The following samples of gas from Wells No. 2 and No. 5 were analyzed by Messrs. Price & Son, of San Francisco, who have kindly placed the results of the analyses at the disposal of the writer. The gas was conveyed in rubber bags from Stockton to San Francisco, and analyzed immediately on its arrival in the latter city. Messrs. Price & Son stated that in these analyses all the hydrocarbon illuminants were estimated as marsh gas:

	Well No. 2.	Well No. 5.
Sample taken—Specific gravity referred to air	0.612	0.607
Marsh gas (CH_4)	60.47 per ct.	62.93 per ct.
Hydrogen (H_2)	11.87 per ct.	11.51 per ct.
Oxygen (O_2)	1.00 per ct.	.70 per ct.
Nitrogen (N_2)	26.66 per ct.	24.36 per ct.
Carbonic di-oxide (CO_2)	trace.	.50 per ct.
Carbonous oxide (CO)	trace.	trace.
	100.00 per ct.	100.00 per ct.

In order to compare the theoretical fuel value of the gas as derived from the analysis, with the practical results obtained by physical experiment, the writer begs to submit the following calculations, the results of which show a wonderful uniformity; indeed, by a curious coincidence, in the case of the gas from Well No. 2, the figures obtained both by analysis and by physical experiment are nearly identical. The calculations, however, are not carried out beyond the third decimal place; and in calculating the results of the physical experiments, the fact that the gas was under a water pressure at 0.6 of an inch is disregarded, as is also the amount of heat lost by the nitrogen shown in the analyses, for the difference occasioned by both these items is less than 1 per cent. In these calculations practical fuel values are taken, namely:

Hydrogen = 29,629 kilo calories.
Carbon = 8,080 kilo calories.
Marsh gas = 11,855 kilo calories.

The figures for marsh gas are the figures of Favre and Silberman, less the latent heat absorbed by converting the hydrogen which the gas contains into water, *i. e.*, 13,063 — 1,208 = 11,855.

Well No. 2.

	Estimated as 1 Cubic Foot.	Weight, in Grammes.	Kilogramme Calories.
Marsh gas (CH_4)	60.47 per ct.	12.350	146.60
Hydrogen (H_2)	11.87 per ct.	0.300 Less 0.05 grammes, required to satisfy 0.406 grammes of O = 0.25 grammes of available H.	7.40
Oxygen (O_2)	1.00 per ct.	0.45	
Nitrogen (N_2)	26.66 per ct.	0	
Carbonic di-oxide (CO_2)	trace.		
Carbonous oxide (CO)	trace.		
	100.00 per ct.		154.00

Thus it is found that one cubic foot of natural gas from Well No. 2 has a fuel value of 154 kilogramme calories. Taking one gramme of carbon as having a fuel value of 8.08 kilo calories, one cubic foot of sample has a fuel value of 19.05 grammes of carbon. Therefore, 1,000 cubic feet of this gas is practically equal to 42 pounds of carbon, or 46 pounds of coke carrying 10 per cent of ash.

Fuel Value of Natural Gas from Well No. 2, as Determined by Physical Experiment.—One cubic foot of this gas, its temperature being 13.2° C., raised the water in the boiler 16.33° C. If the temperature of the gas had been 0° C., one cubic foot of natural gas would have raised the water in the boiler 17.11° C. One cubic foot of hydrogen at 0° C. has a fuel value of 9.3 grammes of carbon. One cubic foot of hydrogen at 0° C. was found to raise the water in the boiler 8.44° C. Therefore, one cubic foot of gas from Well No. 2, its temperature being 0° C., has a fuel value of 18.85 grammes of carbon; and 1,000 cubic feet of this gas have a fuel value of 41.6 pounds of carbon, or practically 1,000 cubic feet of the gas have a fuel value of 46 pounds of coke carrying 10 per cent of ash.

Well No. 5.

	Estimated as 1 Cubic Foot.	Weight, in Grammes.	Kilogramme Calories.
Marsh gas (CH_4)	62.93 per ct.	12.850	152.336
Hydrogen (H_2)	11.51 per ct.	0.292 Less 0.35 grammes, required to satisfy 0.284 grammes of O = 0.257 grammes of available H.	7.614
Oxygen (O_2)	0.70 per ct.	0.284	
Nitrogen (N_2)	24.36 per ct.		
Carbonic di-oxide (CO_2)	0.50 per ct.		
Carbonous oxide (CO)	trace.		
	100.00 per ct.		159.950

Thus we find that the total number of kilo calories in 1 cubic foot of gas from Well No. 5 was practically 160. Therefore, 1 cubic foot of this gas is equal to 19.81 grammes of carbon, and 1,000 cubic feet have a fuel value of 43.6 pounds of carbon, which is practically equal to 48 pounds of coke carrying 10 per cent of ash.

Fuel Value of Natural Gas from Well No. 5, as Determined by Physical Experiment.—One cubic foot of gas from Well No. 5, its temperature being estimated as 0° C., would raise the water in the boiler 18.89° C. One cubic foot of hydrogen at 0° C. would raise the water in the boiler 8.44° C. Therefore, 1 cubic foot of gas from Well No. 5 has a fuel value of 2.238 cubic feet of hydrogen. As the available fuel value of 1 cubic foot of hydrogen equals that of 9.3 grammes of carbon, it follows that 1 cubic foot of gas from Well No. 5 has a fuel value of 20.81 grammes of carbon. One thousand cubic feet of the gas have, therefore, a fuel value of 45.88 pounds of carbon, or practically 50 pounds of coke carrying 10 per cent of ash.

A comparison of the results of the physical experiments on the Stockton natural gas made by the State Mining Bureau, with the theoretical fuel values calculated from the analyses made by Messrs. Price & Son, shows as follows:

From Physical Experiment.	*Calculated from Analysis.*
1,000 cubic feet of an average sample of Stockton natural gas = 50 ℔s. of coke.	1,000 feet from Well No. 2 = 46 ℔s. of coke.
Sample of Well No. 2 = 46 ℔s. of coke.	1,000 feet from Well No. 5 = 48 ℔s. of coke.
Sample of Well No. 3 = 50 ℔s. of coke.	

In the above calculation the gas is estimated at 0° C., and 0.6 of an inch water-pressure. The standard of comparison is coke carrying 10 per cent of ash.

It is interesting to review the facts and figures with regard to the actual cash value of the Stockton gas wells. The well at the court-house in Stockton is 1,917 feet deep, and together with the gasometer and necessary plant, cost $12,000. The yield of this well is estimated at 30,000 cubic feet of gas daily. Estimating the temperature of the gas at 15° C., the well at Stockton court-house yields, in round figures, $6 10 worth of gas daily, or $2,226 50 worth of fuel a year. This calculation is based simply on the average calorific power of the gas.

It is probably a conservative estimate if we say that the relative depth and yield of the Stockton gas wells range from that of wells a little more than 1,000 feet deep, which yield about 2,500 cubic feet of gas daily, to that of the deepest well at Stockton, which is said to be about 2,600 feet deep, and to yield nearly 80,000 cubic feet of gas a day.

The gas-yielding formations of the San Joaquin and Sacramento Valleys are in proximity to the mines of the Sierra, to beds of pottery clay and of sand suitable for the manufacture of glass. The localities where the principal wells are situated possess water communication with the harbor of San Francisco. It needs no stretch of the imagination to appreciate the fact that natural gas is an important factor in the geological economics of the Central Valley of California.

ESTIMATION OF FUEL VALUE OF NATURAL GAS AT SACRAMENTO, AND ALSO IN KERN COUNTY.

Subsequently to making the experiments on the fuel value of the Stockton natural gas, the writer determined the fuel value of the natural gas from the old gas well at Sacramento, from a gas-yielding spring on the Barker ranch in Kern County, and from a well in the Sunset Oil District, also in Kern County. In all these experiments the same method and apparatus were employed as were used in the determination made of the fuel value of the Stockton natural gas.

The following record of these experiments is self-explanatory to those who have followed the description of the experiments made at Stockton:

Name of Well.	Barometric Height Approximated by a Pocket Aneroid	Amount of Gas Burned	Temperature of Gas	Average Temperature of Air	Temperature of Water at Beginning of Experiment	Temperature of Water at End of Experiment
		Cu. Ft.				
Old gas well at Sacramento	29.52 in.	3	18.0° C.	17.85° C.	15.00° C.	50.25° C.
Average of four experiments at gas-yielding spring, Barker Ranch, Kern County	29.00 in.	3	23.5	23.75	19.50	80.00
Gas well in Sec. 28, T. 11 N., R. 23 W., S. B. M. (Sunset Oil District, Kern County)	28.75 in.	3	31.5	32.00	26.75	80.12

Name of Well.	Number of Degrees Water was Raised	Number of Degrees for Each Foot of Gas Burned	Duration of Experiment	Open Pressure of Gas in Meter	Average Temperature at which Products of Combustion were Lost	Loss by Radiation and Conduction, Approximated Experimentally.
			Minutes.	Inch of Water.		
Old gas well at Sacramento	35.25° C.	11.750°C.	40.5	.6	31.00°C.	----------
Average of four experiments at gas-yielding spring, Barker Ranch, Kern County	61.00	20.225	63.0	.6	43.00	2.25°C.
Gas well in Sec. 28, T. 11 N., R. 23 W., S. B. M. (Sunset Oil District, Kern County)	53.38	17.790	65.0	.6	46.25	1.23

Repeated preliminary experiments with the natural gas from the old gas well at Sacramento showed that the best results were obtained by partially closing the air passages at the base of the jets in the Bunsen burner. Repeated experiments with the natural gas at the Barker Well and at the Sunset Oil District showed that, with the burner used, it was impossible to burn the gas economically and faster than at the rate of consumption employed, for a very slight increase in the pressure or the supply of gas made the flame roar.

Taking the fuel value of the Stockton natural gas at a temperature of 16.18° C. as a basis of calculation, we obtain, in round figures, by the methods of calculation heretofore employed, the following fuel values: 2,000 pounds of coke carrying 10 per cent of ash equals 42,500 cubic feet of an average sample of Stockton natural gas; or 63,000 cubic feet of gas from the old gas well at Sacramento; or 36,000 cubic feet of gas from the gas-yielding spring on the Barker ranch in Kern County; or 40,000 cubic feet of natural gas from the well in Sunset Oil District in Kern County.

A comparison of the descriptions of the Stockton and Sacramento gas wells shows that the well from which the gas used in the experiments at Sacramento was obtained, is much shallower than are most of the gas wells at Stockton. As premised when speaking of the gas wells at Stockton, the gas from shallow wells which are bored in the filling of a valley is more likely to be diluted with nitrogen or air than gas which is obtained from the deep wells which furnish gas from strata below the principal supply of artesian water. It is possible that the great fuel value of the gas from the spring on the Barker ranch results from a large amount of sulphuretted hydrogen being present; for although the calorific value of the latter gas is low, its specific gravity is more than double that of marsh gas, and in the experiments cited in this article, the gases used were measured volumetrically. Some sulphuretted hydrogen was also noticeable in the gas from the well in the Sunset Oil District.

The following comparison of the wells from which the gas used in the foregoing experiments was obtained, and the fuel value of the gas which they respectively yield, is not without interest:

Name of Well.	Depth of Well.	Fuel Value of Gas.	Remarks.
The Stockton wells	1,350 to about 2,600 feet.	42,500 cu. ft. = 2,000 lbs. of coke carrying 10 per cent of ash.	These wells appear to penetrate the recent and Quaternary filling of the San Joaquin Valley for more than 1,000 feet.
Old gas well at Sacramento.	,,875 feet	~~63,000~~ 64000 cu. ft. = 2,000 lbs. of coke.	For the first 500 feet this well appears to penetrate the recent and Quaternary filling of the Sacramento Valley; whether or not the harder material penetrated below that depth belongs to an older formation there is no evidence to determine.
Gas from the spring at the Barker ranch, Kern County.		36,000 cu. ft. = 2,000 lbs. of coke.	This spring issues from Tertiary rocks.
Gas from well in Sec. 28, T. 11 N., R. 23 W., S. B. M., in Sunset Oil District, Kern County.	1,350 feet	40,000 cu. ft. = 2,000 lbs. of coke.	

The conditions under which the experiments herein recorded were performed were rendered as uniform as circumstances would permit; indeed, they were more uniform than the conditions would have been had the gas been burned at the different localities under the ordinary conditions attending the utilization of gas for the production of steam, or for other manufacturing purposes. Therefore, differences resulting from barometric pressure, and radiation, etc., have been disregarded, since they would only burden the article with calculations, without materially affecting the results. With regard to the temperature of the gases, however, the various temperatures have been reduced by calculation to 0° C. wherever hydrogen is taken as a standard of fuel value. Wherever the standard of comparison is the average sample of Stockton natural gas, a common temperature of 16.18° C. is employed, for the latter figures represent the average temperature at which the experiments were conducted in Stockton.

The reader will gather some idea of the parity of the conditions attending the different experiments herein recorded, by carefully inspecting and comparing the figures given in the accompanying tables, wherein the conditions attending the various experiments are noted. The apartments in which the experiments were made with hydrogen at San Francisco, and with natural gas at Stockton and Sacramento, were practically free from draft, and the prevailing temperatures of the air, and probably of the walls of those apartments, exhibited a difference of less than 3° C. The mean temperatures reached by the water in the experiments in Stockton and San Francisco, after deducting the temperatures of the air, also exhibited no greater difference. It follows, therefore, that the loss by radiation and conduction would be very similar in the experiments made at these places. The mean temperature reached by the water in the experiments at Sacramento, after deducting the temperature of the air, was considerably less than was the case in the experiments at Stockton and San Francisco. Other things being equal, it follows, therefore, that the loss of heat by radiation and conduction in the experiments made at Sacramento would be less than in those made at Stockton and San Francisco. In the experiments made at the Barker ranch and at the Sunset Oil District, the temperatures of both water and air were higher than was the case in the previous experiments. The loss of heat by radiation and conduction was therefore approximately estimated by experiment in each of those places; and it proved to be very nearly the same as it was in the experiment with hydrogen.

The method employed to approximate the loss by radiation and conduction was the same at San Francisco, the Barker ranch, and the Sunset Oil District. It was as follows: Immediately after making the experiments to determine the fuel value of a sample of gas, a boilerful of water was heated to a temperature equal to the temperature of the air, plus half the number of degrees that the water had been raised above the temperature of the air in the corresponding fuel-value experiments. The boilerful of heated water was then allowed to cool for a time equal to the time occupied by the respective fuel-value experiments, and the amount of heat lost was noted. An examination of the before mentioned tables shows that the difference in the temperature of the air in the fuel-value experiments was compensated by the difference in temperature at which the products of combustion were lost. It must also be noticed that the fuel value obtained for the natural gas at the Barker ranch and the Sunset Oil District, as compared with that obtained for the other samples of gas tested, was slightly lessened by the barometric pressure being a little less at the Barker ranch and at the Sunset Oil District, than it was at Stockton, Sacramento, or San Francisco.

COMPARISON OF STOCKTON NATURAL GAS WITH NATURAL GAS IN EASTERN STATES.

Let us now compare the fuel value of the Stockton gas with the fuel value of samples of natural gas from wells in the Eastern States.

The following analyses were made by S. A. Ford, Chemist to the Edgar Thomson Steel Works, Pennsylvania, as quoted in "Chemical Technology," by Groves and Thorp, vol. 1, p. 290:

Analyses of Natural Gas.

	No. 1.	No. 2.	No. 3.
When tested	Oct. 28, 1884.	Oct. 29, 1884.	Nov. 24, 1884.
Carbonic di-oxide (CO_2)	.80 per ct.	.60 per ct.	nil.
Carbonous oxide (CO)	1.00 per ct.	.80 per ct.	.58 per ct.
Oxygen (O_2)	1.10 per ct.	.80 per ct.	.78 per ct.
Olefiant gas (C_2H_4)	.70 per ct.	.80 per ct.	.98 per ct.
Ethylic hydride (C_2H_6)	3.60 per ct.	5.50 per ct.	7.92 per ct.
Marsh gas (CH_4)	72.18 per ct.	65.25 per ct.	60.70 per ct.
Hydrogen (H_2)	20.02 per ct.	26.16 per ct.	29.03 per ct.
Nitrogen (N_2)	nil.	nil.	nil.
Heat units (in 100 liters)	728.746 ~~per ct.~~	698.752 ~~per ct.~~	627.170 ~~per ct.~~

	No. 4.	No. 5.	No. 6.
When tested	Dec. 4, 1884.	Oct. 18, 1884.	Oct. 25, 1884.
Carbonic di-oxide (CO_2)	.40 per ct.	nil.	.30 per ct.
Carbonous oxide (CO)	.40 per ct.	1.00 per ct.	.60 per ct.
Oxygen (O_2)	.80 per ct.	2.10 per ct.	1.20 per ct.
Olefiant gas (C_2H_4)	.60 per ct.	.80 per ct.	.60 per ct.
Ethylic hydride (C_2H_6)	12.30 per ct.	5.20 per ct.	4.80 per ct.
Marsh gas (CH_4)	49.58 per ct.	57.85 per ct.	75.16 per ct.
Hydrogen (H_2)	35.92 per ct.	9.64 per ct.	14.45 per ct.
Nitrogen (N_2)	nil.	23.41 per ct.	2.89 per ct.
Heat units (in 100 liters)	745.813 ~~per ct.~~	592.380 ~~per ct.~~	745.591 ~~per ct.~~

It is here assumed that these heat units are similar to the heat units used by the author quoted, when, in another paragraph of the work referred to, he estimates the fuel value of an average sample of natural gas. The first four samples were taken from the same well on the day that the gas was analyzed; the last two are from different wells in the East Liberty District. Referring to various authorities, it is found that the foregoing figures fairly represent the average composition of the Eastern natural gas, and it is evident that the greatest factor in influencing the fuel value is the amount of nitrogen present.

In the before-mentioned work on fuels, Mr. Ford is quoted as saying: "I have found that gas from the same well continually varies in composition. Thus, samples of gas from the same well, but taken at different days, varied in nitrogen from 23 per cent to nil; in carbonic acid, from 2 per cent to nil; in oxygen, from 4 per cent to 0.4 per cent, and so on with all the component gases."

In the same work it is stated that an average sample of Eastern natural gas has approximately the following composition:

Carbonic di-oxide (CO_2)	0.60 per cent.
Carbonous oxide (CO)	0.60 per cent.
Oxygen (O_2)	0.80 per cent.
Olefiant gas (C_2H_4)	1.00 per cent.
Ethylic hydride (C_2H_6)	5.00 per cent.
Marsh gas (CH_4)	67.00 per cent.
Hydrogen (H_2)	22.00 per cent.
Nitrogen (N_2)	3.00 per cent.

The same author goes on to show that 100 liters of this gas contain 789,694 heat units, and he states that 64.8585 grammes of carbon have a calorific value equal to 524,046 of these units, and that 1,000 cubic feet of the average sample of natural gas have a fuel value equal to that of 62.97 pounds of coke carrying 10 per cent of ash.

Carrying the calculation a little further, and allowing for the latent heat of steam, which it is necessary to do in order to compare the relative fuel values of the Eastern and of the Stockton gases under the conditions attending the combustion of the gas in the experiments at Stockton, and which usually attends the combustion of gas in practical use, we find that in round figures 1,000 cubic feet of the average sample of Eastern gas has a fuel value equal to that of 58 pounds of coke carrying 10 per cent of ash.

Taking the average sample of Stockton gas as having a fuel value of 1,000 feet equal to that of 50 pounds of coke, such as that to which Mr. Ford compared the Eastern gas, we find that the fuel value of the Stockton gas is about 16 per cent less than that of the sample of Eastern gas above estimated. We also find by referring to the analyses of the Stockton gas, made by Price & Son, that this difference in fuel value is principally occasioned by the amount of nitrogen present. If we compare the heat units as given for 100 liters of the average sample of Eastern natural gas with the heat units given for 100 liters of sample No. 5 of Eastern gas analyzed by Mr. Ford, we find that sample No. 5 has a fuel value practically equal to that of 47 pounds of coke for every 1,000 cubic feet of the gas. Research shows that gases containing a high per cent of nitrogen are by no means uncommon in the Eastern States, and that large industries have been developed on account of natural gas, which from existing data may be inferred to have an average fuel value not much in excess of that of the Stockton natural gas. It is to be borne in mind that large volumes of water flow from the gas wells at Stockton; and it is probable that the nitrogen is largely derived from the air which is drawn down with the water when it sinks into the ground at the head of the artesian system. This air is most likely deoxygenized by ferrous iron or other bases as it accompanies the water in its journey to a lower level; the result being, that a large amount of nitrogen is liberated with the water from the artesian wells. We may conclude from these considerations that if the water were shut off, and the gas obtained from lower strata, not only would the flow of gas be enormously increased, but its quality improved. It is also probable that were the wells tightly cased so as to shut off both gas and water for the first 1,500 feet, much of the nitrogen would be excluded.

It is interesting to note the comparison between the Stockton natural gas and other gases which are used as fuel. The analyses of five samples of the Siemen's producer gas, as given in the "Transactions of the

American Institute of Mining Engineers," and quoted in "Chemical Technology," by Grove and Thorp, vol. 1, is as follows:

	a	*b*	*c*	*d*	*e*
Carbonic di-oxide (CO_2)	3.9 per ct.	9.3 per ct.	1.5 per ct.	6.1 per ct.	8.6 per ct.
Carbonous oxide (CO)	27.3 per ct.	16.5 per ct.	23.6 per ct.	22.3 per ct.	20.0 per ct.
Hydrogen (H_2)	....	8.6 per ct.	6.0 per ct.	28.7 per ct.	8.7 per ct.
Marsh gas (CH_4)	1.4 per ct.	2.7 per ct.	3.0 per ct.	1.0 per ct.	1.2 per ct.
Nitrogen (N_2)	67.4 per ct.	62.9 per ct.	65.9 per ct.	41.9 per ct.	61.4 per ct.

Assuming that these percentage compositions are volumetric, and eliminating the smaller fractions, we obtain by the methods of calculation heretofore employed in this article, the following equivalents of fuel value:

1,000 cubic feet of sample *a* = 8.0 lbs. of coke carrying 10 per cent of ash.
1,000 cubic feet of sample *b* = 8.2 lbs. of coke carrying 10 per cent of ash.
1,000 cubic feet of sample *c* = 9.6 lbs. of coke carrying 10 per cent of ash.
1,000 cubic feet of sample *d* = 13.0 lbs. of coke carrying 10 per cent of ash.
1,000 cubic feet of sample *e* = 8.0 lbs. of coke carrying 10 per cent of ash.

The average fuel value, therefore, of these samples of producer gas is 1,000 cubic feet, equal to, practically, 9.3 pounds of coke carrying 10 per cent of ash.

A description of by far the best producer gas of which the writer can find any record is to be found in "Grove and Thorp's Chemical Technology," vol. 1, pp. 261–285. It is there stated as follows:

"The best quality of (producer) gas obtained in practice seems to have been that produced by the Strong water gas apparatus. The following is an analysis of the dry gas, after having been washed, made by Dr. G. E. Moore, of Jersey City, for the American Gas, Fuel, and Light Company, New York, who own the patent for the Lowe and Strong apparatus:

"Strong" Gas Composition by Volume.

Oxygen (O_2)	0.77 per cent.
Carbonic di-oxide (CO_2)	2.05 per cent.
Nitrogen (N_2)	4.43 per cent.
Carbonous oxide (CO)	35.88 per cent.
Hydrogen (H_2)	52.76 per cent.
Marsh gas (CH_4)	4.11 per cent.
	100.00 per cent.

From this formula we find by calculation that 1,000 cubic feet of this gas have a fuel value practically equal to that of 23.9 pounds of coke carrying 10 per cent of ash. In this estimation it is assumed that the oxygen in the "dry gas" was free; if it were combined with hydrogen, about half a pound of coke would have to be deducted from the coke equivalents given.

In the "Transactions of the American Institute of Mining Engineers," vol. 19, we find the following remarks on producer and petroleum water gas. Referring to the producer gas, two average samples are quoted which were the products of the following processes:

Method A.—Open grates; no steam in blasts. Loss of carbon in ash, 20 per cent weight of coal. Carbon gasified 62 per cent weight of coal. Loss of potential heat in ash per kilo of coal, 1,616 kilo calories.

Method B.—Open grates; steam jet in blast. Loss of carbon in ash, 6 per cent weight of coal. Loss of potential heat in ash per kilo of coal, 4,848 kilo calories.

Analysis of Producer Gas. (Calculated as one cubic foot.)

	CO_2	O_2	C_2H_4	CO	H_2	CH_4	N_2
Sample A	4.84	0.40	0.34	22.10	6.80	3.74	61.73
Sample B	5.30	0.54	0.36	22.74	8.37	2.56	60.13

We find that 1,000 cubic feet of sample A has a fuel value practically equivalent to 10.2 pounds of coke carrying 10 per cent of ash, and that the fuel value of 1,000 feet of sample B equals 9.7 pounds of similar coke.

Referring to petroleum water gas, the same records state that "the following are analyses of various gases taken from furnace using oil fuel":

Sample of Gas taken after passing through Checkers.

	CO_2	C_2H_4	O_2	CO	H_2	CH_4	N_2
No. 1	4.6	0.0	1.8	9.6	51.6	0.4	24.0
No. 2	5.6	0.4	2.0	11.2	51.8	7.2	21.8
No. 3	4.4	0.0	4.0	6.4	42.2	7.0	36.0
No. 4	6.6	0.0	0.6	10.0	37.3	7.6	37.9
No. 5	4.0	7.6	2.0	5.4	44.1	22.1	17.0
No. 6	4.0	7.6	2.0	5.4	46.5	23.1	11.4
No. 7	4.4	3.6	2.4	6.0	44.4	19.0	20.2

Undecomposed steam	Sample 1	240 grammes per C. M.
	Sample 2	122 grammes per C. M.

The oil gas referred to in these analyses was made by vaporizing crude petroleum by a jet of superheated steam and heating the mixture to 300° or 400° C. If such a mixture of vapors is put into the hot chamber of a regenerative furnace, the reaction caused by the high temperature, thorough mixing, and impact, creates permanent gases with decomposition of carbon. The steam brings with it some oxygen and nitrogen, which are dissolved in the water in the boilers, and this oxygen, together with that of the steam, tends to pick up the deposit of carbon with liberation of hydrogen.

It will be noticed that the foregoing analyses of petroleum water gas show a wide variation of composition. The first four samples were taken after the gas had traversed about 5 feet of open hearth checker-work at a temperature of 1,200° C. The last three samples were taken after it had passed through 3 feet of heating furnace in checker-work at a much lower temperature, and represent the oil vapors in various stages of decomposition. The presence of so much free oxygen, the high per cent of carbonic di-oxide, and the large amount of steam when considered in connection with carbonaceous components, illustrate plainly the fact that a long time and high temperature are necessary for the completion of the reactions incident to the gasification of oil fuel.

The average composition of the samples of the petroleum water gas mentioned is therefore as follows:

	CO_2	C_2H_4	O_2	CO	H_2	CH_4	N_2
From the first four samples of fixed gas	5.30	0.10	2.10	9.30	45.72	7.55	29.92
From the last three samples	4.13	5.73	1.93	5.60	45.00	21.40	16.20

By calculation it is found that 1,000 cubic feet of gas representing the average of the first four samples of petroleum water gas have a fuel value of practically 17.4 pounds of coke carrying 10 per cent of ash. In like manner, it is seen that an average sample representing the last three samples of petroleum water gas have a fuel value practically equal to that of 33 pounds of coke carrying 10 per cent of ash.

Having reviewed to some extent the composition and fuel value of California and Eastern natural gas and producer and petroleum water gas, it is interesting to compare them with a gas made by the destructive distillation of coal before the introduction of producer and petroleum water gases.

Let us take the analysis made by Bunsen of gas prepared from Cannel coal in Manchester, England, calculated as one cubic foot. (See Bunsen's Gasometry, p. 113.)

Hydrogen (H_2)	45.48 per cent.
Marsh gas (CH_4)	34.90 per cent.
Carbonous oxide (CO)	6.64 per cent.
Elayl (C_4H_4)	4.08 per cent.
Ditetryl (C_8H_8)	2.38 per cent.
Sulphuretted hydrogen (H_2S)	.29 per cent.
Nitrogen (N_2)	2.46 per cent.
Carbonic di-oxide (CO_2)	3.67 per cent.
	100.00 per cent.

By calculation it is found that 1,000 cubic feet of this gas have, in round numbers, a fuel value of 51 pounds of coke carrying 10 per cent of ash.

Disregarding fractions, the gases thus far considered represent the following fuel values, as compared with coke carrying 10 per cent of ash.

Eastern natural gas (considered by Mr. Ford to be of average composition)	Fuel value = 58 lbs. of coke.
Sample of Manchester coal gas	Fuel value = 51 lbs. of coke.
Average of Stockton gas	Fuel value = 50 lbs. of coke.
Sample of natural gas No. 5, from East Liberty, Pa.	Fuel value = 47 lbs. of coke.
Petroleum water gas before becoming a fixed gas, described in the "Transactions of the American Institute of Mining Engineers," vol. 19.	Fuel value = 33 lbs. of coke.
Petroleum water gas as a fixed gas (from same authority)	Fuel value = 17 lbs. of coke.
Water gas from analysis made for the owners of the Lowe & Strong patents	Fuel value = 24 lbs. of coke.
Siemens producer gas, from average of analyses	Fuel value = 9 lbs. of coke.
Sample A, producer gas, referred to in the "Transactions of the American Institute of Mining Engineers," vol. 19	Fuel value = 10 lbs. of coke.
Sample B (from same authority)	Fuel value = 9 lbs. of coke.

In the calculations on which the above figures are based, the writer estimated the gases as possessing a temperature of 0° C., and as being subjected to a pressure of one atmosphere. He disregarded the fact that in his physical experiments with natural gas at Stockton the gas was measured under a pressure of six-tenths of an inch of water; for the increase in the fuel value of the gas resulting from so slight a pressure would be less than a quarter of one per cent.

The coke to which the gases mentioned in this article are compared is supposed to have a composition of carbon 90 per cent and ash 10 per cent.

RELATIVE FUEL VALUE OF STOCKTON NATURAL GAS AND PACIFIC COAST SOLID FUELS.

The reader will doubtless be curious to learn how the Stockton natural gas compares in fuel value with the solid fuels obtainable on the Pacific Coast. Unfortunately the writer has been unable to find any ultimate analyses of California coals, although numerous proximate analyses have been made. In the Census Reports on Mining, however, there are both the ultimate and proximate analyses of several samples of coals and lignites from the State of Washington. With this data at command there is submitted for comparison the proximate analyses of coals to be found in the market of California, and the average composition of coal and lignites from Washington, which the writer has calculated from the proximate and ultimate analyses given in the Census Report on Mining. Moreover, by means of the ultimate analyses of the coal and lignites from Washington, the caloric value of these solid fuels can be compared with the Stockton natural gas.

Analyses of some Coals and Lignites used in California.

	Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
Sample of coal from California Mine, Fresno County. (Analyzed by Dr. W. D. Johnston, Chemist to the California State Mining Bureau)	11.25	48.50	31.40	8.85	----------
Ione coal, from Mine No. 3 of Ione Coal and Iron Co. (Analyzed by Dr. W. D. Johnston)	13.25	49.00	27.25	10.50	----------
Mount Diablo coal, Black Diamond vein. (As given in State Geological Survey Report, Geology of California, vol. 1, p. 30)	14.68	33.89	46.84	5.52	----------
Seattle coal, average of two samples. (Analyzed by Mr. H. G. Hanks; see VIIth Report of California State Mining Bureau)	9.18	36.90	46.99	6.46	---------
Wellington coal. (Analyzed by Messrs. Price & Son)	0.99	29.09	64.97	3.51	1.44

Referring to the Tenth Census Report, Vol. XV, and the proximate analyses of coals and lignites as given therein, we find that samples 11, 12, 19, 20, 21, 33, 34, 35, 36, 37, 64, and 65 are coking coals, although in three instances the coke does not appear to have any value. We also find that samples 68, 69, 71, 80, 47, 23, 25, and 26 are non-coking coals, or coals of which the coke is worthless. By calculation from the data given in the census report, we obtain the following average compositions:

From Proximate Analyses of Coals and Lignites from Washington.

	Water.	Volatile Matter.	Fixed Carbon.	Ash.	Sulphur.
Coking coal	1.70	31.28	54.11	12.90	0.65
Non-coking coal	3.23	32.32	52.15	12.36	0.53

From Ultimate Analyses of the Combustible Matter Contained in Same Samples.

	Carbon.	Hydrogen.	Oxygen and Nitrogen.
Coking coal	83.31	5.26	11.43
Non-coking coal	82.52	4.81	12.66

Regarding the water, ash, and sulphur in these average samples as inert, for the calorific effect of the sulphur is offset by the heat required to convert the hygroscopic water into steam, it is found by calculation that the relative fuel value of these samples of coal is practically as follows:

Sample of non-coking coal = 6,977 kilo calories per kilogramme.
Sample of coking coal, = 7,122 kilo calories per kilogramme.

Referring to "Chemical Technology," by Groves & Thorp, vol. 1, p. 57, the analyses of the ten samples of anthracite were given. As in the case of the Washington coals, the writer, for the purpose of estimating the fuel value, calculated the average composition of the ten samples, and found it to be practically as follows:

Carbon	89.88 per cent.
Hydrogen	2.80 per cent.
Oxygen, nitrogen, and sulphur	4.01 per cent.
Ash	3.63 per cent.

Simply regarding the carbon and hydrogen as the calorific constituents of this average sample of anthracite, it is found by calculation that it possesses a fuel value of practically 8,092 kilo calories per kilogramme.

Referring to the previous calculations with regard to the Stockton natural gas, it can readily be seen that 1,000 feet of that gas at a temperature of 16.18° C. have a fuel value of practically 155,900 kilo calories. Thus it is found that the relative fuel value of the Stockton natural gas and the coals, estimated, is as follows:

1 ton of anthracite	= 47,000 cu. ft. of Stockton natural gas.
1 ton of average sample of coking coal from Washington	= 41,360 cu. ft. of Stockton natural gas.
1 ton of average sample of non-coking coal from Washington	= 40,700 cu. ft. of Stockton natural gas.

In our VIIth Annual Report a short table was published showing the relative fuel value of twelve different kinds of coal which are still in great demand in the California market. The relative fuel values, as shown in the table, are approximate, and were derived from practical experiments by the Spring Valley Water Company, Messrs. Garratt, and others. As the demand for the VIIth Annual Report has long ago exhausted the edition, it will be in order to reproduce the table, and to add thereto a column giving in round figures the number of feet of Stockton gas required to do the same amount of work as could be done by a ton of each variety of coal named. Assuming anthracite to have a fuel value as calculated, and applying its equivalent in Stockton natural gas to the table mentioned, we obtain, in round figures, the following schedule:

Relative Fuel Value of Different Coals as Compared with Each Other, and as Compared to Stockton Natural Gas.

Kind of Coal.	Relative Fuel Value.	Remarks.	Cubic Feet of Gas Equal to 1 Ton of 2,000 lbs. of Coal.
Mt. Diablo	1,000	Experiments at Spring Valley Water Works	30,400
Seattle	1,170		35,570
Sydney	1,502		45,660
Welsh	1,472		44,750
Bellingham Bay	1,148		34,900
Nanaimo	1,277		38,800
Anthracite	1,546		47,000
Wellington	1,407		42,710
Nanaimo	1,335	Exp'ts at Garratt's foundry	40,580
Wellington	1,295		39,370
Seattle	1,177	Experiments on ferry-boat	35,780
Seattle	1,330	Probable results of test on C. P. R. R.	40,430

As might be expected, the variable quality of different consignments of coal and the different conditions attending the last four experiments, occasioned a difference in results; but no doubt the series of tests made by the Spring Valley Water Company afford the most accurate means of comparison, for their experiments appear to have been conducted under approximately similar conditions.

Having compared the relative calorific value of 1,000 feet of Stockton natural gas with that of one ton of an average sample of bituminous coal from Washington, it is found that the gas at 30 cents a thousand cubic feet is as cheap a fuel as the coal would be at $12 30 a ton of 2,000 pounds. If we take the last six samples of bituminous coal used in the practical experiments made at the Spring Valley Waterworks and compare them with their fuel equivalent in gas, about the same figures are obtained as those arrived at by calculation from the analysis of the coal from Washington.

Hitherto we have only considered the value of the natural gas as demonstrated by comparing its calorific value with that of the other fuels. The advantages that manufacturers have experienced by using gas instead of solid fuel should also be considered briefly. It is shown in an able article on natural gas, by Mr. J. D. Weeks, which is published in "Mineral Resources of the United States, 1885," that in the manufacture of flint glass a saving of 46 per cent was effected by using natural gas instead of coal, to which might be added the saving in wear and tear of furnace and in labor; moreover, a better quality of glass was produced than when solid fuel was used. The records of the steel and iron industry are replete with evidence of the saving occasioned by the use of gaseous fuel, especially in the matter of labor.

A great reduction in the amount of "waste iron" has also been noted, and the item of repairs, which is a large one in this industry, is reduced to the minimum. A saving of $3 to the ton of bar iron is regarded as a very conservative estimate where gas is used, as against the production of one ton of bar iron by any other fuel. In this connection much that is said about the advantages to be derived from using producer and petroleum gases will doubly apply in the use of natural gas; and we have already seen how the actual calorific values of these gases compare with one another.

We learn in the "Transactions of the American Institute of Mining Engineers," vol. 19, p. 1005, in speaking of the producer gas, that, even where coal was only $3 a ton, many large firms effected a direct gain of from 33⅓ to 50 per cent in labor, and over 40 per cent in fuel, by the substitution of producer gas for coal. This economy resulted from the gas requiring less labor and the furnace less repairs than was the case when coal was used, and from the fact that the combustion of the gas left no solid residue, nor did it produce deleterious vapors. Other reasons were that the quality of the gas was uniform, and its combustion complete; that the gas was self-transporting, and that it could be ignited under any desired conditions, producing a quick, sharp-heating flame of high temperature.

In the Eastern States it has been estimated that in practical use 20,000 feet of producer gas often accomplished better results than a ton of coal directly fired, although it will be seen by a glance at what has been previously said, that the actual calorific value of 20,000 feet of producer gas is very much less than that of one ton of coal.

The before-mentioned records also state that practical working has shown that in melting 2,000 pounds of brass in 100-pound crucibles, 12,000 feet of water gas were consumed. That in using the same size of crucibles in works melting from 5 to 10 tons of metal a day with coal, it takes 2,000 pounds of coal for 2,000 pounds of brass. This is a striking comparison, since the units of heat in the coal was seven and one half times more than in the gas. It is stated that one ton of coal will make 40,000 feet of water gas, which will accomplish as much as three and a half tons of coal.

It is obvious that the economy experienced by the use of gas in metallurgical industries extends to every manufacture and domestic requirement where heat is needed.

RECORD OF DISTILLATION TESTS OF SAMPLES OF OIL MENTIONED IN THIS BULLETIN.

Sample from Oil Springs on Rathburn Oil Claim, Colusa County.

		Specific Gravity.
Crude oil	....	0.982, about 13° B.
Distillate below 250° Centigrade	1.00 per cent.	
Distillate between 250° and 325° Centigrade	60.00 per cent.	0.950, about 18° B.

Nearly all of the distillate came over at 300° Centigrade.

Sample from Well No. 3, Group 2, Sec. 28, Sunset Oil District, Kern County.

		Specific Gravity.
Crude oil	....	0.956, about 17° B.
Distillate below 250° C.	1.00 per cent.	
Distillate below 320° C.	48.33 per cent.	0.876, about 30° B.

Sample from Well No. 2, Group 2, Sunset Oil District.

		Specific Gravity.
Crude oil	....	0.971, about 14° B.
Distillate below 250° C., about	1.00 per cent.	
Distillate below 325° C.	13.00 per cent.	0.893, about 27° B.

This sample of oil smelled strongly of sulphuretted hydrogen.

Sample from Oil Wells, Group 1, Sunset Oil District.

		Specific Gravity.
Crude oil (maltha)	....	1.01, about 10° B.
Distillate below 250° C.	0.60 per cent.	
Distillate below 320° C.	40.00 per cent.	0.881, about 29° B.

This sample was obtained from a tank which was said to be filled with a mixture of oils from Oil Wells, Group 1.

Sample from Well near Flowing Well, Sunset Oil District.

		Specific Gravity.
Crude oil		.966, about 15° B
Distillate below 200° C.	0.60 per cent.	.840, about 37° B.
Distillate below 250° C.	5.00 per cent.	.845, about 36° B.
Distillate below 300° C.	8.60 per cent.	.870, about 31° B.
Distillate below 320° C.	5.20 per cent.	.875, about 30° B.

Sample from Oil Well penetrating Dark-Colored Shale Formation Nine Miles North of Coalinga.

		Specific Gravity.
Crude oil		.852, about 34° B.
Distillate below 110° C.	0.60 per cent.	
Distillate below 150° C.	32.00 per cent.	.799, about 45° B.
Distillate below 200° C.	27.60 per cent.	.833, about 38° B.
Distillate below 250° C.	16.60 per cent.	.875, about 30° B.
Distillate below 320° C.	12.00 per cent.	.911, about 24° B.

The well from which this sample of oil was taken penetrates Cretaceous formations.

Sample of Oil (Maltha) from Spring in Oil District South of Coalinga.

		Specific Gravity.
Crude oil		.974, about 14° B
Distillate below 250° C. (came over with water)	1.00 per cent.	
Distillate below 320° C.	2.30 per cent.	.820, about 41° B.

Sample from Oil Spring in Light-Colored Shales, Nine Miles North of Coalinga.

		Specific Gravity.
Crude oil		.988, about 12° B.
Below a temperature of 200° C. a small amount of oil came over with water.		
Distillate below 250° C.	2.30 per cent.	
Distillate below 320° C.	6.20 per cent.	.961, about 16° B.

Sample from Well in Vallecitos.

		Specific Gravity.
Crude oil		.975, about 14° B.
Distillate below 250° C.	1.43 per cent.	
Distillate below 320° C.	9.00 per cent.	.886, about 32° B.

PARTIAL ANALYSES OF SAMPLES OF WATER REFERRED TO IN THIS BULLETIN.

In order to determine whether or not the water from the wells mentioned in the foregoing pages is of any value as brine, the following partial analyses were made. In these determinations the residues were subjected to sufficient heat to get rid of any hydrocarbons present, without decomposing the carbonate of lime:

Water from Well No. 3, Oil Wells Group 2, Sunset Oil District.

Amount of sample required to neutralize one gramme of sulphuric acid, 2,766 cc.

	Grammes to Gallon.
Total residue	138.840
Amount of residue soluble in water	137.050
Partial analysis of soluble residue:	
Sodium chloride	118.095
Calcium chloride	16.375
Magnesium chloride	2.480
Iodine	0.075

The portion of the residue which was insoluble in water effervesced, and nearly dissolved when treated with cold dilute hydrochloric acid. The portion soluble in water showed the presence of sulphates and carbonates in very small quantities.

Water from Well No. 2, Oil Wells Group 2, Sunset Oil District.

Amount of sample required to neutralize one gramme of sulphuric acid, 818 cc.:

	Grammes to Gallon.
Total residue	40.77
Amount of residue soluble in water	38.800
Partial analysis of soluble portion:	
Sodium chloride	33.521
Magnesium chloride	1.880
Magnesium sulphate	1.668
Calcium sulphate	1.431

This sample smelled strongly of sulphuretted hydrogen. The portion of the residue which was insoluble in water effervesced and nearly dissolved when treated with cold dilute hydrochloric acid. The portion soluble in water also showed the presence of alkaline carbonates.

50 cc. of this sample, when concentrated to 10 cc., gave a strong reaction for iodine.

Water from Well in Section 13, T. 11 N., R. 24 W., S. B. M., Sunset Oil District, Kern County.

Amount of sample required to neutralize one gramme of sulphuric acid, 127 cc.

	Grammes to Gallon.
Total residue	73.332
Amount of residue soluble in water	71.712

The portion of the residue which was soluble in water contained 54.81 grammes of sodium chloride to the gallon calculated from the amount of chlorine present. Only very small quantities of calcium and magnesium were found in this portion of the residue, which also showed traces of sulphates and large amounts of alkaline carbonates without concentration; this sample gave a slight reaction for iodine.

Sample from Spring near Flag 6, Sunset Oil District. (See sketch-map.)

Amount of sample required to neutralize one gramme of sulphuric acid, 446 cc.

	Grammes to Gallon.
Total residue	28.365
Amount of residue soluble in water	22.270

The soluble portion of the residue contained 10.58 grammes of sodium chloride to the gallon, calculated from the amount of chlorine present. Only very small quantities of calcium and magnesium were found in this portion of the residue, which also contained sulphates and alkaline carbonates. This sample smelled strongly of sulphuretted hydrogen.

Sample from Well at Salt Marsh, Sunset Oil District.

Amount of sample required to neutralize one gramme of sulphuric acid, 305 cc.

	Grammes to Gallon.
Total amount of residue	46.645
Amount of residue soluble in water	43.300

The soluble portion of this residue contained 37.44 grammes of sodium chloride to the gallon. Only very small amounts of calcium and magnesium were found in this portion of the residue, which also showed the presence of sulphates in small quantities, and alkaline carbonates. 100 cc. of this water, when boiled down to 10 cc., gave a strong reaction for iodine. Sample smelled of sulphuretted hydrogen.

Sample from the Flowing Well in the Oil District Nine Miles North of Coalinga.

Amount of water required to neutralize one gramme of sulphuric acid, 932 cc.

	Grammes to Gallon.
Total residue	66.64
Amount of residue soluble in water	64.00
Partial analysis of soluble portion of residue:	
Sodium chloride	58.030
Calcium	1.135
Magnesium	4.648

When 50 cc. of this sample were concentrated to 10 cc., a strong reaction for iodine was obtained; traces of sulphates and small quantities of the alkaline carbonates were also present in the water. A sample of water which was subsequently obtained from this well was found to contain 0.016 grammes of iodine to the gallon.

Sample from Petersen Ranch, near Sites, Colusa County.

A sample of mother liquor, which was forwarded to the Mining Bureau from the salt works on the Petersen ranch, near Sites, in Colusa County, was found to contain 2.239 grammes of iodine to the gallon.

In each of the foregoing water analyses that portion of the residue which was soluble in water gave a slight precipitate after the addition of ammonium chloride and ammonium hydrate.

In the following table the amount of solid matter, common salt, and iodine contained in one gallon of sea water is compared with the amount held in solution by the brines mentioned in this bulletin (small fractions are eliminated):

	Solid Matter. Grammes.	Salt in 1 Gallon. Grammes.	Iodine.
Sea water maximum. (See Manual of Mineralogy, by J. D. Dana.)	139.9	Max. 93.3 Min. 69.9	----------
Sea water minimum. (See Manual of Mineralogy, by J. D. Dana.)	121.0	Max. 80.7 Min. 60.5	----------
Water from spring on Petersen ranch, near Sites, Colusa County. (Analysis made by Dr. W. D. Johnston; see Tenth Report of State Mineralogist, p. 164)	204.7	About 102.3	0.129
Well No. 3, Oil Wells Group 2, Sunset Oil District	138.8	118.1	0.075
Well No. 2, Oil Wells Group 2, Sunset Oil District	40.8	33.5	Determined qualitatively.
Spring near Flag 6, Sunset Oil District	28.3	10.6	----------
Well at Salt Marsh, Sunset Oil District	46.6	37.4	Determined qualitatively.
Flowing well in Sec. 13, Sunset Oil District	73.3	54.8	Determined qualitatively.
Flowing well, oil district 9 miles north of Coalinga	66.6	58.0	0.016
Mother liquor from salt works on Petersen ranch, near Sites, Colusa County	----------	----------	2.239

EXPERIMENTS ON EVAPORATION.

In order to get some idea as to the rate at which brine would evaporate if it were exposed to the sun and air in the Sunset Oil District, the writer conducted two experiments. The apparatus used in these experiments consisted of a thick earthenware dish eleven inches in diameter at the top, eight inches in diameter at the bottom, and two and a half inches deep. During each experiment the vessel was kept as nearly as possible about two-thirds full of brine. The record of these experiments is as follows:

Sample Marked.	Date at which Experiment Commenced.	Duration of Experiment.	Amount of Brine Taken.	Amount of Brine at End of Experiment.	Amount of Water Evaporated.
(*a*) Brine from flowing well in Sec. 15, T. 11 N., R. 24 W.	June 4, 2 P.M.	89 hours.	3,000 cc.	102 cc.	2,898 cc.
(*b*) Brine from Salt Marsh	June 24, 10 P.M.	92 hours.	3,600 cc.	470 cc.	3,130 cc.

On the day the first experiments on evaporation commenced, the following thermometric observations were made with glass Centigrade thermometers, which hung freely in the air:

Time of Observation:	$12^h\ 5^m$ P.M.	1^h P. M.	$2^h\ 30^m$ P.M.	$3^h\ 15^m$ P.M.	$4^h\ 25^m$ P.M.	$5^h\ 40^m$ P.M.
Thermometer exposed to sun and north wind	37.50° C.	38.50° C.	39.75° C.	40.00° C.	39.00° C.	38.75° C.
Thermometer exposed to sun but screened from north wind	42.75	42.75	45.00	44.75	40.00	39.00
Thermometer in shade exposed to north wind	36.00	37.50	37.50	37.75	37.50	37.25

The day on which these experiments were made was considered by the inhabitants of the Sunset District to be a warm, summer day. During the second experiment on evaporation the weather was somewhat cooler than during the first experiment. During the before-mentioned experiments on evaporation, the vessel containing the brine was exposed to the sun and north wind.

In this connection it is interesting to note that the maximum temperature registered by the Southern Pacific Railroad in the shade at Bakersfield on June 4, 1893, was 102° Fahr., equal to 38.5° C. An idea of the temperature prevailing in this portion of the San Joaquin Valley may be gathered from the following records of the Southern Pacific Railroad Company, of thermometric observations made in the shade at Bakersfield, during the year 1893:

Month.	Maximum.	Minimum.	Mean.
1893—January	69.0° F.	32.0° F.	45.7° F.
February	71.0	32.0	52.2
March	83.0	40.0	55.8
April	83.0	46.0	62.7
May	96.0	59.0	75.0
June	102.0	65.0	79.4
July	108.0	70.0	87.9
August	108.0	72.0	85.1
September	100.0	59.0	72.2
October	79.0	50.0	63.3
November	79.0	35.0	55.7
December	70.0	38.0	51.9

IMPROVEMENTS IN MACHINERY USED FOR DRILLING DEEP WELLS.

The following improvements have been devised and used by Mr. W. E. Youle, Superintendent of the Sunset Oil Works and of the works belonging to the Standard Oil and Asphaltum Company at Asphalto. The band-wheel and frame used in drilling deep wells is commonly held in place by jack-posts, which are keyed into heavy sills and secured by subsills and mudsills. Mr. Youle now uses a truss-frame anchored by two one-inch bolts, which extend into a sill 8 feet long and 12 inches in thickness. This sill is covered with boards and buried to the depth of about 4 feet, with earth tamped upon it. The ends of the bolts at the bottom of the sill are secured by drift keys instead of nuts. A truss-frame thus secured is found to be very stable for deep drilling, and saves about 4,000 feet of square timber. The writer saw such a truss-frame employed at the Sunset Oil District, when Well No. 3, of Oil Wells Group 2, was being drilled. The set of tools then in use weighed more than one ton, and the well was 1,300 feet in depth, but no trembling was observed in the truss-frame. The friction pulley of the sand-reel, which is used to elevate and lower the sand-pump, is usually attached to a lever which has a friction bearing on the band-wheel. It was found that this gearing had a tendency to roughen the band-wheel and injure the belt. To remedy this, Mr. Youle now sets his sand-reel at such a distance from the band-wheel that it can be run by a belt from a supplementary wheel, which is lagged on to the side of the band-wheel. This supplementary wheel is supplied with flanges to prevent the belt which drives the sand-reel from running off. This belt is put on so loosely that it can rest on carriers when the sand-reel is not in use. The carriers are placed between the pulleys, and although the belt does not sag, it is sufficiently slack to avoid, as much as possible, any friction on the sand-reel belt during the process of drilling. When the sand-pump is required, the sand-reel belt is brought into position by a tightener, which is operated by a lever. This lever is connected by a rod to an arm in the derrick, on the same principle as are the connections used when frictional gearing is employed. A back-brake is attached to the sand-reel, and it can be brought into play during the process of lowering the sand-pump by throwing it on back motion. The brake is operated by the same arm as that governing the tightener. A sand-reel was operated in this manner for three months at the Sunset Wells, without the reel and belting exhibiting any signs of being the worse for wear.

A great improvement has also been made in the bull-wheels. Those of ordinary construction consist of a wooden shaft 13 feet long and 13 inches square, with a four-winged, cast-iron gudgeon mortised on each end, around which wrought-iron bands are shrunk. Near each end of the shaft are wooden arms "put on octagon." Around the outer diameter of these arms segments or cants of planks are fastened to form the periphery of the wheel. In the wheel built by Mr. Youle, the wooden shaft is replaced by 10-inch wrought-iron drive-pipe. Two cast-iron flanges are fastened to each end of this pipe, their centers being counterbored to admit the passage of the pipe, and each end flange terminates in a gudgeon. The flanges are pressed on by hydraulic pressure, and a very rigid connection is made. The wooden wheels, which are bolted between the flanges, are simply nailed together so as to give the proper diameter to the wheels. To increase the diameter of the bull-wheel shaft an old cable is reeled upon it until it has attained the required dimensions. These wheels can be readily "knocked down" for shipment. A pair of these wheels were in constant use for five months at the Sunset Oil Wells, and showed no signs of deterioration.

In driving long strings of casing from the top, difficulty frequently arises from the pipe buckling. To obviate this Mr. Youle devised the following method for driving strings of casing from the bottom: While enough pressure is simultaneously brought to bear on the top of the casing to make it follow and to prevent the joints from pulling apart, a heavy steel coupling is screwed or riveted within the last joint of the main string of casing. The diameter of this coupling, measured between the threads, is an eighth of an inch less than the inside diameter of the casing. The constriction thus formed furnishes a shoulder for a plug, which is lowered at the end of the tools, to rest on. When the plug is in place, driving is commenced. One of the principal advantages of driving casing from the bottom is that it jars and loosens the surrounding earth or rock at the point where there is the greatest resistance to the downward passage of the pipe.

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