PETROLEUM AND NATURAL GAS.

THE MINER RANCH OIL FIELD, CONTRA COSTA COUNTY, CAL.[a]

By RALPH ARNOLD.

Location.—The Miner ranch oil field is located on Lauterwasser Creek, one of the branches of San Pablo Creek, near De Laveaga, Contra Costa County, Cal. It is about 8 miles north-northeast of Oakland and is reached by road from that city and also from the several towns south of San Pablo Bay and west of Mount Diablo. The topography in the vicinity is characterized by moderately steep-sided canyons and rounded hills, some of which attain an elevation of over 1,500 feet above the adjacent valleys. The elevation at the wells, which are in the hills immediately south of Lauterwasser Creek, is between 500 and 700 feet above sea level.

HISTORY OF PETROLEUM PROSPECTING IN CONTRA COSTA COUNTY.[b]

Contra Costa County was one of the first counties in California in which petroleum was discovered, its presence being known as far back as 1864, when prospect wells were drilled 1½ miles south of the Empire coal mine. The following is a summary of the attempted petroleum devolopments in the county to date:

1864. J. W. Cruikshank, about 1½ miles south of the Empire coal mine. Several experimental wells, one 300 feet deep; green oil of high specific gravity; pumped about 15 barrels.

1865. Adams Petroleum Company, on Coates estate, south of Empire coal mine. Several shallow wells, from which some oil was obtained.

[a] The writer wishes to acknowledge his indebtedness to Dr. J. C. Merriam, of Berkeley, and Mr. W. E. Holbrook, president of the American Oil and Refinery Company, of San Francisco, for courtesies extended and assistance rendered during the examination of this field.

[b] The information contained in this section is derived largely from reports by W. L. Watts in Thirteenth Rept. California State Mineralogist, 1896, pp. 570-571, and Bull. No. 19 California State Mining Bureau, 1900, pp. 156-157.

1889. Chandler well, on Miner ranch, south bank of Lauterwasser Creek. One well, 200 feet deep, yielded small quantity of heavy oil and water.

1895. Cumming well, on Miner ranch, one-fourth mile east of Chandler well. Penetrates 20 feet of petroliferous shale and then 280 feet of sandstone; yielded traces of petroleum.

1896. Sonntag well, on Allen ranch, one-half mile east of the Cumming well. 100 feet deep, in light-colored sandstone.

1899. J. W. Laymance, on Old Tar ranch, 2 miles east of San Pablo. 170-foot well, encountered seepages of oil.

1900. Mount Diablo Oil Company, on Old Tar ranch. Several wells drilled many years ago; drilling operations begun again in 1900, but failed to get oil.

American Oil and Refinery Company. (See body of this report.)

Contra Costa Oil and Petroleum Company, on Coates estate, 1½ miles south of Empire coal mine. One or more wells.

Grand Pacific Oil Company, on Hodges ranch, 1 mile east of Lafayette. One or more wells.

Tide Water Oil Development Company, Coates estate, 1 mile south of the well site of the Contra Costa Oil and Petroleum Company; ceased operations in 1904.

Sobrante Oil and Investment Company, on Castro tract, a little over 3 miles northeasterly from San Pablo. One or more wells, but no production; abandoned.

San Pablo Oil Company, on Mulford ranch, 1 mile northeast of San Pablo. One well 670 feet deep; traces of oil and considerable gas; now abandoned.

Point Richmond Oil Company, on Mulford ranch, 3 miles northeast of San Pablo. Two 100-foot wells, drilled near seepage, but got no production.

Flood ranch, 1½ miles south of Miner ranch. Old well with traces of oil on water.

National Paraffin Company, 1¼ miles northeast of Lafayette. One well, 1,694 feet deep; no production.

Near the corner of secs. 9, 10, 15, and 16, T. 1 N., R. 1 E., Mount Diablo meridian. An old well is said to have shown traces of oil.

Geology and structure.—The principal structural feature in the region of the Miner ranch is a southeastward-plunging anticline which crosses Lauterwasser Creek just east of the ranch house. Along the axis of this fold the following formations are exposed in order, beginning a mile or so northwest of the field and extending to its southeast edge: Tejon (Eocene) sandstone; 200± feet of brown sandstone, possibly Vaqueros (lower Miocene); 800± feet of Monterey (middle Miocene), 300 feet shale and 500± feet sandstone, in which are intercalated minor quantities of soft shale; and, finally, the feebly coherent fresh-water conglomerates, sandstones, and shales of the Orindan (Pliocene) formation of Lawson and Palache.[a] The petroleum deposits are in the shales and sandstones of the Miocene.

The sandstones below and above the Monterey shale are practically alike, being brown to gray in color, medium grained, and largely quartzitic. The upper sandstone is locally fossiliferous, although

[a] Bull. Dept. Geology, Univ. California, vol. 2, 1902, p. 371.

the state of preservation of the fossils usually precludes anything but a rough identification. The Monterey shale is fairly hard and is dark colored in fresh exposures, but weathers to a much lighter color. It contains many of the yellow and gray calcareous concretions so characteristic of the Monterey at most places in the Coast Range. The shale is largely organic in origin, foraminifers and diatoms being found in it abundantly. The organic remains in the shale are believed to be the source of the oil. The shale is considerably contorted, especially near the axis of the fold, dips of 42° S. 86° E. and 40° S. 70° E. being recorded within a short distance of each other in the bed of Lauterwasser Creek, northeast of the Miner ranch house. At the same locality the shale is exceedingly petroliferous, yielding a very prominent scum of light oil when the rock in the stream bed is disturbed with a pick. The dips in the overlying sandstone are not as easily obtainable as those in the shale, but it is thought that the dip on the northeast flank of the fold grows gradually less toward the northeast.

Wells.—Eight wells have been drilled in the Miner ranch field, none of which have so far been successful. They range in depth from about 570 feet to more than 2,750 feet. All lie on the northeast flank of the Miner ranch anticline, and all start in the sandstone above the Monterey shale, penetrating at first the upper sands and intercalated soft shales, and the deeper ones eventually reaching the Monterey shale. All the wells have shown more or less gas; in fact, the abundance of the gas is one of the characteristics of this field. It is said that the gas pressure was responsible for the collapse of the casing in at least two of the wells. One well is said to have encountered a pocket of oil at a depth of about 1,300 feet, which flowed 300 barrels of oil in nine hours. This is the only well in the field that has actually produced with the exception of the Flood well, 1½ miles to the south, which is reported as having yielded five barrels of 29° oil. The oil and gas apparently occur in pockets or lenses and no well-defined oil sand or petroliferous zone has yet been proved to be present.

Characteristics of the oil and gas.—The most interesting item in connection with the oil from the Miner ranch field is its relatively light gravity, said to be about 29°, as compared with the oils from the other fields in the State. As none of the wells were producing oil at the time of the writer's visit (September, 1907), it has been impossible to get samples of the oil for analysis in time to be included in this report. The gas from the Miner ranch field is noteworthy because of its relatively high marsh-gas content as compared with many of the gases from the eastern fields, especially those of

Kansas. Two analyses[a] of the gas taken at Miner ranch, one in 1904 and the other in 1907, are as follows:

Analyses of natural gas from Miner ranch, Contra Costa County, Cal.

1.		2.	
Marsh gas (CH_4).....per cent..	93.0	Marsh gas (CH_4).....per cent..	92.3
Hydrogen (H_2).....do....	3.3	Hydrogen (H_2).....do....	7.5
Carbonic acid gas (CO_2).....do....	.4	Loss and unestimated.....do....	0.2
Nitrogen (N) and residuum.....do....	3.3		100.0
	100.0		
		Calorific value..British thermal units..	1,059.3
Specific gravity (air=1), calculated.....	0.558		
Calorific value, calculated, British thermal units.....	1,009		
Combustible.....per cent..	96.3		
Noncombustible.....do....	3.7		

1. By California Gas and Electric Co., San Francisco, 1904.
2. By A. Auchie Cunningham, San Francisco, 1907.

Conclusions concerning future development.—The Miner ranch oil field seems to have been pretty well prospected with the drill, and as no productive wells have so far been brought in and no well-defined oil sands or zones discovered, it appears reasonable to suppose that future development will fail to disclose any important deposits of oil. There is no question that considerable quantities of oil are present in the Monterey shale and adjacent beds, not only here but in other parts of the county, as is clearly indicated by the prospect holes and surface evidence; but there are also many reasons for believing that this oil is so uniformly disseminated in the shales and sands, with the possible exception of local and relatively unimportant pockets, as to preclude its withdrawal in commercial quantities through wells. The development of gas in the territory is another matter, but as the oil and gas have the same origin and are influenced similarly by the same conditions, it is believed that no large bodies of gas are contained in the formations of the region. Another item that must be considered in drawing conclusions concerning the future of this field is that the organic Monterey shale, which is believed to be the source of both the oil and gas, is here but about 300 feet thick, an amount entirely inadequate under the most favorable conditions for supplying large quantities of hydrocarbons. The structural conditions, on the other hand, are in general favorable for the accumulation of the oil and gas were they present in sufficient quantities to pay for exploitation.

[a] These analyses have been kindly furnished by Mr. W. E. Holbrook, president of the American Oil and Refinery Company, which at present holds the Miner ranch property.

PETROLEUM IN SOUTHERN UTAH.

By G. B. RICHARDSON.

INTRODUCTION.

The recent discovery of petroleum near Virgin City, Utah, has caused much local excitement and attracted considerable capital. Outside of newspaper items, however, very little has been published concerning the oil, and the following note has been prepared to help supply the demand for information. The writer's personal knowledge of the field is limited to the information obtained during a day's visit to Virgin City shortly after the announcement of the discovery.

LOCATION.

Virgin City is situated on Virgin River in Washington County, in the southwest corner of Utah, and is distant about 90 miles by road from Lund, the nearest station on the San Pedro, Los Angeles and Salt Lake Railroad. The new oil field is in the Plateau province, near the eastern boundary of the Basin Ranges. The country rises northeastward from an elevation of about 3,250 feet at Virgin City to over 10,000 feet on the crest of the plateau 30 miles distant. The ascent is accomplished by successive benches which rise steplike one above another. This region is drained by Virgin River and its tributaries, which for many miles flow through steep narrow canyons among some of the grandest scenery on the continent. The area here considered is included in the region covered by C. E. Dutton's report on "The Geology of the High Plateaus of Utah," published in 1880.

OUTLINE OF GEOLOGY.

STRATIGRAPHY.

This portion of the Plateau province is underlain by almost flat-lying strata which range in age from Carboniferous to Eocene. The several formations are distinctly marked lithologically and are characteristically colored so that they can be readily distinguished.

They outcrop in broad belts extending in a general east-west direction, the harder rocks forming escarpments and the softer ones the intervening stretches. The oldest formation in the Virgin City region is a thick, massive gray limestone of upper Carboniferous age which underlies the broad plateau between Virgin River and the Grand Canyon of the Colorado. Above this limestone there is a mass of red beds of variable thickness, in the vicinity of Virgin City approximating 3,000 feet. These are in the main soft, thin-bedded rocks, chiefly argillaceous and calcareous shales, with some beds of sandstone and limestone. The group of red rocks is separated into two distinct parts by a formation composed of gray sandstone and conglomerate, which in the area considered is less than 100 feet thick, though in Arizona it is reported to be much thicker. Occurring between softer rocks, this siliceous formation is prominent and commonly constitutes a broad bench capping the underlying beds in a scarp, while the upper softer rocks have been eroded from the platfrom and form the slope of the next succeeding escarpment. The rocks beneath the prominent sandstone and conglomerate are probably of Permian age, and the conglomerate, with the overlying red beds, is considered to be Triassic. The lower red beds are the oil-bearing rocks.

Above the soft red beds there is a great development of sandstone which in this region is about 2,500 feet thick. The lower part of this sandstone is characteristically dark red; the upper part is peculiarly cross-bedded and is of a prevailing light color. This great mass of sandstone is the most conspicuous geologic feature of the region. It forms prominent cliffs which can be followed for many miles and through which deep canyons have been cut.

The sandstone is succeeded by about 1,200 feet of generally soft varicolored beds, including reddish and green shales, white limestone, and gypsum of Jurassic age. These rocks are commonly eroded into badland topography. They are overlain by about 3,000 feet of buff and gray sandstones and shales which contain workable beds of coal and are of Upper Cretaceous age. Above these rocks are varicolored shale, sandstone, and limestone of Eocene age which outcrop in the Pink Cliffs and cap the summit of the high plateaus.

Although the rocks of the plateau region in the vicinity of Virgin City are prevailingly sedimentary, there are small areas covered by basaltic lavas of post-Eocene age.

STRUCTURE.

The strata in general dip northeastward at a low angle, averaging possibly between 1° and 2°. The continuity of the beds is broken, however, by a number of faults trending in general north and south, some of which have displacements of 1,000 feet or more. One zone of

dislocation extends approximately along Hurricane Cliff, through which Virgin River cuts its way about 7 miles below Virgin City. This zone of fracture has been traced from the Grand Canyon to Virgin River and northward along the western base of the plateau in the vicinity of the Mormon settlements of Torquerville, Belleview, Kanarra, and Cedar City. Along portions of this zone, especially between Cedar City and Kanarra, the strata are much disturbed and are steeply tilted. Another conspicuous line of disturbance extends along the headwaters of Virgin River in what is known as Long Valley.

OCCURRENCE OF PETROLEUM.

The Carboniferous limestone outcrops a few miles west of Virgin City and the town is immediately underlain by the Permian (?) red beds, in which Virgin River has cut a relatively broad valley. The overlying sandstone-conglomerate formation marks a prominent bench north, east, and south of the town, beyond which, to the north and east, the upper red beds slope up to the base of the escarpment made by the massive red sandstone.

Oil seeps have long been known in the vicinity of Virgin City. One of them occurs close to the river about 1½ miles west of the town, and it is reported that the existence of this seep was the cause of sinking the discovery well in the summer of 1907. This well is located in the flood plain of North Creek, a tributary of Virgin River, about 2 miles north of Virgin City. The boring was started in the lower red beds and apparently did not pass through them, though it must have stopped not far from the bottom of the formation, near the Carboniferous limestone. A complete record of the drill hole was not kept. Oil was struck on July 13, 1907, at 566 feet below the surface and the well was sunk to 610 feet. The oil is reported to stand in the well 300 feet below the surface, thus being under pressure sufficient to cause it to rise 266 feet. A few hundred barrels are said to have been pumped when work was stopped by a flood on July 27. This stage of development was reached when the writer visited the field a few days later.

The following statement of conditions at Virgin City in January, 1908, is extracted from a letter from Mr. Thomas Downey, of the Paraffin Virgin Oil Company. Fifteen oil rigs were then in the field, but only four were being operated. Seven wells had been sunk supposedly to the oil horizon and some oil was found in each, but the amounts were not given by Mr. Downey. He states, however, that none are as good as the discovery well, which is reported to produce about 10 barrels in twenty-four hours. Claims have been staked far and wide, but oil has not yet been reported outside of the immediate vicinity of Virgin City.

The occurrence of petroleum in red beds is unusual. Such beds in general are believed to have accumulated in bodies of water in which there was little life, for the presence of much organic matter would tend to reduce the ferric salts of the pigment to more somber-colored compounds. If barren conditions existed in this area during the deposition of the red beds, the source of the petroleum probably must be sought in the decomposition of organic matter in the underlying Carboniferous limestone.

QUALITY OF THE OIL.

A small sample was collected by the writer from an open vat in which the oil had been exposed to the weather for a week or more. This sample was examined by David T. Day, who reports that it has a specific gravity of 0.9225, equivalent to 22° Baumé, and that it contains some paraffin, a large percentage of asphalt, and apparently considerable sulphur, including hydrogen sulphide. A larger sample, received by Dr. Day, was analyzed by him with the following results:

Chemical examination of crude petroleum from Virgin City, Utah.

Color, black.
Odor, hydrogen sulphide.
Specific gravity, 0.918 = 22.5° Baumé.
Results of distillation:
Sample began to boil at 60° Centigrade.

Distillate obtained—	Per cent.
Below 150° C.—gasoline and naphtha	2.1
Between 150° and 300° C.—illuminating oil (specific gravity, 0.784)	19.5
Residue (specific gravity, 0.9475)	78.4

Examination of the gasoline and illuminating oils obtained above showed both to be principally saturated hydrocarbons, probably chiefly of the paraffin series. Examination of the residue showed it to contain 49.7 per cent of asphalt and 29.4 per cent of paraffin wax, the remainder consisting of heavy oils and resinous material. From the above it is evident that though a satisfactory illuminating oil can be obtained from this Utah crude petroleum, the yield is comparatively small and the petroleum is better suited to use as a fuel oil. This rendered the determination of the sulphur advisable, and by Carius's method the result was 0.45 per cent. Much of this is in the form of hydrogen sulphide, easily separated by steaming, hence the oil is preferable for fuel purposes to Texas oil. The percentage of sulphur obtained is lower than that found by other analysts, the difference being probably due to the fact that this sample was taken from a barrel which had been standing a month or more since taken from the well.

FUTURE OF THE FIELD.

The encouraging news that petroleum of a fair grade was found in promising quantity in the first well is offset by the fact that six others have been sunk without encountering oil in paying amounts. Yet, considering the present scanty knowledge of the conditions, little can

be predicted concerning the future of this field. Whether oil exists here in profitable amount can be determined only by the drill. To judge from what is known of the geology, the general conditions are not unpromising, although there are unfavorable complications. In many oil-bearing areas an anticlinal structure has prevented the escape of petroleum stored in the rocks, but the strata here are not folded; moreover, the Virgin field is traversed by profound faults that possibly provided means of escape for oil that may have been present. The thickness of the oil-bearing stratum, which appears to be a layer of sand in the lower red beds, has not been reported and whether or not it is persistent over a wide area is undetermined. However, the stratigraphy of the lower red beds is known to be varied and it is probable that the oil-bearing rocks occur as lenses rather than as persistent beds. If the petroleum has accumulated in lenses of porous sandstone the surrounding relatively impervious shale would tend to prevent its escape, so that under the circumstances this possible mode of occurrence of petroleum in the Virgin field is fortunate rather than otherwise. But, on the other hand, such hypothetical reservoirs can not be predicted by surface indications and an unusually large element of chance confronts the prospector.

In prospecting in the possible eastward continuation of this field, the outcrop of the massive red sandstone that lies above the red shale will serve as a valuable aid. It would be futile to attempt to strike the Virgin City oil horizon in wells situated above this formation, because of the great thickness of the rocks that would have to be penetrated. The sandstone-conglomerate formation that separates the upper and lower red beds is also an important horizon marker in following the oil-bearing rocks. It should be borne in mind that the Virgin City oil occurs in the red beds beneath this siliceous formation, which usually is conspicuous.

GAS FIELDS OF THE BIGHORN BASIN, WYOMING.

By CHESTER W. WASHBURNE.

INTRODUCTION.

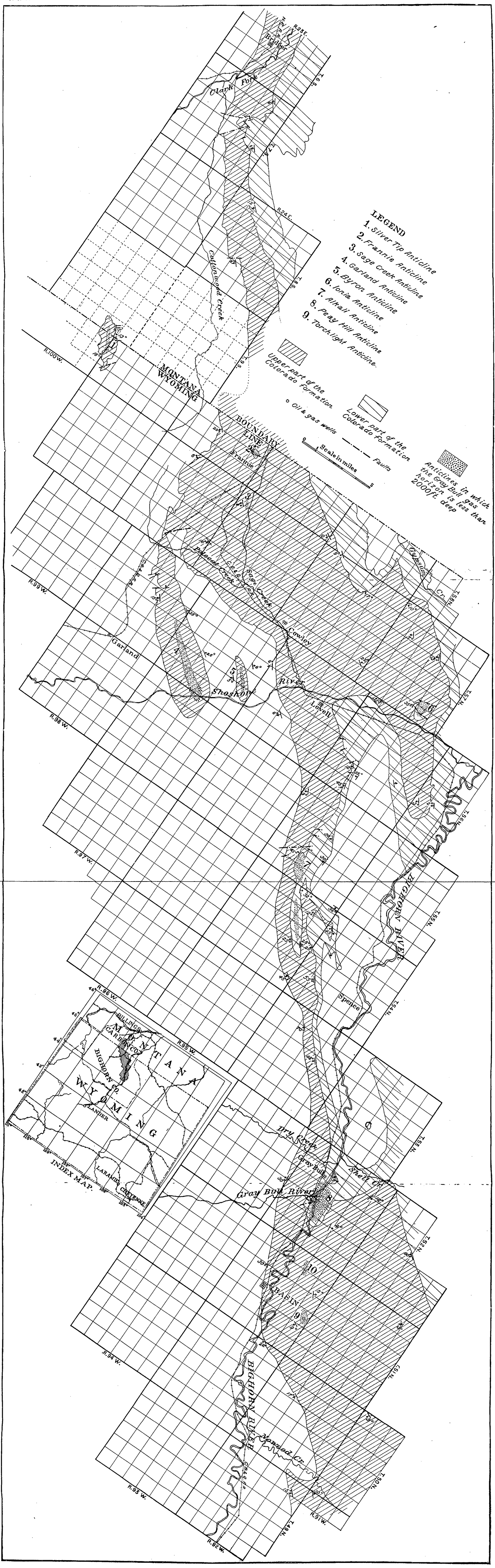
A strong flow of natural gas has recently been obtained in a well near Gray Bull, Wyo. In view of the wide distribution of the strata that contain the gas at Gray Bull, and the signs of gas at other places, suggesting the further extent of the gas-producing region, a description of the field seems desirable.

The field work on which the present paper is based was done in the summer of 1907 in the course of an investigation of the coal deposits and general geology, made under the direction of C. A. Fisher. Max A. Pishel and Homer P. Little acted as field assistants. For well records and similar data, the writer is indebted to Henry Sherard and Philip Minor, of Basin, Wyo., and to L. A. Corey, of Bridger, Mont.

The only previous mention of oil or gas within the field studied by the writer is in the report by C. A. Fisher on the geology and water resources of the Bighorn basin.[a] Fisher mentions the escape of gas from alluvial sands near Byron, Wyo., and from a dug well 3 miles east of Basin, Wyo.

The Bonanza field, close to the southeast corner of the area studied by the writer (see Pl. III), has been described by several geologists. In 1888 L. D. Ricketts[b] described an oil spring in sec. 23, T. 49 N., R. 91 W., and gave an analysis of the oil. Later W. C. Knight[c] also mentioned the same spring. Knight visited the Bonanza oil field in 1903 and found two abandoned wells, one of which is reported to have struck some oil, the other only artesian water. The wells, according to Knight, were poorly located. Fisher[d] describes the oil springs near Bonanza and gives an analysis of the oil.

[a] Prof. Paper U. S. Geol. Survey No. 53, p. 59.
[b] Rept. Territorial Geologist of Wyoming, 1888, pp. 39–40.
[c] Bull. Wyoming Exp. Sta. No. 14, 1893, p. 11.
[d] Loc. cit.



MAP SHOWING POSSIBLE GAS FIELDS ON THE EAST SIDE OF THE BIGHORN BASIN, WYOMING.

GEOLOGIC CONDITIONS.

STRATIGRAPHY.

GENERAL OUTLINE.

A knowledge of the stratigraphic column is most important to the driller. This column is as follows:

Stratigraphic column in Bighorn basin, Wyoming.[a]

System or series.	Group.	Formation.	Thickness (feet).	Characteristics.
Tertiary.	Lower Eocene.	Wasatch.	500+	Bright-colored terrestrial clays.
		Fort Union.	1,000 to 2,000	Dark-colored shale, with coal, and massive sandstone.
Upper Cretaceous.		Laramie.	150 to 700	Massive sandstone with subordinate shale, coal bearing.
	Montana.		150	Dark marine shale.
			300 to 400	Variegated terrestrial clays and soft sandstone.
			400 to 500	Massive fresh- and brackish-water sandstones and dark shale.
			150 to 225	Massive fresh- and brackish-water sandstones, separated by carbonaceous shale, usually coal bearing.
		Colorado.	4,400	Dark shale with one or two conspicuous sandstones, not divisible in this field, though more than 1,500 feet of the lower part of the group is known to be equivalent to the Benton shale.
(?) Lower Cretaceous.		Cloverly.	0 to 275	Bright-colored terrestrial clays, with massive sandstones at the top and bottom.
(?) Jurassic.		Morrison.	250 to 350	Bright, variegated terrestrial clays and soft sandstone.
Jurassic.		Sundance.	225	Marine limestone, shale, and sandstone.
(?)		Chugwater.	600 to 800	"Red Beds," bright-red sandstone.
Pennsylvanian.		Embar.	215	Marine limestone with red shale at base.
		Tensleep.	85	Sandstone.
		Amsden.	90	Red shale and purplish sandstone, with a little limestone.
Mississippian.		Madison.	1,000	Massive-bedded limestone.

[a] For the recognition of the formations in the field the writer is indebted to the guidance of C. A. Fisher. The subdivisions of the Montana group are correlated with similar subdivisions proposed by Stanton and Hatcher, in the Judith River region of northern Montana. (Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: Bull. U. S. Geol. Survey No. 257, 1905.) This correlation also is made possible through the work of Fisher, who has traced the formations southward from the type locality into Wyoming and who will soon publish his conclusions on the subject in one of the scientific journals.

To the prospector for gas the essential part of this stratigraphic column is the Colorado formation, the lower part of which is summarized in the following table:

Generalized section of lower part of Colorado formation in Bighorn basin, Wyoming.

	Feet.
Sandstone, thin bedded. Referred to as sandstone B. Absent in the northern part of the district	20–45
Shales with a few thin beds of sandstone containing a little gas in the Torchlight dome, and both gas and oil in the well 3 miles northeast of Basin	275
Sandstone, massive yellow. Referred to as sandstone A	65–100
Shales, black	185
Shale, gray, sandy, hard, dense, siliceous, a very persistent bed and a conspicuous ridge maker at the top of the Mowry shale	3–5
Shales, gray and black, with many fossil fish scales; contain numerous layers of hard flinty shale, and one 3-foot bed of bentonite; the Mowry shale	200
Shales, dark bluish and black, with a few beds of volcanic ash and white clay (bentonite) in the upper part	250
Shales, black, carbonaceous, in many places oily, locally containing one or more lenses of sandstone in the lower 100 feet	300
Sandstone, thin beds 3 to 18 inches thick, weathering brown, which are separated by partings of black shale 1 to 12 inches thick; the "rusty beds"	20–100

In most sections the total thickness of this part of the formation is about 1,350 feet.

THE GAS HORIZON.

Some uncertainty arises from the lack of precise knowledge of the gas horizon. There can be no doubt that the gas sand is close to the base of the black Colorado shales, but it can not yet be determined whether it is a sandstone in the lower part of the shales, the "rusty beds" of thin-bedded sandstone at the base of the shales, or the underlying Cloverly sandstone. This range of uncertainty amounts to about 150 feet. In the writer's opinion, based on the log of the Gray Bull well, the gas is obtained either from the "rusty beds" at the base of the Colorado, or from some sandstone in the shales less than 100 feet above the "rusty beds," with the probabilities strong in favor of the latter position. Coarse, hard, porous sandstones in the latter position have been observed at a number of localities, but they are lenticular and in many places absent. The "rusty beds" are a constant feature of the base of the marine Cretaceous. Seemingly they are as a group a true basal sandstone, resting upon a rather smooth surface of erosion. Beneath this erosional surface at some localities is a heavy sandstone, probably the lower sandstone of the Cloverly formation; but at most places the Cloverly sandstone is absent and the "rusty beds" rest upon maroon, pink, or bright-green shales which are regarded as part of the Morrison formation, though they may belong to the Cloverly. There can be no doubt as to the lenticular nature of the Cloverly sandstone and its absence over most of the area. The field evidence indicates that the sandstone was removed by erosion before the deposition of the overlying marine strata of the Upper Cretaceous.

If the only gas horizon is that of the Cloverly sandstone, prospecting in the region will be most uncertain because of the limited distribution of that bed, as a well might be drilled where the structure was favorable for the accumulation of gas, yet not obtain gas because of the absence of the Cloverly sandstone. This condition is illustrated diagrammatically in fig. 21. A is an anticline in which the lenticular sandstone near the bottom of the Colorado, the "rusty beds," and the Cloverly sandstone are all three present. B is an anticline in which the "rusty beds" are the only possible gas-bearing strata, the Cloverly sandstone having been removed by pre-Colorado erosion. In the absence of the Cloverly, the "rusty beds" could

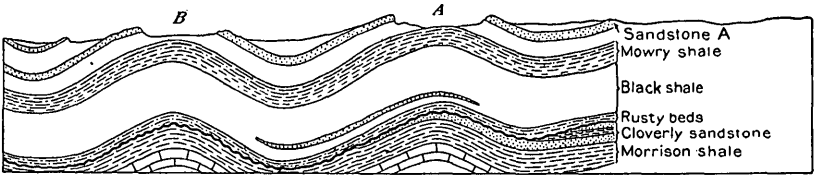


FIG. 21.—Hypothetical section showing gas-bearing strata present in anticline A and absent in B.

probably serve as a gas reservoir. Uncertainty prevails also as to the distribution of the lenses of sandstone in the black basal Colorado shales. These lenses may or may not be present at any locality where a well might be located.

SOURCES OF THE OIL AND GAS.

The source of the oil and gas of the Colorado sandstones is probably the black shales at the base of the Colorado. These shales are oily in most exposures throughout the Rocky Mountain region. The oil of the "Red Beds" and of the Madison limestone, mentioned on page 361, is probably derived from the latter rock. Both of the sources here noted as possible are marine formations.

STRUCTURE.

The Bighorn basin gas fields are on the slopes of the anticline of the Bighorn Mountains. The dips of the region are in general westward at angles of 5° to 20°, but this westward slope is interrupted by numerous small anticlines. It is in these minor folds that gas may be looked for. They are isolated from each other and rise abruptly from the surrounding areas. Most of them have the form of slightly elongate domes with broad crests and gently inclined ends. The ground plans of the anticlines, as shown by the maps, are elliptical, with the major axis of each ellipse parallel to the adjacent front of the Bighorn Mountains.

The anticlines of importance as possible sources of gas are situated about 15 to 20 miles from the Bighorn Mountain front. Their crests at the surface are near the sandstones about 1,000 feet above the

base of the Colorado, referred to as sandstones A and B, or in the underlying Mowry shale or the black carbonaceous shale at the base of the Colorado. Anticlines whose tops are in strata over 1,500 feet above the base of the Colorado need not be considered as possible sources of gas, for many years, because of the great depth of the gas horizon. When the field has been proved these anticlines may become sources of gas, if the value of the product should warrant such deep drilling. Likewise, those anticlines whose crest is in rocks close to the base of the Colorado shale are not to be considered as sources of gas, because of insufficient cover. The remaining anticlines which may be considered as possible gas reservoirs are nine in number, as follows:

Silvertip anticline, 22 miles south of Bridger, Mont.
Frannie anticline, 1 mile west of Frannie, Wyo.
Sage Creek anticline, 2 miles south of Frannie, Wyo.
Garland anticline, 5 miles northeast of Garland, Wyo.
Byron anticline, 3 miles north of Byron, Wyo.
Ionia anticline, 8 miles northeast of Lovell, Wyo.
Alkali anticline, 10 miles south of Lovell, Wyo.
Peay Hill anticline, 2 miles southwest of Gray Bull, Wyo.
Torchlight anticline, 3 miles east of Basin, Wyo.

DETAILED DESCRIPTIONS.

PEAY HILL ANTICLINE.

Along Bighorn River near Gray Bull, Wyo., there is a small, low anticline about 2½ miles long and 2 miles wide. On account of its broad, flat form it is known to the oil drillers as the "Peay Hill dome." A gas well has been drilled in the central part of this dome on the east bank of Bighorn River, in the northwest corner of sec. 21, T. 52 N., R. 93 W. This well was drilled for the Peay Hill Oil and Development Company by Philip Minor and Henry Sherard, to whom the writer is indebted for the following record:

Log of the Peay Hill Oil and Development Company's gas well, 1½ miles southeast of Gray Bull, Wyo.

	Thickness.	Depth.[a]
	Feet.	*Feet.*
Shale	17	17
Shale, hard, dark, probably the ridge-making layer of the Mowry	3-4	20
Shale, dark colored	300	320
Clay, soft, white, probably bentonite, causing the well to cave in badly	3	323
Shale, dark	127	450
Clay, white, sandy	40-50	495
Shale, black	155	650
Shale, thin layer, hard	1(?)	651
Shale, black	49	700
Rock, thin layer, very hard	1(?)	701
Shale, black	49	750
Rock, very hard	7	757
Shale, black	38	795
Rock, hard	5	800
Sandstone, containing gas under high pressure (base not reached)	1	801

[a] "Depth" in all the logs in this paper refers to the base of the respective strata.

The top of the well is 165 feet below the base of a massive sandstone, 65 to 75 feet thick, which forms the top of the bluffs above Gray Bull. This sandstone will be referred to as sandstone A. It is conspicuous in nearly all its outcrops, and hence a very important horizon marker in the Colorado formation. The Gray Bull gas horizon is 950 to 965 feet below the bottom of this sandstone.

The diameter of this well is 5⅝ inches and its depth is 801 feet. The well is cased down for 500 feet. It has maintained a steady roaring flame over 50 feet high almost from the time it was drilled, July 14, 1907, to the date of this writing, January, 1908. It is reported that the initial height of the flame was about 70 feet, but this can not be verified; certainly the gas well is one of remarkable volume and through it large quantities of gas have escaped from this reservoir. Some idea of the pressure of this well may be obtained from the fact that the escaping gas is sufficient to lift a large log chain composed of ½-inch iron. No instrumental measurements of pressure have been made, but a rough calculation based on the size of stones which the gas would eject shows that the pressure in September, 1907, was over 600 pounds to the square inch. Whether or not this pressure is diminishing can not be determined now, for according to the most reliable information no change has been detected up to the present time. One of the strangest features of this occurrence is the fact that the well is drilled within a few feet of a normal fault, yet obtains gas under high pressure. The throw of the fault is about 24 feet. One-fourth mile north of the well is another fault the throw of which is 60 feet. Henry Sherard reports a 10-foot fault in the sandstone 250 yards south of the last-mentioned fault.

From a study of the nearest available geologic section, made about 10 miles northwest of Gray Bull, it would seem highly probable that the gas in the Gray Bull well is obtained from a lenticular, nonpersistent sandstone about 100 or 150 feet above the base of the Colorado formation, in a series of black shales. Such a sandstone outcrops on the wagon road from Shell to Lovell, about 6 miles northeast of the gas well. This sandstone is coarse grained and of loose, porous texture. It is about 10 or 15 feet thick and from its porosity it would seem to be well suited to hold gas. When examined in the outcrop, however, no odor of oil or gas could be detected in this rock. Another possible position of the gas horizon is in the "rusty beds" about 50 or 100 feet below this sandstone Moreover, it is thought by some that the gas is obtained from the Cloverly sandstone, which is the next underlying member of the stratigraphic column. The maximum stratigraphic range of uncertainty is about 150 feet. The only way the Gray Bull gas horizon can be definitely located at present is by reference to the first sandstone above the Mowry shale. This sandstone is

exposed on the river bluffs opposite Gray Bull, and may be designated sandstone A. The gas horizon is 950 to 965 feet below its bottom.

The drilling of the Peay Hill well near Gray Bull is very important for an understanding of the economic geology of the region. It is the first well to obtain a flow of gas in commercial quantities, and it furnishes an important lesson for the drilling of wells in the future by indicating the caving nature of the soft shales encountered in drilling and the need of strong casing. On account of the lack of proper casing in this well, it has been found impossible to close it and to prevent the escape of gas in valuable quantities. Unless some means are found to stop this flow of gas very soon, an appreciable diminution of pressure and ultimate exhaustion of the well may be expected.

GARLAND ANTICLINE.

One of the sharpest and most pronounced anticlines of the region is known as the Garland anticline. This fold is about 7 miles long, extending from Polecat Creek, near the crossing of the Cody branch of the Chicago, Burlington and Quincy Railroad, to Shoshone River, 1 mile above Byron, Wyo. Three wells have been drilled in this anticline about 2 miles west of Byron for the purpose of obtaining oil, but the boring did not penetrate to the base of the Colorado. The wells were drilled by the Montana and Wyoming Oil Company, of Billings, Mont. The depth of the wells is about 900 feet. The well first drilled furnished sufficient gas to run the engine during the drilling of the second and third wells. Moreover, gas has been observed by Fisher[a] escaping from alluvial sands overlying this anticline. The wells do not reach the horizon of the beds that yield the gas near Gray Bull, and it is not known whether or not the anticline contains commercial quantities of gas.

The Gray Bull gas horizon at the base of the Colorado would be found at a depth of about 1,500 feet beneath the highest point of the axis of the Garland anticline. Gas might occur in commercial quantities at a higher horizon if sandstone were encountered of sufficient thickness to serve as a reservoir. This may be inferred from the occurrence of gas in the wells near Byron at various horizons in the lower part of the Colorado shale. A satisfactory test of the gas field can be made only by drilling entirely through the Colorado into the underlying sandstone.

The three wells mentioned above, which were drilled about 100 yards apart, have all furnished small quantities of oil. Accurate logs of the wells could not be obtained from the officers of the company, and hence the oil horizon can not be located closely. Descriptions furnished by the drillers, however, leave no doubt that the oil is obtained from a thin sandstone, not over 3 feet thick, in the upper

[a] Fisher, C. A., Prof. Paper U. S. Geol. Survey No. 53, 1906, p. 59.

part of the black basal Colorado shales. This "oil sand" is overlain by 3 or 4 inches of fine-grained limestone. So far as the writer knows, this is the only limestone ever found in the Colorado formation in the Bighorn basin. If the limestone outcrops at the surface, it has never been observed. The quality of the oil is very high, as shown by the following report by David T. Day on oil from well No. 1:

The oil is light red by transmitted light, with brilliant green fluorescence. It contains no water. The odor is almost like that of Pennsylvania oil, and apparently the oil contains no sulphur, therefore no determination was made. Specific gravity at 15° C., compared with water at 4° C., is 0.8315. The specimen in the small bottle submitted by you shows 0.816.[a] Distillation of the sample gave the following results:

Initial boiling point 77° C.

	Per cent.
Naphtha (specific gravity 0.722)	14
Illuminating oil (specific gravity 0.761)	28
Light lubricating oil	17.5
Residue suitable for cylinder oil	36
Loss	4.5

Such an oil as this would make very satisfactory oil, if transportation facilities were afforded, for by properly adjusting the distillation method a larger percentage of illuminating oil could be obtained. This is shown by the low specific gravity of the distillates.

The quantity of oil that could be obtained from these wells is not known to the writer. They are kept tightly closed, and no tanks or other means of storing the oil have been prepared. Until the wells are opened and their flow is measured for a period of several days, their capacity must remain unknown. In the absence of such tests the general inference is that these wells have not yielded oil in commercial quantities.

TORCHLIGHT ANTICLINE.

The Torchlight anticline, or "dome," as it is known to the prospectors, is about 3 miles east of Basin, Wyo. The dome is small, being about 1 mile long and one-half mile wide, and forms part of a much larger anticline extending a mile or more to the northwest. The dips of the larger anticline are so gentle that it seems doubtful whether its structure is sufficiently pronounced to favor the accumulation of gas. The small dome, however, must be considered a favorable structural feature. The crest of this little dome is in black shales, probably between sandstones A and B. (See section, p. 350.) If such is the case, the gas horizon would be found at a depth of 1,150 or 1,200 feet. This figure is uncertain because there is doubt as to the correlation of the sandstone surrounding the gas field, here designated sandstone B. It is thought to be the same as a sandstone occurring in many places 275 feet above sandstone A.

[a] This specimen is from the well of the Union Gas and Oil Company, 3 miles northeast of Basin, Wyo.

The Torchlight Drilling and Mining Association (Limited), of Basin, Wyo., has two wells on this anticline. Both wells are 2 inches in diameter. Well No. 1 is 106 feet deep. It obtains gas from sandy shale between depths of 15 and 85 feet, with a very strong flow of gas from a thin sandstone at a depth of 60 feet. This sandstone carries water highly charged with bitter salts. The log of well No. 2 is given below. The principal gas horizon of this well is a 30-foot thin-bedded sandstone encountered at a depth of 192 feet. The sandstone is saturated with gas and contains some oil. The pressure of the gas is between 35 and 55 pounds per square inch, so that ordinarily the water in the well, standing 65 feet from the surface, holds the gas quiet, but when the water is pumped out to a depth of 110 feet there is a good flow of gas. Part of this gas is used to supply a 4-horsepower engine and two stoves at the driller's camp.

The soil on the Torchlight dome is in places impregnated with bituminous matter which has escaped from the underlying rocks. An open pit, 8 feet deep, is said to give off a strong odor of ammonia, probably a product of organic decomposition.

Log of well No. 2, Torchlight Drilling and Mining Association, 3 miles east of Basin, Wyo.

	Thickness.	Depth.
	Feet.	*Feet.*
Shale, sandy	125	125
Sandstone A, containing "sulphur water, with some soda and iron;" traces of gas	35	160
Shale, with some sandstone	32	192
Sandstone, thin bedded, containing gas and a little oil	30	222

OTHER FAVORABLE LOCALITIES.

SILVERTIP ANTICLINE.

The Silvertip anticline is on the State line between Montana and Wyoming, about 20 miles northwest of Garland, Wyo. The heart of the anticline is a depression known locally as Elk Basin. The boundaries of this basin correspond approximately with the boundaries of the gas field which might be developed by very deep drilling. As thus limited, the gas field would be about 3 miles long and less than a mile wide. The crest of the anticline is in the upper part of the Colorado formation, and the depth to the rock which is gas bearing at Gray Bull is about 3,000 feet. This great depth precludes the possibility of an early development of the field, if indeed it should be exploited at all. But the structure is so favorable for the accumulation of gas at this point that the possibility of the field needs to be pointed out. The anticline is cut by many cross faults trending at right angles to the strike. The throw of some of these faults is over

200 feet, but on account of the depth of the gas horizon, it is believed that they would not interfere with the accumulation of gas.

FRANNIE ANTICLINE.

One mile west of Frannie, Wyo., there is a low anticline in sandstone A, a stratum which has been used as a horizon marker throughout the extent of the field studied. The depth of the Gray Bull gas horizon beneath the crest of this anticline is about 1,000 or 1,100 feet, but it is of course doubtful whether or not the bed is actually gas bearing at this place. The anticline is crossed by a fault trending northeastward, with a downthrow of about 50 feet on the southeast side. The most favorable location for a prospect well on this anticline would be near the southeast corner of the SW. ¼ SW. ¼ sec. 24, T. 58 N., R. 98 W.

SAGE CREEK ANTICLINE.

Another anticline about 2 miles south of Frannie station is here designated the Sage Creek anticline, because of its nearness to Sage Creek. It is possibly connected with the Frannie anticline, which lies 3 miles farther northwest. It is a low dome of sandstone 200 yards west of Sage Creek, on the south line of sec. 6, T. 57 N., R. 97 W. The anticline is poorly exposed, being partly covered by drifting sand, but the fact that sandstone A outcrops in flat beds at this point is sufficient to indicate the presence of an anticline. The area within which it would be practicable to reach the Gray Bull gas horizon by drilling, in this anticline, is very small. The most favorable location for a well would be about 200 yards northeast of the south quarter corner of sec. 6. The gas horizon at this place would be found at a depth of about 1,100 feet.

BYRON ANTICLINE.

About 3 miles northeast of Byron, Wyo., there is an anticline on which a well is being drilled by the Montana and Wyoming Oil Company, for the purpose of obtaining oil or gas. This anticline is favorably situated in the geologic column for the accumulation of gas, and it may be found by prospecting that the Gray Bull gas horizon is not too deep. The writer has not visited this locality and hence has no reliable data as to the depth of the gas horizon, but it will probably be deeper here than in the Gray Bull anticline.

IONIA ANTICLINE.

On the north bank of Shoshone River about 8 miles northeast of Lovell, Wyo., there is a low anticline exposing the lower Colorado sandstones. These sandstones make a low ridge about the margin of the

anticline within which the Mowry shale outcrops in an anticlinal basin. The structure is complicated by the presence of several normal faults. The throw of these faults probably does not exceed 200 feet, but it is not definitely known, and it is therefore impossible to say whether or not they interfere with the accumulation of gas. Probably, however, there is no such interference even if the faults cut the gas-bearing strata, because similar faults are known in the Gray Bull anticline close to a productive gas well. Moreover, there are extensively faulted gas fields in California, Roumania, and other parts of the world. The depth of the Gray Bull gas horizon beneath the crest of this anticline would probably be about 800 feet, but as in all other localities not yet tested by adequate drilling, it is not known that the beds of this horizon actually contain gas in the Ionia anticline.

ALKALI ANTICLINE.

About 10 miles southeast of Lovell, Wyo., there is a long, narrow anticline in the Colorado shale. The northwest end of the anticline is in the SW. ¼ sec. 28, T. 55 N., R. 95 W. From this point the anticline extends over 6 miles southeastward to a point within 14 miles of Gray Bull. In most of the anticline the basal Colorado shales are exposed and eroded probably nearly to their base. Hence the anticline may not be a good gas reservoir on account of insufficient cover. If gas occurs in the top of the Cloverly sandstone or in the sandstones of the "rusty beds," as thought by some, it would be found at very shallow depths in the greater part of the anticline. Not having seen the anticline, the writer is unable to estimate the actual depth of the Gray Bull gas horizon. However, it is probable that if found at all, the gas would be at a depth of less than 200 or 300 feet. This is true especially of the central part of the anticline. In case it seems likely that the cover of shale is sufficient to protect the gas reservoir, the most favorable locality for a well would be near the west quarter corner of sec. 11, T. 54 N., R. 95 W.

The northern end of this anticline includes a subordinate dome of the Mowry shale. Within this part of the anticline, the gas stratum would be covered by 500 or 600 feet of shales, and for this reason the locality would be favorable for the accumulation of gas. The crest of the anticline, which may be considered the most favorable point for the location of a gas well, is in the SE. ¼ SW. ¼ sec. 28, T. 55 N., R. 95 W.

A POSSIBLE DOME NEAR BASIN.

A well is being drilled for gas by Henry Sherard, of the Union Gas and Oil Company, about 3 miles northeast of Basin, Wyo., near the northwest corner of sec. 11, T. 51 N., R. 93 W. The structure at this locality is that of a very gentle anticlinal flexure on the flanks of a larger anticline that extends from the Peay Hill dome near Gray Bull

to the Torchlight dome 3 miles east of Basin. The structure can not be thoroughly worked out because of the lack of exposures, but from the tracing of a thin sandstone along the hillside it would seem probable that the well is located on the side of a small minor anticline of domical form. The rocks at the well are not exposed, but from the depth of sandstone B in the well, it is probable either that there is a fault between the hillside and the well, or that the concealed rocks dip westward at an angle of over 10°.

The possible dome on which this well is located is so small and gentle that it must be regarded as a structure of doubtful favorability for gas. Such a faint structure may indicate a more pronounced dome and a good gas reservoir below, or the structure may die out downward within a short distance and no gas reservoir be present. In the latter case, the location of the well, which is on the limb of the larger anticline, would be better for oil or water than for gas, should either exist in commercial quantities. The depth of the Gray Bull gas horizon at this well is between 1,450 and 1,500 feet.

Log of the Union Gas and Oil Company's Well No. 1, 8 miles northeast of Basin, Wyo.

	Thickness.	Depth.
	Feet.	*Feet.*
Shale, yellowish	6	6
Shale, gray	111	117
Sandstone, light gray, probably sandstone B	43	160
Shale, light gray	37	197
Shale, black with thin beds of brown fine-grained sandstone containing some gas and oil	22	219
Shale, light gray, with a little grit; small amount of gas and oil	27	246
Shale, sandy, with some gas	79	325
Shale, dark, with some very hard layers	75	400
Shale, gray	41	441
Sandstone, with gas and water; doubtless sandstone A	64	505
Shale, sandy, with a little water	42	547
Shale, dark gray	157	704

DOUBTFUL ANTICLINES.

At a few places along the eastern border of the Bighorn basin there are indications of anticlinal folds whose precise form is unknown. These anticlines were not studied in the field and it is not possible at this time to say whether or not they may be possible gas fields.

In the NW. ¼ sec. 14, T. 7 S., R. 23 E., about 4 miles south-southeast of Bridger, Mont., there is a small dome or partial dome of this sort in sandstone A. Only the western and northern sides of this dome were seen and it is possible that the structure is not complete, as no eastward or southward dips have been determined. However, the locality is worthy of investigation by any prospector who may desire to bore for gas in that locality.

In the flats north of Cowley and Lovell, Wyo., there may be small anticlines that were not discovered in the field. At the time the geology of that neighborhood was studied, the economic importance

of anticlines was not realized, and no special pains were taken to find them. They would be difficult to detect in the flats because there is no outcrop of any rock except the Colorado shale, in which faint structural features are hard to see.

The shale hills east of Basin, in the western part of T. 51 N., R. 92 W., and the northeastern part of T. 51 N., R. 93 W., have a broad anticlinal structure. Gas might accumulate in this anticline, but the depth to the Gray Bull gas horizon would be more than 2,000 feet.

Outside of the region embraced in this report, there are doubtless a great many anticlines just as suitable for the accumulation of gas. These have not been tested as yet, and it is not wise to predict that gas will or will not be found in them until such tests have been made. The map of the Bighorn basin made by C. A. Fisher [a] shows that favorable structural conditions are present in the southern and western margins of the basin. One of the anticlines shown on this map is about 6 miles southwest of the Morrison ranch, in T. 44 N., Rs. 97–98 W.; another is near Sunshine, in T. 47 N., R. 101 W.; another near Fourbear, in T. 48 N., R. 103 W.; another near Pitchfork ranch, in T. 48 N., R. 102 W.; another in the southern part of Oregon basin, about 10 miles southeast of Cody, Wyo.; and another on Shoshone River at the mouth of Cottonwood Creek, 1 mile east of Cody. Fisher [b] mentions a well drilled for oil on the Cottonwood Creek anticline, but does not state the depth of the well, and hence it is uncertain whether or not it reached the Gray Bull gas horizon at the base of the Colorado.

E. G. Woodruff, of the United States Geological Survey, informs the writer that the lower part of the Colorado shale is exposed in an anticline in upper Buffalo basin and in another anticline on Grass Creek in the southwest part of the Bighorn basin. These anticlines are indicated on Fisher's map by patches of so-called "Pierre shale" in T. 47 N., R. 100 W., and T. 46 N., R. 98 W.

W. C. Knight [c] has described an anticline in Colorado shale near the head of Cottonwood Creek, 15 miles east of Worland. By digging out a mud spring on this anticline, in or near sec. 29, T. 47 N., R. 90 W., Knight was able to obtain some light-green oil which was analyzed by E. E. Slosson.[d]

It is, of course, not possible to predict the occurrence of gas in anticlines so far away from those which have actually been tested. The writer merely desires to call attention to the existence at these places of favorable structural features in the same strata that bear gas near Basin, Gray Bull, and Byron. At present there is no reason to think

[a] Prof. Paper U. S. Geol. Survey No. 53, 1906, Pl. III.

[b] Op. cit., p. 59.

[c] The Bonanza, Cottonwood, and Douglas oil fields: Bull. No. 6, Petroleum series, Univ. Wyoming School of Mines, July 1903, pp. 14–17.

[d] Knight, W. C., op. cit., p. 27.

that gas will be found on the west side of the Bighorn basin, though the possibility must be admitted.

It should be kept in mind that at the present time only one well has been drilled down to the principal gas horizon. This well, which is 2 miles south of Gray Bull, yields a strong flow of gas, and inasmuch as the strata containing the gas here remain apparently unchanged in character throughout the region and as gas escapes from these strata at widely separated places, an extension of the gas field may well be inferred. Certainly the existence of favorable structure in the same rocks close to the Gray Bull well warrants the drilling of test wells. It should be noted that the writer makes no prediction that gas will or will not be found in any of the anticlines.

INDICATIONS OF OTHER POSSIBLE GAS AND OIL HORIZONS.

The Madison limestone in Sheep Canyon, 15 miles north of Basin, shows many signs of oil. The rock is black in places from the contained carbonaceous material and has a distinct oily smell when freshly broken. It is reported that there was a small oil spring in this canyon before the railroad was built but that the spring has been covered by the railroad grade. The occurrence of asphaltum or other solid hydrocarbons in many small cavities and fissures in the Madison limestone is further proof of the existence of oil in that rock.

Considering the fact that oil has been found near Lander, Wyo., in rocks of Carboniferous age, it would seem not unlikely that it might also be found here. However, the wells which have been drilled near Bonanza, about 25 miles southeast of Basin, where the structure is favorable for the accumulation of oil and gas, were unsuccessful. These wells are described in Fisher's report on the Bighorn basin.[a]

W. W. Peay, of Basin, reports a bed of asphalt mixed with sand and rock on the head of Alkali Creek, one-half to 1 mile north of the wagon road between Hyattville and Shell. Mr. Peay states that in T. 52 N., R. 90 W., the following land has been filed on for the purpose of quarrying the asphalt: SE. ¼ sec. 29, SW. ¼ sec. 28, NE. ¼ sec. 32, NW. ¼ sec. 33. The asphalt occurs in "blanket" form, as a bed 10 feet thick, lying on a hilly surface of limestone or sandstone. About half of the bed is reported to be asphalt, and the remainder to be sand and rock which the asphalt binds together in a firm mass. The bed is overlain by 10 feet or more of incoherent rock fragments and soil. Apparently the asphalt has exuded from the Pennsylvanian rocks at this place and cemented the base of the rock mantle. The occurrence of so large a deposit of asphalt is an excellent argument for the presence of oil in the upper Paleozoic strata.

[a] Fisher, C. A., Prof. Paper U. S. Geol. Survey No. 53, 1906, p. 59.

The strata next overlying the Pennsylvanian rocks are the "Red Beds," which also contain signs of oil. On an anticline 7 miles southeast of Bridger, Mont., according to C. A. Fisher, the "Red Beds" contain a stratum of coarse-grained greenish sandstone about 10 feet thick highly impregnated with oil.

UTILIZATION OF THE GAS.

So far, no use has been made of the gas escaping from the Gray Bull gas well. Except in the city of Basin, which in 1907 had about 1,000 inhabitants, there will be little demand for gas for lighting purposes until the population of the district increases considerably. An important use might be in connection with sugar factories, which are greatly needed to care for the sugar beets grown on the irrigated lands. At present the nearest sugar factory is at Billings, to which the beets are shipped 195 miles by rail at a cost of 5 cents per hundredweight. As coal is abundant and would be cheap, if mined on a large scale, the gas can not compete with it except very close to the wells. Fortunately the productive well near Gray Bull is less than 2,000 feet from the Chicago, Burlington and Quincy Railroad, beside which there is a most excellent location for a sugar-beet factory or other industrial plant. The well being drilled by the Union Gas and Oil Company near Basin and some of the other possible gas fields described in this paper, are also close to good factory sites on the railroad.

SUGGESTIONS TO PROSPECTORS.

The conditions on the east side of the Bighorn basin are favorable for the prospector. Rock exposures are good and abundant; the structure is simple; the topography is of gentle relief; there is no timber except on the river bottom. The Chicago, Burlington and Quincy Railroad traverses the field for its entire length, and in the summer heavy machinery can easily be hauled from the railroad to almost any point in the basin over the wagon roads and plains.

Drilling is not expensive. It is reported on good authority that the cost of drilling the present gas wells near Basin and Gray Bull is less than $1 a foot, for a well 800 feet deep. To this should be added about $1 a foot for casing. The softness of the Colorado shale makes this low cost of drilling possible; unfortunately, it necessitates casing the greater part of every well. Some beds of white clay, probably bentonite, are especially troublesome. When the water of a well reaches this clay it softens and flows slowly into the well. There is much caving also in all parts of the Colorado shale.

In searching for possible gas fields in this region the important strata to observe are the sandstones in the lower part of the Colo-

rado formation referred to in this paper as sandstones A and B (see section on p. 350), and the immediately underlying Mowry shale. The latter are hard siliceous and calcareous shales, containing many fossil fish scales and forming conspicuous ridges. Both the sandstones and the Mowry shale have prominent outcrops and hence they are most serviceable to the prospector in his search for anticlines. Anticlines in the Colorado shales probably exist, but none have been found, possibly on account of the poor exposure of these shales when they have low dips. The map (Pl. III) shows all the favorable anticlines within its borders that are indicated by outcrops of sandstones A and B.

THE LABARGE OIL FIELD, CENTRAL UINTA COUNTY, WYO.

By ALFRED R. SCHULTZ.

INTRODUCTION.

This paper is a brief statement of some observations made by the writer during the summers of 1905 and 1906 while examining the coal fields in southern and central Uinta County, Wyo. It is the purpose to give a short description of the occurrence of oil in Uinta County and to point out the probable geologic relations of the oil-bearing beds furnishing the oil recently discovered east of Labarge Ridge to the oil-bearing shale that gives rise to the oil springs and wells in southern Uinta County.

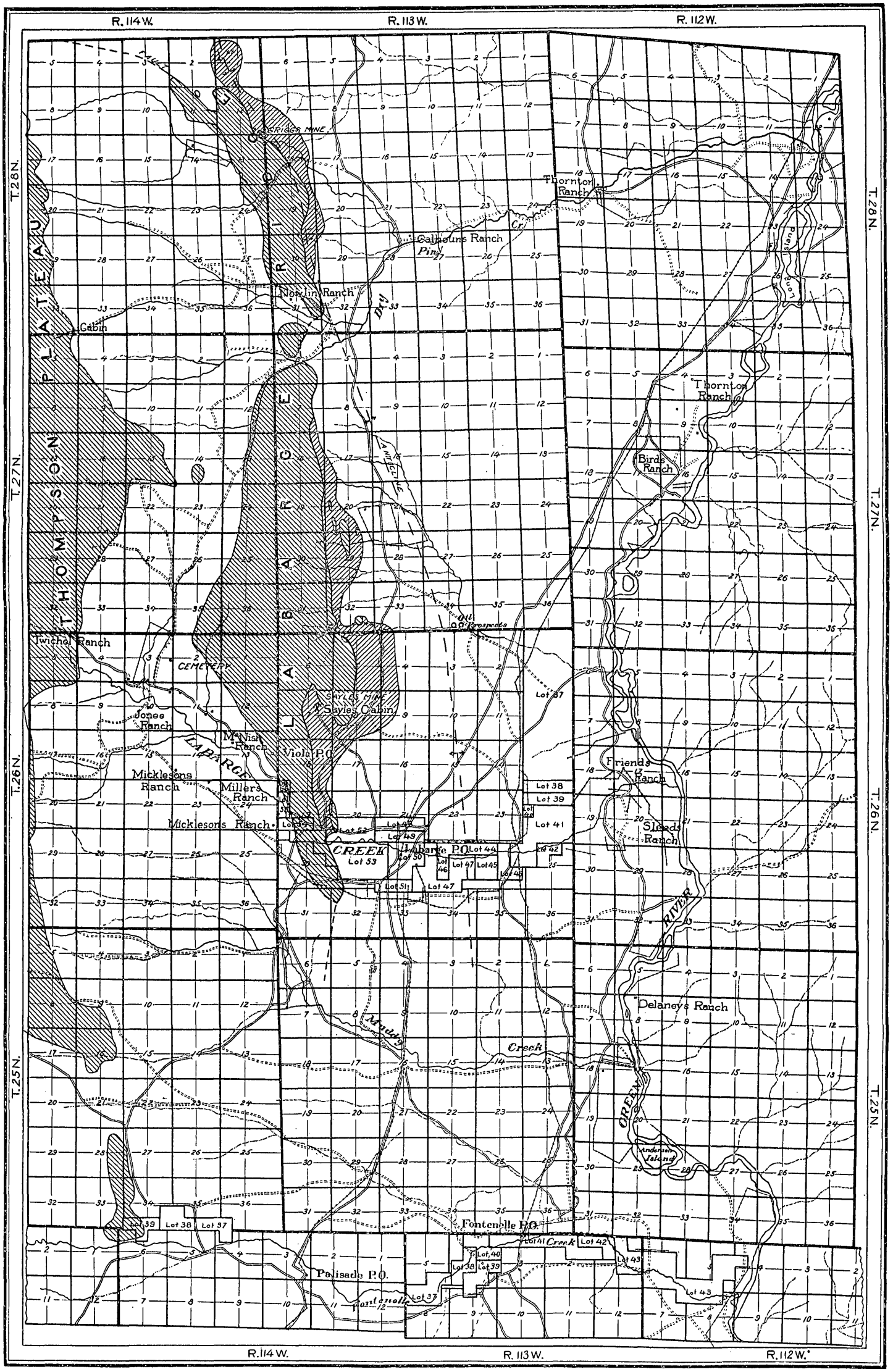
HISTORICAL SKETCH.

The occurrence of oil in southwestern Wyoming has been known for nearly three-fourths of a century. Many of the early trappers and fur traders, who built Fort Bonneville and the trading post at Fort Bridger, knew the location of the oil springs in this region and visited them in their annual trapping tours. The first published account of oil in southwestern Wyoming was the result of an examination made by the Mormons in 1847 on their pioneer journey across the great plains. For a brief historical sketch of the discovery of the oil springs on Hilliard Flat, the Carter oil spring, and those in the Fossil syncline near Fossil, Wyo., the reader is referred to the preliminary report [a] on coal and oil in southern Uinta County.

A few miles southwest of the Carter oil spring, in sec. 7, T. 14 N., R. 118 W., oil was found by the Oregon Short Line Railroad in 1900 and 1902, while constructing the Aspen tunnel, and a considerable oil seepage was encountered along the fault plane about 1,600 feet from the west portal of the tunnel. The oil springs along the east front of Absaroka Ridge north of Kemmerer were probably referred to in Lander's report of 1859,[b] where he makes the general statement that

[a] Veatch, A. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 342-344.

[b] Lander, F. W., Preliminary report upon explorations west of South Pass for a suitable locality for the Fort Kearney, South Pass, and Honey Lake wagon route; 35th Cong., 2d sess., Senate Doc. No. 36, vol. 10, p. 33.



MAP SHOWING THE LABARGE OIL FIELD, CENTRAL UINTA COUNTY, WYO.

in the mountains along the divide in latitude 42° north there are "beds of coal, iron, and slate and a spring of peculiar mineral oil which by chemical process may be made suitable for lubricating machinery." No further description of the spring is given and the exact location is not known. The later geologic reports do not mention oil springs north of the Fossil locality. A brief description of the oil springs in southern Uinta County is given in the Wyoming reports by W. C. Knight and E. E. Slosson.[a] For a full discussion of the oil discovery in the vicinity of Spring Valley and of the developments in southern Uinta County from 1900 to 1905, the reader is referred to the reports of A. C. Veatch.[b] Since 1905 prospecting and development work have continued in the region about Spring Valley. The Pittsburg-Salt Lake Oil Company has filed proof of labor on most of its property and the people interested in oil are holding their locations. The Pittsburg-Salt Lake Oil Company discontinued drilling about December 15, 1907, and will commence drilling again in the spring. The International Consolidated Oil Company is putting down a couple of wells and has been working all winter. Two other companies expect to begin work soon and the outlook is very promising for a great deal of development work the coming summer. During the last three months of 1907 the Pittsburg-Salt Lake Oil Company shipped seven cars of refined oil and two cars of gasoline.

North of Kemmerer no prospecting for oil was carried on during the oil excitement in southern Uinta County. Oil discoveries have been reported, however, at various times from several localities along the east front of Absaroka Ridge and from Green River basin east of Meridian Ridge and Thompson Plateau. Considerable excitement was caused during the summer of 1907 by the discovery of oil east of Labarge Ridge in T. 27 N., R. 113 W. Numerous placer claims were soon staked out over the country between Labarge Ridge and Green River. Plans were outlined to prospect this region by churn- and diamond-drill borings during the coming season. While visiting the Labarge Ridge locality in September, 1907, the writer had an opportunity to examine this field hurriedly and collect a sample of oil from one of the shallow prospect wells shown on the accompanying map (Pl. IV).

LOCATION AND TOPOGRAPHY.

The Labarge oil field lies along the east base of Labarge Ridge and extends from Labarge Creek northward to the vicinity of South Piney Creek in T. 28 N., R. 113 W. (See Pl. IV.) The greater portion of the area forms a plain sloping gently eastward toward Green River.

[a] Bull. No. 3, Petroleum series, School of Mines, Univ. Wyoming, 1899.

[b] Bull. U. S. Geol. Survey No. 285, 1906, pp. 342-353; Prof. Paper U. S. Geol. Survey No. 56, 1907, pp. 139-162.

Tertiary topography, with its characteristic mesas and highly colored escarpments, is prominent in the western half of the area and along part of Green River. On the west the area is bounded by Labarge Ridge, which forms a prominent range 500 to 1,500 feet higher than the adjacent country and attains an elevation of 9,200 feet at several points along its crest. The topographic features of this range, which is composed of Carboniferous, Devonian, and Cambrian rocks, afford a marked contrast to those of the Tertiary beds east of the range. For a brief description of the surface features of the region west of Labarge Ridge, the reader is referred to a preliminary report[a] on the coal in central Uinta County.

GEOLOGIC SUCCESSION.

The succession of the Tertiary and Cretaceous rocks in this general region, together with their economic importance, is given in the accompanying table.

Only a part of the geologic section is exposed in the Labarge Ridge locality. The beds composing that ridge consist of "Upper Cambrian," Devonian, and Carboniferous rocks, and east of the ridge are small exposures of Adaville and Hilliard beds, covered throughout the greater part of the region by the nearly horizontal Tertiary strata.

Generalized section of Tertiary and Cretaceous rocks in central Uinta County, Wyo.

System.	Group.	Formation.	Thickness (feet).	Characteristics.	Economic value.
Tertiary.	Green River.	Green River.[b]	200	Thin-bedded shales, sandstones, and limestones, for the most part light colored.	
	Wasatch.	Knight.	c 500	Beds of red and yellow sandy clays interlaminated with white, gray, and yellow sandstones. Local areas of concretionary limestone.	East of Labarge Ridge yields oil which has probably risen from underlying Cretaceous beds.
		Unconformity.			
		Almy.	500	Red and yellowish-white conglomerates, sandstones, and sandy clays.	
	Upper Laramie.	Evanston.[c]	9,500	Gray and yellow shales and clays, with gray and yellow sandstone beds, containing several minor coal beds, none of which are developed. Same age as the Almy coals near Evanston, Wyo.	**Coal bearing.** Several minor coal beds of workable thickness have been observed. None have been prospected or developed. Coal similar to the Evanston and Almy coals of southwestern Uinta County.
		Unconformity.			

[a] Schultz, A. R., Bull. U. S. Geol. Survey No. 316, 1907, p. 212.

[b] Estimate of Clarence King of maximum thickness in Green River basin southeast of this region is 2,000 feet; only a portion of the beds occur in this area.

[c] Upper limit not seen.

Generalized section of Tertiary and Cretaceous rocks in central Uinta County, Wyo.—Con.

System.	Group.	Formation.	Thickness (feet).	Characteristics.	Economic value.
Cretaceous.	Lower Laramie.	Adaville.	2,800	Gray, yellow, and brown clays and shales with irregularly bedded brown and white sandstones and numerous beds of coal. The lower beds of this formation contain plants and invertebrate remains that are referred to the uppermost Montana; the upper beds contain lower Laramie leaves.	**Prolifically coal bearing** throughout. A few prospect pits only are opened in this area. At Sayle's mine a 180-foot tunnel has been opened in a 6-foot bed and considerable coal mined for local use. Several other mines supply coal for ranch use.
	Montana.				
	Colorado. Niobrara.	Hilliard.	3,000	Gray and black sandy shales and shaly sandstones that weather readily and afford few exposures. Usually a region of low relief.	
	Colorado. Benton.	Frontier.	2,400 to 3,800	Alternating beds of gray and yellow clays, shales, and sandstones containing numerous beds of coal. Forms pronounced ridges or hogbacks in southern part of area east of Absaroka Ridge. Near top of formation is a pronounced bed of coarse sandstone, locally conglomeratic, containing numerous large oysters. This is the Oyster Ridge sandstone. Farther north this formation loses its characteristic hogback topography.	**Prolifically coal bearing** throughout the area. Farther south the Kemmerer, Willow Creek, Carter, and Spring Valley coals have been developed. The Kemmerer coals are extensively mined at Frontier, Diamondville, Oakley, Glencoe, and Cumberland. Within this area only Wright's mine and a few prospect pits have been opened, the coal being supplied to ranchers. Contains good building stone.
		Aspen.	1,200 to 1,800	Gray and black shales, shaly sandstone, and beds of compact gray sandstone and bluish limestone containing fish scales; commonly weathers silver-gray and shows little white specks in some of the sandstones.	**Oil bearing.** Contains oil developed in wells northeast of Spring Valley, and probable source of oil in Hilliard, Carter, and Fossil oil springs and in springs north of Kemmerer and in vicinity of Labarge Ridge.
	Bear River.	Bear River.[a]	800 to 1,500	Black shale, shaly sandstone, and shaly limestone with abundant invertebrate fossils. Several thin beds of coal and bituminous shale.	**Coal bearing.** Coal beds so far as noted are too thin and impure to be of any value. **Oil bearing.** Oil in this formation southeast of Spring Valley in two wells.

[a] The Bear River beds are underlain by marine Jurassic. The beds appear to be conformable. Other evidence seems to indicate that an unconformity exists between the Bear River and Jurassic beds.

STRUCTURE.

The east base of Labarge Ridge, or the eastern boundary of the Paleozoic rocks, marks the location of an overthrust fault, which here brings "Upper Cambrian" beds in contact with Montana shales and sandstone. East of the fault lies the axis of a low anticline. This axis was observed in the cretaceous beds east of Labarge Ridge in T. 28 N., R. 113 W. The dips on both sides of the anticline are from 20° to 35°. Within a short distance to the south all traces of the east limb of the anticline in the Cretaceous beds are lost beneath the Tertiary beds, which here dip toward Green River at approxi-

mately 5°. The beds along the west limb of the anticline are exposed at several localities and dip at 20° to 45°, N. 70° W. The southward extension of the anticlinal crest may be represented by the low arch seen in the Tertiary beds in the southern portion of T. 27 N., R. 113 W.

OCCURRENCE AND ORIGIN OF THE OIL.

The oil-bearing shale of southern Uinta County does not outcrop in the Labarge Ridge locality. The oil, however, in this field is believed to come from the same horizon as in southern Uinta County, namely, that of the Aspen (Benton) shale. None of the natural oil springs in southern Uinta County occur along the outcrop of the shale that supplies the oil in the Spring Valley wells. So far as field observations have been made, no trace of oil was seen anywhere along the outcrop of the Aspen shale. The springs are all in the region of profound disturbance along the Absaroka fault and its associated secondary faults. The oil springs of Hilliard Flat, the Carter oil spring, and the seepage near the west end of the Aspen tunnel are located along a secondary fault, but those on Twin Creek lie along the line of the main fault. The oil observed at all these springs probably represents leakage from the oil-bearing shale along the fault line, having been forced up through the water which has penetrated to this shale along the fault contact.

North of Hams Fork oil indications have been observed at several places along the east base of the Absaroka and Salt River ranges, near the fault line. Oil was observed on the water along some of the streams tributary to Fontenelle Creek. In Pomeroy Basin oil indications were observed on the water in a number of marshes, in quaking asp groves and low depressions. It is reported that about 12 miles north of Kemmerer, along Mammoth Hollow, there is a spot where gas makes its escape and on a damp morning can readily be detected by its rank odor. Indian tradition has it that many years ago there used to be near this same locality an oil spring from which oil flowed. No trace of this spring was seen during the course of the writer's work. However, owing to the heavy covering of talus and timber in this vicinity, as well as to the numerous springs that rise on the mountain sides or flow from snowbanks near the crest of the range, traces of oil are not so readily seen or recognized as in the southern part of the county. In the northern part of the field examined in 1906, about 2½ miles west of Snake River, along the north line of T. 39 N., R. 116 W., oil was observed on the water and in footprint depressions. The oil seen here has a distinct odor and a greasy feel.

Farther north in Idaho, east of the Pierres Hole (Big Hole) Mountains, W. E. McDonald observed strong surface indications of the presence of oil in the vicinity of David Breckenridge's ranch and

later vigorously prosecuted the work of boring for oil on this ranch. So far as the writer was able to learn, Mr. McDonald struck a 10-foot bed of coal at a depth of 650 feet, but found nothing in the way of oil that indicated values.

Although no prospecting, drilling, or development work has been done north of Kemmerer on the oil-bearing Aspen and Bear River shales to determine whether they contain as much oil as the beds at Spring Valley, their occurrence throughout this region, east of the Absaroka and Salt River ranges and east of the Wyoming Range, is certain. They extend from Spring Valley in southern Uinta County to Snake River in northern Uinta County, and it is not improbable that they contain oil throughout this area in much the same abundance as has been found in the southern part of it. The approximate distribution of these oil-bearing shales can be inferred on consulting the map accompanying the preliminary report on the coal fields in a portion of central Uinta County,[a] as they occupy a narrow belt along the east side of the areas mapped as containing Frontier coals. No oil is found along the outcrop of these beds so far as observed. This fact, however, does not prove that oil is not present, as the oil near the surface may all have escaped or settled toward the synclinal axis, so that it is not noticeable on the surface.

In the vicinity of Spring Valley,[b] the only locality where the Aspen shale has been developed, the oil is found in sandy layers in a black shale near the base of the formation. Failure to obtain oil in this locality has been recorded in three types of wells—(1) those not deep enough to reach the oil-bearing beds; (2) those which on account of irregularities of the sandy layers in the Aspen (Benton) shale fail to produce oil, although oil is present in adjacent wells; (3) those located on the outcrop of the shale, particularly near the lower or eastern edge, where the bed is less than 500 feet thick. Although in general no oil is found along the outcrop of the oil-bearing shale, the amount increases down the dip. The conditions of the oil problem in the Spring Valley locality as well as in much of the territory north of that place, can best be set forth by the following statement:[c]

> The oil-bearing beds are entirely dry when the oil is pumped out of the wells; no water follows. Water occurs in the overlying Wasatch beds and in the sandstones of the Frontier formation, and is also reported in a sandstone several hundred feet below the main oil sands, as in the Jager well and the Consolidated Oil Company well. The occurrence of large quantities of water in the Bettys well and the Baker well has been regarded by some as affecting the oil situation, but the water-bearing beds here are in no way connected with the oil-bearing strata. The anticlinal theory, according to which oil accumulates by floating upon water on the flanks or crests of

[a] Schultz, A. R., Bull. U. S. Geol. Survey No. 316, 1902, p. 212.

[b] Veatch, A. C., Bull. U. S. Geol. Survey No. 285, 1906, pp. 342-353; Prof. Paper U. S. Geol. Survey No. 56, 1907, pp. 143-144.

[c] Veatch, A. C., Geography and geology of southwestern Wyoming: Prof. Paper U. S. Geol. Survey No. 56, 1907, p. 158.

anticlines, does not seem to apply to this field, for one of the essential factors in the theory—the water in the oil-bearing sand—is not present. The absence of water in the oil-bearing sands, together with the fact that springs do not occur along the outcrops of the beds and the irregularity shown in the position of the oil-bearing sands in adjoining wells, suggests that the oil has been formed from the shale in which it is found and that the oil-bearing shales represent local sandy layers more or less perfectly surrounded by shale in which the oil has accumulated. This is the case also in the Boulder and Florence fields, although at those localities the shales are geologically younger. In the absence of water, oil tends to move down the dip and, so far as the continuity of the porous beds will allow, to collect in the troughs of the synclines. This is apparently the case in this field, and the position of this syncline and the depth of the oil-bearing shale at its lowest point then become matters of considerable economic importance.

Because of the rising and pitching of the Lazeart syncline, the oil-bearing shale in the synclinal trough lies at various depths below the surface along the axis. In a part of the region the depth of the oil-bearing shale along this axis is practically prohibitive to development work. However, the soft character of the beds suggests that the pressure of the superincumbent rocks may be great enough to practically close the pore space, so that the maximum accumulation of oil may be found at some point on the limb of the syncline, between the axis and the outcrop. In the vicinity of the fault, where the oil beds are at great depth, the oil leakage along the fault contact may be partly cut off for the same reason and the oil may be stored on the limb of the syncline. If the above-outlined conditions are true, prospecting in much of this field should be restricted to the shallow portions of the synclinal basin and to the region between the axis of the syncline and the outcrop of the oil-bearing shale on the west flank of the Meridian anticline, as the depth of the oil-bearing shale along part of the axis of the syncline is practically prohibitive to profitable development.

One of the most favorable localities for oil prospecting is in the vicinity of Wright's ranch, in T. 23 N., R. 116 W., where the oil-bearing shale lies from 2,500 to 4,000 feet below the surface along the center of the syncline. Almost as favorable a locality is that along Fontenelle Creek, near the north end of the Lazeart syncline. The depth of the oil-bearing shale in the center of the syncline is such that wells could be readily sunk, and test holes in this region are likely to yield results. Similar results may be expected in the synclinal trough that crosses Little Greys and Snake rivers in the northern part of the field.

In southern Uinta County the well of the Pittsburg-Salt Lake Company, in sec. 10, T. 14 N., R. 118 W., developed an oil-bearing bed in the lower part of the Bear River formation.[a] The oil is black and more in the nature of a lubricating oil than that of the Aspen shale.

[a] Veatch, A. C., Geography and geology of southwestern Wyoming: Prof. Paper U. S. Geol. Survey No. 56, 1907, p. 159.

Although the Bear River formation extends throughout this area, lying conformably below the Aspen shale in a narrow belt along its east side, nothing further was learned about these oil-bearing beds. At no point within this field have wells been drilled to test the oil-bearing properties of either the Aspen or the Bear River shale.

East of Labarge Ridge no outcrop of Aspen shale was seen. The oil springs observed in this locality resemble those in the Fossil region in that the strata around the springs belong to the Tertiary. The Wasatch beds here lie in a gentle anticline, with dips of about 5°, and may represent the southern continuation of the anticline above mentioned at the north end of Labarge Ridge. It is believed that the oil comes from the Aspen shale, which here lies from 2,000 to 4,000 feet below the surface. The oil is probably forced up through the water which has penetrated to the oil-bearing shale along the fault east of Labarge Ridge, and escapes at various points along the fault line. Part of the oil may be collected along the low anticlinal crest in the fairly waterlogged beds of the Wasatch and makes its escape into the valley where the oil prospects are located.

Whether the oil-bearing sands in this locality are dry like those at Spring Valley, or whether there is sufficient water present to float the oil and make it accumulate on the crests of anticlines, can not be determined until drill holes are put down to the oil horizons. The success of much of the future prospecting depends on this factor, the correct determination of which becomes therefore a matter of considerable economic importance. If the anticlinal theory of oil accumulation applies here drilling should be done along the anticlinal axis east of Labarge Ridge; on the other hand, if the rocks are dry the oil has collected in the troughs of synclines and prospecting should not be carried on along the anticlinal crest. If the synclinal occurrence prevails here the conditions in the Labarge oil field are manifestly more unfavorable for the accumulation of oil in commercial quantities.

QUALITY OF THE OIL.

All of the oil obtained from springs in southern Uinta County is a dark, heavy oil which may have been derived from the Aspen shale oils by the evaporation of the more volatile portions. Slosson[a] gives the gravity of the Carter oil as 21.5° Baumé and that of the Fossil or Twin Creek oil as 19.7° Baumé. The gravity of the Fossil oil is given by the Union Pacific Railroad[b] as 26.75° Baumé. The results of analyses of the Spring Valley petroleum and a sample collected from a shallow well about 3 feet square and 6 feet deep, sunk near the center of a drain about 4 miles east of Labarge Ridge, are given below. The

[a] Slosson, E. E., Bull. No. 3, Petroleum series, School of Mines, Univ. Wyoming, 1899, p. 31.
[b] Mineral Resources U. S. for 1885, U. S. Geol. Survey, 1886, p. 154.

latter sample was taken from an open pit which contained more than a foot of dark-colored, heavy oil. Considerable oil was taken from this pit during the summer by various persons who visited the region. The oil was also used by the ranchers in Green River basin as machine oil and proved highly satisfactory. It did not rise to the surface, but appeared to drain into the soil that filled the valley. At several points in the valley oil was encountered by sinking shallow wells a few feet into this soil.

Tests of oil from well of Pittsburg-Salt Lake Oil Company in sec. 22, T. 15 N., R. 118 W., 1 mile north of Spring Valley.

[By C. F. Mabery, Cleveland, Ohio, 1906.]

Temperature (°C.) at which gas was given off on distillation.	Percentage.	Gravity (°Baumé).	Nature of product.
50–150	21.3	65	Gasoline.
150–305	39.7	44	Burning oil.
305–350	16.4	36	Gas oil.
350–380	15.4	37	Oil partlycracked.

Residue, 7.2. Specific gravity, 0.81,=44° B. The oil begins to crack at 350°; of course this product is really gas oil. The distillates at 305°–350°, 350°–380°, and the residue contain much paraffin. These oils become solid when cooled in tap water with paraffin, so the yield is large. We refined some of the burning oil, not, however, with reference to flash or complete absence of color; it refines very easily, and gives a very fine grade of burning oil. Of course the proportions of products will be somewhat different on a refining scale (1,000 barrels)—probably larger, rather than smaller, than is given on the small scale. This petroleum is different from any of the numerous specimens that I have previously examined from Wyoming. A large amount of very light gasoline can be separated by strong cooling. With respect to the large proportion of gasoline and of burning oil, also of paraffin, this petroleum is one of the most valuable that I have ever examined. It is a nonsulphur oil; percentage of sulphur, 0.03.

Test of oil from shallow pit east of Labarge Ridge, Green River basin, in sec. 34, T. 27 N., R. 113 W.

[By Dr. David T. Day, United States Geological Survey, January 8, 1908.]

Temperature (°C.) at which gas was given off on distillation.	Percentage.	Specific gravity.	Nature of product.
Below 150	Trace.		
150–300	34	0.891	Suitable for burning.

Specific gravity of the original oil, 0.9435=18.75° Baumé. The oil was collected from seepage into a shallow well. It had evidently suffered oxidation, as shown by the considerable amount of resins contained. These resins made it difficult to completely separate water from the oil. The distillation was, therefore, slow and somewhat unsatisfactory. There is no indication of sulphur in the oil, no quantitative test being obtained by oxidation, and there is no odor of sulphur.

The specific gravity of the oil suitable for burning was so high that this portion was treated with sulphuric acid to determine whether the oil consisted of hydrocarbons of the paraffin (Pennsylvania) series. The amount absorbed by sulphuric acid was

not abnormally large, and left a pleasant-smelling, refined product. The examination of the residue not distilling below 300° was extremely interesting. In addition to an oil soluble in cold alcohol, probably plain paraffin hydrocarbons, it gave a considerable amount soluble in boiling alcohol, which should have consisted entirely of paraffin wax, but did consist to a large extent of resins entirely absorbed by strong sulphuric acid, and giving evidence of being terpenes. The portion insoluble in boiling absolute alcohol, which should consist ordinarily of asphalt, gave, instead of the usual hard black asphalt, a soft sticky material characteristic of the transition stage of resins into asphalt.

While the oil has suffered too much oxidation to be interesting from the refiner's standpoint, it is extremely interesting scientifically, on account of the effects of the oxidation, showing, as given above, the intermediate stage between oil and ordinary hard asphalt.

SURVEY PUBLICATIONS ON PETROLEUM AND NATURAL GAS.

The following list includes the more important papers relative to oil and gas published by the United States Geological Survey or by members of its staff. Certain of the geologic folios contain references to oil, gas, and asphaltum; when these commodities are of importance in a particular area, they are listed in italics (pp. 9–11).

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BOUTWELL, J. M. Oil and asphalt prospects in Salt Lake basin, Utah. In Bulletin No. 260, pp. 468–479. 1905.

CLAPP, F. G. The Nineveh and Gordon oil sands in western Greene County, Pa. In Bulletin No. 285, pp. 362–366. 1906.

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FULLER, M. L. Asphalt, oil, and gas in southwestern Indiana. In Bulletin No. 213, pp. 333–335. 1903.

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——— Structural work during 1901–2 in the eastern Ohio oil fields. In Bulletin No. 213, pp. 336–344. 1903.

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ASPHALT.

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