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OIL POSSIBILITIES IN AND AROUND BAXTER BASIN, IN THE ROCK SPRINGS UPLIFT, SWEETWATER COUNTY, WYOMING

BY

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OIL POSSIBILITIES IN AND AROUND BAXTER BASIN, IN THE ROCK SPRINGS UPLIFT, SWEETWATER COUNTY, WYOMING.

By Alfred Reginald Schultz.

INTRODUCTION.

PURPOSE OF THE REPORT.

The following preliminary report has been prepared in order to make public certain data bearing on the presence of oil in Baxter Basin, in the Rock Springs uplift, in Wyoming, and on the occurrence of oil shale around the uplift. These data were collected by the writer and his assistants in 1907 and 1908 while they were mapping the coal beds in the Rock Springs field. Preliminary reports on the northern and southern parts of the Rock Springs coal field were published in 1909 and 1910.[1] It was the writer's intention at that time to prepare a preliminary report on the possibility of obtaining oil in Baxter Basin as well as a complete report on the geology, structure, and economic deposits of the Rock Springs field. A trip to South America in 1910 and other Survey work made it impossible to prepare these reports, so that much of the information obtained in the field in 1907 and 1908 has therefore not been made public.

As the stratigraphy and structure in Baxter Basin are favorable to the accumulation of oil and gas, if these substances were originally present in the strata, and as this favorable structure is well shown on the maps accompanying the two reports above mentioned and on the maps accompanying the report of the Fortieth Parallel Survey,[2] the Geological Survey frequently receives requests for information concerning the possible occurrence of oil and gas in that basin. In view of this demand for information and in view of the fact that oil companies are again drilling for oil at several places in the basin, the information on file in the Survey is here made available to all who may be interested in this field. A brief summary is also given of the occurrence of oil shale in the late Tertiary beds

[1] U. S. Geol. Survey Bull. 341, pp. 256–282, 1909; Bull. 381, pp. 104–186, 1910.
[2] U. S. Geol. Expl. 40th Par. Rept., vol. 1, 1878.

around the greater part of the Rock Springs uplift, particularly that part of it which surrounds Baxter Basin, as well as a review of some facts which indicate that the central area of the Rock Springs uplift probably contains oil and gas.

LOCATION OF THE FIELD.

The Rock Springs uplift is in Tps. 13 to 25 N., Rs. 98 to 106 W. sixth principal meridian, in the central part of Sweetwater County, Wyo., on the east side of Green River, in the southern part of the

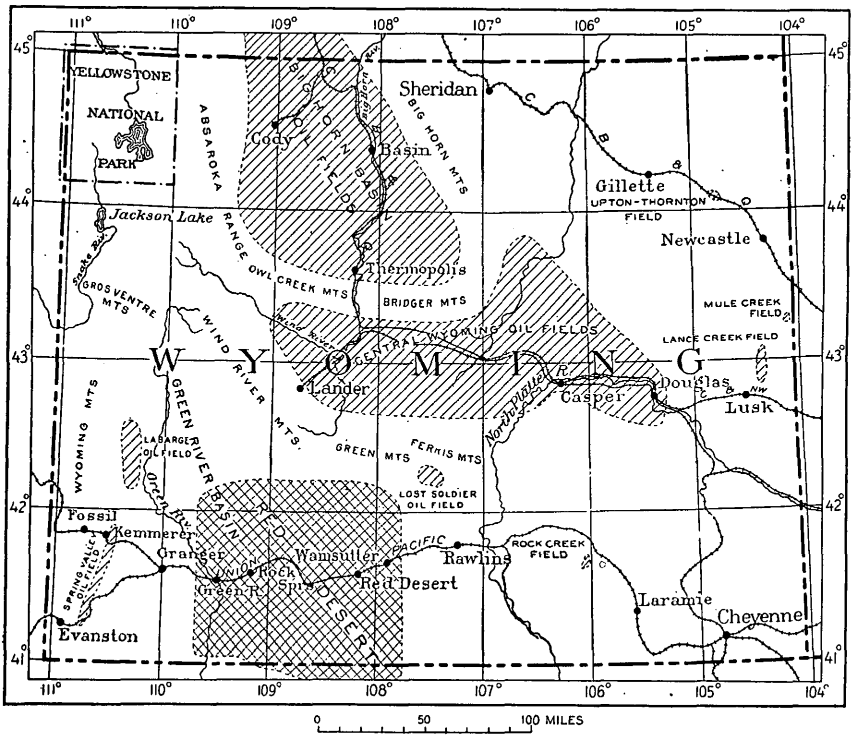


FIGURE 1.—Index map showing location of Rock Springs uplift (area shown by cross-hatching), Sweetwater County, Wyo.

State, the south end of the field being only a few miles north of the Wyoming-Colorado State line. (See fig. 1.) It lies at the crest of a low structural dome in the Great Wyoming Desert, in the eastern part of the Green River Basin. The rim of Tertiary beds that lies within this eroded dome forms a natural boundary that defines the outcrops of the older and the newer rocks. The beds of oil shale are found in the upper part of the Tertiary beds that form this rim, and search for oil and gas should be made in the rocks of the central part of the low structural dome—that is, in Baxter Basin, in Tps. 16 to 21 N., Rs. 103 and 104 W.

The entire uplift lies in the drainage basin of Green River, and the south end of the dome is only 12 miles north of the north flank of the Uinta Mountains. The central part of the dome—Baxter Basin—lies entirely within the drainage basin of Bitter Creek, a tributary of Green River from the east, and the south end of the basin is approximately 25 miles north of the Uinta Mountains.

The easiest line of approach is along the Union Pacific Railroad to Rock Springs, Wyo., thence by private conveyance over wagon roads that run directly east and southeast to Baxter Basin. The country as a whole is open and easily accessible, but there has been little travel in the region except along the main roads leading from Rock Springs, most of which run along Bitter Creek valley and the larger valleys tributary to Bitter Creek.

The Union Pacific is the only railroad that crosses this area, and nearly all points in the Rock Springs field are readily accessible from the main line. Several projected lines have been surveyed across the north end of the uplift, but no company has yet begun active construction along these routes. The location of the Union Pacific Railroad places it in a position to control the future development of the field. The grade along its line is moderate, and by short spurs with light grades, similar to those of the Superior, Gum, Reliance, and Sweetwater branches, it will be comparatively easy to reach all points at which oil, oil shale, and gas may be developed. For the southern half of the field the most accessible routes lie along the main tributaries of Bitter Creek—Little Bitter, Killpecker, and Salt Wells creeks and their tributaries. Spurs built up any of these valleys would be natural feeders to the trunk line along Bitter Creek.

HISTORY OF OIL PROSPECTING.

Very little oil prospecting has been done within the area of the Rock Springs uplift or within Baxter Basin. The geologic structure, however, has long been regarded by oil men as favorable for the accumulation of oil and gas. The preliminary surveys of this region made by the Government for the purpose of locating a practicable route for one of the transcontinental railroads culminated in the organization of the Fortieth Parallel Survey, which mapped the region along this route in 1876. The early work of King and his associates in that survey clearly indicated the favorable structure in the Rock Springs uplift. Upon the completion of the Union Pacific Railroad in this region, in 1868, active development of its mineral resources began. The work was, however, restricted almost entirely to coal, the output of which increased from 22,329 tons in 1869 to 2,969,601 tons in 1912. This area was rapidly converted into one of the most important coal-mining centers in the West, and the necessity for homes for thousands of miners and their families led to the building of small towns along the railroad line and the encouragement of agricultural pursuits wherever feasible. Although transportation facilities made access to the field easy, and an admirable view of the geologic structure favorable for the accumulation of oil and gas was furnished from the car windows of the passenger trains, no endeavor was made to find oil or gas within the area until 1900.

As early as 1888 Louis D. Ricketts, territorial geologist of Wyoming, stated in his annual report to the governor that he understood that there were oil indications in the Eocene rocks along the Union Pacific Railroad but that no oil springs had been developed in Sweetwater County.

Active prospecting for the purpose of discovering oil in the Rock Springs uplift was undertaken in 1900 by two companies, both of which partly tested the area in Baxter Basin a few miles east of the town of Rock Springs. Two wells were put down by George B. Harmon for the National Exploration & Drilling Co., which represented Belgian and American interests. One of these wells No. 44, was in the SW. ¼ SE. ¼ sec. 8, T. 19 N., R. 103 W., a short distance north of the Union Pacific Railroad track about halfway between Baxter and Salt Wells station. This well is reported to have reached a depth of 2,300 feet and to have found some gas but no oil or water. The other well drilled by this company (No. 46) is in the SW. ¼ SE. ¼ sec. 17, T. 18 N., R. 104 W., at Sixmile Spring, approximately 5 miles in a straight line southeast of Rock Springs. This well is reported to have been drilled to a depth of 2,400 feet, but it did not reach as low a stratigraphic horizon as the other well, which was started in beds approximately 2,000 feet lower in the geologic section. The Sixmile Spring well is reported to be 13 inches in diameter. It passed through water-bearing beds at depths of 30 and 90 feet and yielded a small showing of oil at 625 feet, which was probably obtained from beds near the top of the shale group exposed in Baxter Basin. Neither of these wells, however, has adequately tested the possibility of obtaining oil in the Baxter Basin anticline, and they do not vitiate the conclusion that the structure and geologic conditions here are favorable for the development of a large oil pool.

Several other wells were drilled about this time in Baxter Basin south of Bitter Creek, in the bench lands between Baxter and Salt Wells station, several miles southeast of the well in sec. 8, T. 19 N., R. 103 W., mentioned above. One of these wells, No. 45, is in the SW. ¼ NW. ¼ sec. 22, T. 19 N., R. 103 W. It is reported that none of the wells in this vicinity were drilled as deep as the one in sec. 8 or the Union Pacific well at Salt Wells station. The drill passed through nothing but shale similar to that exposed in the anticline south of Baxter station. According to reports, these wells encountered a little gas but no oil or water, and they are in every respect similar to the one north of the railroad track, in sec. 8. No oil was encountered in any of the wells in Baxter Basin, and drilling was discontinued without having adequately tested the territory that had for 35 years been considered structurally favorable for the accumulation of an oil pool.

In the last two or three years considerable interest has again been shown by oil men in the Baxter Basin anticline, and drilling is going on in the Dry Lake area, north of Aspen Mountain and approximately 10 miles in a straight line southeast of Rock Springs. Three companies—the Dry Lake Oil & Gas Co., the American Oil Co., and the Midwest Oil Co.—have been actively engaged in drilling wells in this part of Baxter Basin. It is reported that a flow of gas under a pressure of several hundred pounds has been struck and that small quantities of oil have been obtained.

Drilling southeast of Baxter Basin, in the Vermilion Creek country, was reported during the summer of 1915. The exact location of the drilling and the depth to which the rock was penetrated are not known to the writer. The structure is favorable in that vicinity, but the oil sands, if present, lie at great depth. Unless the oil has seeped upward and is now stored in reservoirs near the surface there is not much hope of encountering oil at shallow depths.

LAND SURVEYS.

Most of the area within which the Rock Springs uplift lies was surveyed by the General Land Office between 1875 and 1885. Many of the townships, however, were very poorly surveyed or not surveyed at all before plats were submitted for approval, and some of the land corners were not established or at least not permanently marked so that they could be found when the lands were required for agriculture or mining. The lack of corners and accurate surveys soon led to confusion and litigation, and it became necessary for the Government to resurvey all the area originally covered by public-land surveys. In 1907 and 1908, when the geologic mapping by the writer was done, the townships not previously subdivided by the General Land Office were surveyed, and topographic and township plats were made at the same time. Similar maps and resurvey plats were made of those townships in which the old survey could not be accepted as reliable and in which it was necessary to establish Government corners before the lands could be classified and a valuation placed upon the economic deposits they contained. A considerable tract was resurveyed in this region by the General Land Office in 1906; 24 townships were resurveyed in 1907; and the work was continued in 1908, 1909, and 1910, until all the area within the Rock Springs uplift was resurveyed and authentic corners were established.

Surveys and resurveys made by the General Land Office from 1900 to 1915 cover all the land in southern Wyoming from Tps. 12 to 24 N. and Rs. 101 to 112 W., inclusive. All the township, section, and auxiliary corners established in the resurveys of these townships are well marked, and no difficulty in finding them should be encountered by anyone who is interested in these lands. Many of the corners set by the Government in these resurveyed townships, including all set since August 1, 1907, are marked by iron posts carrying tablets stamped with the designation of the section, township, and range. Corners marked in this manner are of great value to settlers and land purchasers, because they make it possible to locate land accurately and quickly anywhere in the township without the aid of a surveyor.

METHODS OF FIELD WORK.

No unusual method was adopted in mapping the stratigraphy and structure of the Rock Springs dome, and no particular attention was given to the study of the geologic conditions in Baxter Basin with a view of determining favorable oil structure or outlining any secondary structural features. The primary object of the field work in 1907 and 1908 was to obtain data for classifying the coal beds in the Rock Springs uplift, and the detailed work was restricted mostly to the examination of the several coal groups. Data were obtained on the remainder of the field, however, so that complete geologic and topographic maps of each township were made and good vertical and horizontal control was maintained throughout the field.

In 1907 the northern and northeastern part of the Baxter Basin was mapped topographically (contour interval 50 feet) and geologically in connection with the inspection of the resurveyed townships. In the same year and in 1908 certain townships in the northern part of the Rock Springs field and two townships in the southeastern part were mapped topographically (contour interval 50 feet) and geologically in connection with the subdivision of these townships and the preparation of a Land Office plat. All the geologic and topographic locations, as well as the line measurements, were made by stadia. An idea of the accuracy of the location of points of geologic and topographic interest may be gathered from the fact that approximately ninety locations were made in each square mile.

By far the greatest part of Baxter Basin, however, is included in the Rock Springs quadrangle, which was mapped by the United States Geological Survey in the summer of 1908 on a scale of 1 inch to the mile, with a contour interval of 50 feet. Later in the season photographic copies of this base map were used in mapping the geology, formation contacts, and other data of economic importance.

No maps other than township plats were available for field use in the remainder of Baxter Basin or the remainder of the Rock Springs uplift outside of the areas of detailed mapping mentioned above. It was therefore necessary to make topographic maps of these portions of the field as the geologic work progressed. In such territory all ocations—section corners, dip readings, outcrops, faults, and formation contacts, and the like—were made either (1) by pacing section lines or making a traverse from land corners found by such pacing, or (2) by plane-table station work, supplemented by plane-table traverse, triangulation, and intersection, checked and tied to land corners. In areas where no corners could be found plane-table control was used entirely, road and line stadia traverses being made wherever necessary.

Altitudes were carried by stadia, altimeter, Locke level, and aneroid, and all were adjusted to the temporary and permanent bench marks along the line of levels run around the dome from Rock Springs north up Killpecker Valley to Steamboat Mountain, thence south to Point of Rocks, Black Buttes, and around the south end of the dome back to Rock Springs. Lines were run one-fourth to one-half mile apart. The formation contacts, the faults, and the outcrops of all the more important coal beds were traversed, and the traverses were tied to land corners. The field sheets were made on the scale of 2 inches to the mile, with a contour interval of 50 feet, and are on file in the Geological Survey. The maps accompanying the present report have been prepared from the field sheets, and although approximately correct they may differ in minor particulars from the large-scale maps.

TOPOGRAPHY.

GENERAL FEATURES.

The Rock Springs uplift lies along the eastern margin of the Green River Basin and includes on the northeast a part of the Great Divide Basin. It is a low structural dome that divides the nearly horizontal Tertiary beds in this part of Wyoming into two areas—one on the east, the other on the west—in which the topographic conditions are very nearly identical. The older beds exposed in the area of the uplift give rise to topographic features very different and distinct from those produced by the surrounding Tertiary beds, whose topographic features are characteristic of the Green River Basin. Moreover, within the area of the Rock Springs uplift there are five distinct topographic districts, each presenting entirely different characteristics from those of its neighbor. Only the most prominent peaks and ridges on the dome rise higher than the adjacent Tertiary escarpment. The divide between the Green River and Great Divide basins has no topographic identity or distinctness. It lies for the most part several miles east of the dome and is formed in some places of Tertiary rocks, in others of Cretaceous rocks, and in still others of igneous rocks. The divide is irregular, extending across several distinct topographic districts.

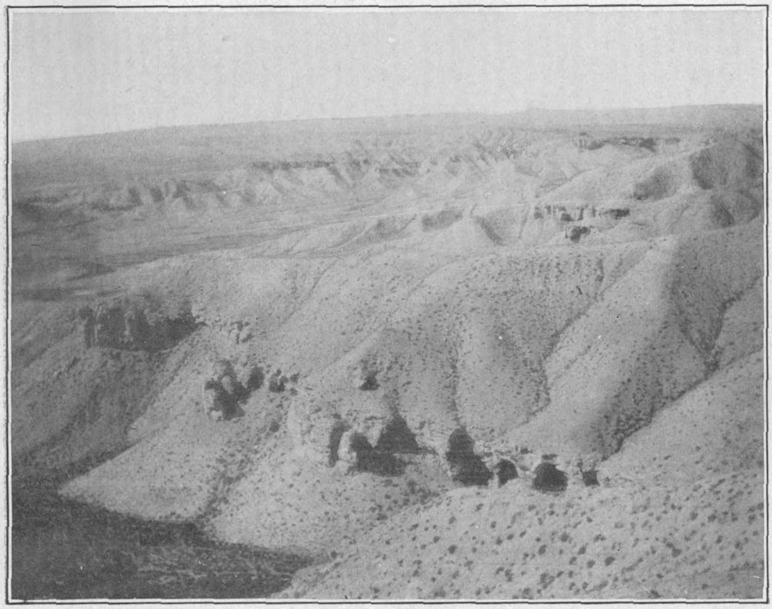
The principal topographic features of this field are due to (1) hard, resistant sandstone and the associated beds of the Mesaverde formation; (2) hard, resistant limestone and sandstone and associated beds of the nearly horizontal Green River and Wasatch formations; (3) migrating sand; (4) soft beds of the Wasatch formation, the Lewis shale (overlying the Mesaverde), and the Baxter shale (underlying the Mesaverde), in the central part of the dome; (5) gravel slopes of the Bishop conglomerate; and (6) igneous rock.

These features are briefly described in the reports cited above, and will not individually be considered further in this report. It seems advisable, however, to give a somewhat more complete statement regarding the relief in Baxter Basin, where prospecting for oil will no doubt be done in the future, and regarding the surrounding Tertiary escarpments and table-like forms in which the oil shale occurs and which in the future will be prospected for these deposits.

RELIEF.

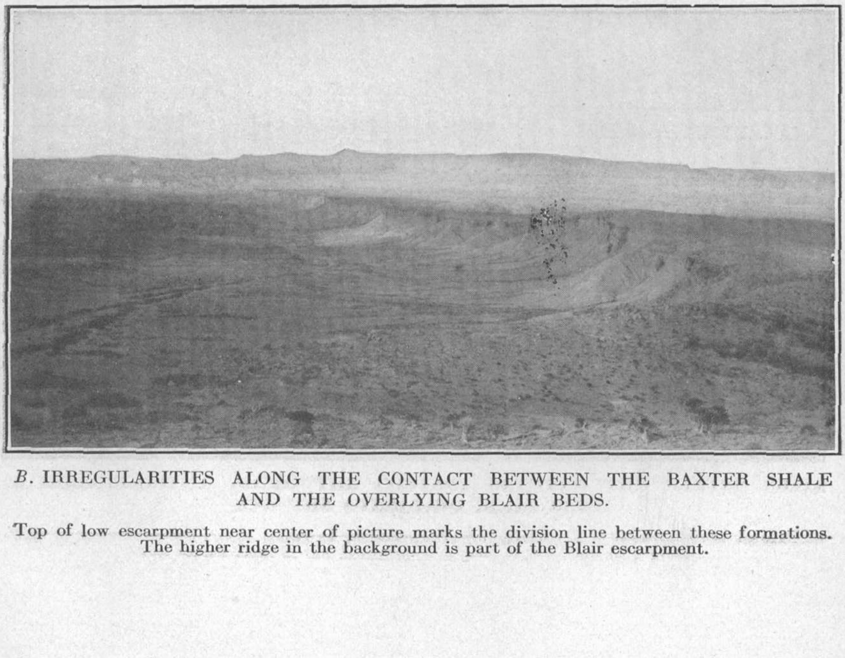
The country along the central part of the crest of the low structural dome in Baxter Basin is barren and desolate. Though it is traversed and cut by numerous valleys and dry gulches the effect of relief is lost in the distance, and the somber color of the treeless hills causes each ridge to merge with the next, forming a broad rolling expanse whose prevailing tones are drab and dark gray. In spite of the fact that the relief is in places from 100 to 300 feet and much of the area is cut into sharp ridges and benches, the general appearance from a distance is that of a vast, broad valley, whose surface is nearly level. The general irregularity of the surface and some idea of the type of topography here encountered are well shown in Plates II and III, *A*, and on the Survey's topographic map of the Rock Springs quadrangle.

Encircling this broad basin and rising above it are bold escarpments formed by the edges of tilted strata of hard, resistant sandstone of the Mesaverde formation. These escarpments are easily recognized and form convenient key rocks by which the geologist can determine relative positions in the stratigraphic section. Some of these ridges contain the most valuable coal beds of the field. They are in general separated from one another and from areas of equally or more elevated younger rocks by belts of low relief. The Mesaverde in this field is divided into either three or four distinct members, the number depending upon the position assigned to the base of the formation. Persons interested in prospecting for oil in Baxter Basin need concern themselves only with the basal member, which is free from carbonaceous matter throughout the field.



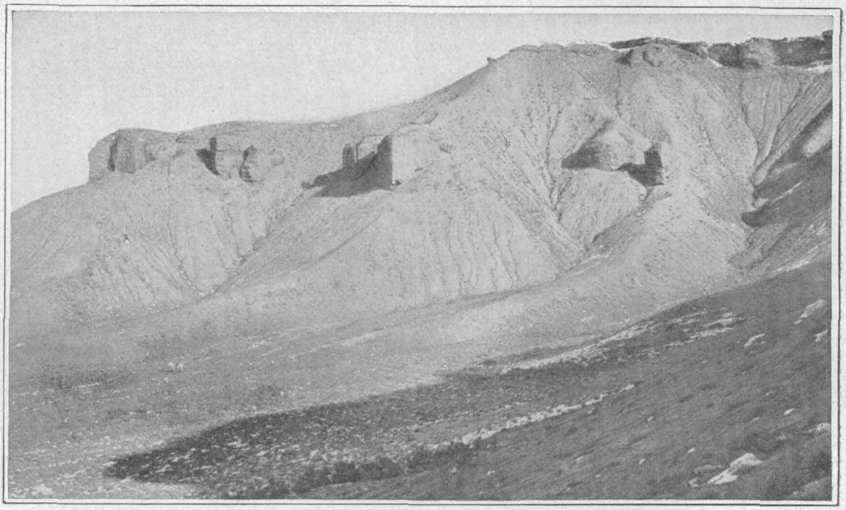
A. TOPOGRAPHY OF BAXTER SHALE AS SEEN FROM THE NORTHWEST CORNER OF SEC. 8, T. 18 N., R. 102 W., LOOKING NORTH.

Note the peculiar type of weathering due to the peculiarities of the shale and shaly sandstone.



B. IRREGULARITIES ALONG THE CONTACT BETWEEN THE BAXTER SHALE AND THE OVERLYING BLAIR BEDS.

Top of low escarpment near center of picture marks the division line between these formations. The higher ridge in the background is part of the Blair escarpment.

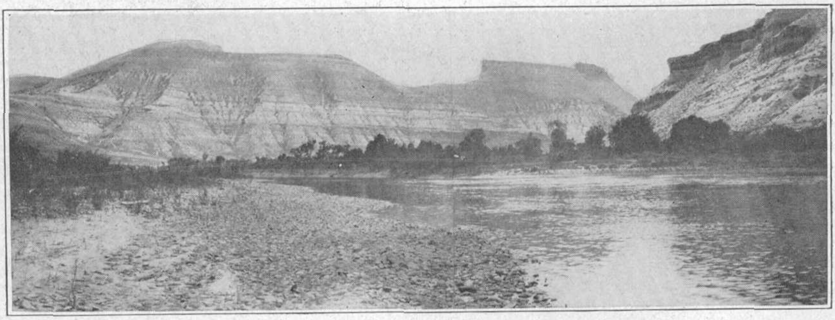


A. TYPICAL WEATHERED SURFACE OF BAXTER SHALE.

Showing the nearly perpendicular faces and the steep slopes of the small ridges and numerous valleys. (See also Pl. II.)

B. ESCARPMENTS FORMED BY THE GREEN RIVER BEDS ON THE EAST SIDE OF THE ROCK SPRINGS UPLIFT.

Top of the highest escarpment is capped by Laney shale. "Tower sandstone" not shown in picture but forms the cap rock at Pine Buttes. Lower escarpment at left of picture is the lower member or Tipton shale. The intervening beds are the Cathedral Bluffs red beds as exposed in Laney Rim, in T. 19 N., R. 96 W.



C. GREEN RIVER BEDS ALONG THE WEST SIDE OF THE ROCK SPRINGS UPLIFT.

Note the contact between the Laney shale and the "Tower sandstone" at right of picture and the peculiar bedding of shales at left of picture. Green River in the foreground in Fivehole Basin, T. 16 N., R. 106 W.

Two pronounced depressions are carved in the soft shale—one in the Lewis shale overlying and the other in the Baxter shale underlying the four sandstone members of the Mesaverde formation—as described in the published reports. These low valleys are natural routes of travel and afford easy access from the railroad to the more rugged ridges lying between them. The shale below the Mesaverde sandstones gives rise to low relief in the central part of the Rock Springs dome and is the chief cause for the development of Baxter Basin, from which it derives its name. The harder rocks over this part of the dome have been removed by erosion, which has thus formed an anticlinal valley. Around this anticlinal valley runs a low escarpment formed by the cut edge of the sandstone member at the top of the Baxter shale, which marks the contact of the shale and the overlying Blair formation. Outside of this and in places fading into it and completely encircling the central area is the escarpment of the Blair formation (described in Bulletins 341 and 381 as the basal member of the Mesaverde formation). Outside of this outer and higher escarpment are other still higher escarpments formed by beds of sandstone stratigraphically above the Blair and separated from each other by valleys and depressions developed in the intervening softer beds.

Within parts of Baxter Basin both north and south of Bitter Creek broad flats and terrace benches have been formed by streams. Similar broad flats are found along Bitter Creek and Salt Wells Creek. On the flat terraces and valley bottoms are two intermittent lakes that cover approximately 100 and 300 acres and often contain water throughout the year. The greater part of the area of the Blair formation, however, is occupied by badlands developed on the shale and on some small intervening areas capped by terrace gravels. The streams have cut deep, narrow valleys in the shale but have not had time to lower the hills between or develop more gradual slopes. As the hills are reduced in height and the valleys widened broad flats like those mentioned above are formed.

DRAINAGE.

The drainage of this area for the most part flows to the Pacific. The main streams are not affected by the Rock Springs dome, which in a way connects the Uinta and Wind River mountains. The most prominent stream in this field is Bitter Creek, which controls the major part of the drainage of the dome. It flows across the central portion of the dome at nearly right angles to the major axis and has carved a broad valley, along which runs the Union Pacific Railroad. The three largest tributaries of Bitter Creek—Killpecker, Little Bitter, and Salt Wells creeks—have been shaped indirectly by the fold. On account of the difference in the hardness of the beds these valleys extend in the main along the strike of the beds and are approximately at right angles to Bitter Creek. In some places, as in the valleys of Salt Wells and Black Buttes creeks, the small streams cut across several of the ridges before joining the main stream, and one of the tributaries of Salt Wells creek cuts three times across a pronounced hogback ridge in the Mesaverde formation 1,000 feet in height instead of following the softer shale along the strike of the beds.

At the south end of the dome the streams do not cut directly across the major axis. Red Creek, on the west side, drains southward into Green River after cutting a channel through part of the Uinta uplift. On the east side of the axis Vermilion Creek flows southeastward, paralleling the Uinta uplift, through the upper half of its course and finally cuts directly across part of this uplift and unites with Green River near the south end of Browns Park. On the west side of the dome between Red Creek and Jack Morrow Creek all the streams not included in the Bitter Creek drainage basin are more or less nearly at right angles to the major axis and flow westward into Green River.

All the area in the northeastern part of the uplift not tributary to Bitter Creek drains to the east, and the water flows into the Great Divide Basin, which includes an area of approximately 4,200 square miles. The divide between these two drainage systems lies along the crest of Cathedral Bluffs or Laney Rim, swings northwestward and crosses the Union Pacific Railroad track just west of Robinson, thence trends in a northwesterly direction to Steamboat Mountain, thence northward to Oregon Buttes and southeast of Pacific, Wyo., where the east and west divides reunite. The location of this divide within the area here mapped may be seen on the accompanying map (Pl. I, in pocket).

In the Great Divide Basin there are numerous small dry lake beds, alkali lakes, and alkali, clay, and red flats, the largest of which is the Red Desert flat, near the center of the basin. In the northern part of the region, within the sand-dune area, there are also numerous small lakes that are fed by melting snow and ice in and beneath the sand dunes. Throughout this region very few rocks are exposed, and the dip slopes are well covered by gravel and loose soil.

In Baxter Basin the principal stream of the Rock Springs region, Bitter Creek, cuts directly across the northern half of the central part of the dome, and all the small streams lying entirely within the basin drain directly into Bitter Creek or Salt Wells Creek, a large tributary from the south that heads near the south end of the Rock Springs uplift, flows north across the eastern part of the basin, and empties into Bitter Creek about halfway between Salt Wells and Baxter stations.

Bitter Creek is the only permanent stream in Baxter Basin. It is reported that during dry seasons even this stream fails to flow throughout its length, but in 1908, when the field examination was made, there was flowing water through the entire distance during the summer. Through much of its course Bitter Creek flows in intrenched ditches that lie from 10 to 15 feet below the flood plains of the stream, so that the small amount of water can not readily be raised to the surface or diverted into ditches.

Salt Wells Creek and some of its larger tributaries have flowing water in the southern part of the Rock Springs uplift, near their headwaters, but in Baxter Basin they flow only in rainy weather, and for a short time thereafter water stands in pools along a dry bed. Salt Wells Creek is therefore mapped as an intermittent stream, although it is of considerable size and flows throughout the year in its upper course.

WATER SUPPLY.

AREA SURROUNDING BAXTER BASIN.

In the greater part of the Rock Springs uplift water for drinking and domestic use is somewhat difficult to obtain. The surface water and that reached by shallow, open wells, or by drilling are both alkaline, and many of the springs contain considerable hydrogen sulphide and mineral matter. So far as ascertained the wells sunk in the alluvium of stream valleys or in the rock to shallow depths are not satisfactory. The water in them is of uncertain quality and very scanty in amount. Most of them yield water that is more alkaline than that of Bitter Creek. It should be possible, however, to supply small temporary mining operations by drilling wells into the underlying sandstone of the Tertiary or Mesaverde formations, both of which contain water under artesian pressure and will yield flowing water in parts of the area. It appears from the records of flowing and other wells at Rock Springs, Superior, Bitter Creek, and other points along the Union Pacific Railroad that water can be obtained in almost any part of the Rock Springs field, outside of Baxter Basin, by drilling to considerable depths. Whether the supply will be large enough to meet the full demand of a mining camp can be determined only by careful and systematic drilling. In many parts of the field, particularly in the Great Divide Basin, water may be obtained by drilling to relatively shallow depths, say several hundred feet, but this water is very likely to be highly alkaline. The water in Bitter Creek, the only permanent stream within this area, can be used but is not altogether palatable. During the summer in dry weather the water is so bad that it is hardly fit for the use of stock. At Rock Springs the water from Bitter Creek and from the mines is used to some extent for stock, but all water for domestic purposes is pumped 15 miles from Green River. The streams are in the main intermittent, springs are comparatively few, and water holes for stock are extremely valuable. Numerous small streams and springs occur on the slopes of the mountains and along the high table-lands adjoining them.

The only part of the Rock Springs uplift that contains numerous permanent small creeks and has a considerable quantity of flowing water lies in the southern part of the area in the vicinity of Little, Miller, and Pine mountains. Most of the lands along these small creeks lie at altitudes of 7,200 to 8,000 feet above sea level and are therefore not favorably adapted to agriculture but are primarily valuable as watering places for stock on the surrounding range. Water becomes scarce toward the north, east, and west from these mountains, and within a few miles all the permanent streams and springs have disapperared and only here and there is a small spring found along a fault line or in a most favorable locality. In the northern part of the field, within the sand-dune area, there are numerous small lakes that are fed by melting snow and ice.

The formation that is most abundantly water bearing and supplies a large amount of the surface water in the southern part of the field is the Bishop conglomerate, which feeds most of the small streams in this vicinity. Springs within and along the base of this formation and in the limestone and sandstone underlying the conglomerate are rather numerous for the semiarid region, and the quality of the water is excellent.

Another stratigraphic position which shows a tendency to develop springs is the boundary between the Wasatch and Green River formations. The springs at this horizon, however, are as a rule rather small and not capable of furnishing a large supply.

Springs within the outcrop of the Mesaverde formation are as a rule located along fault lines and furnish a very meager supply. The sandstones of the Mesaverde, however, are capable of yielding large quantities of water, as shown in the mines at Rock Springs, Sweetwater, and Superior. Flowing wells have been obtained from beds in this formation at Point of Rocks, Superior, Rock Springs, and Sweetwater, and similar flows can no doubt be obtained from these beds in many other parts of the field. At one time the city of Superior attempted to get a sufficient supply of water from this source for all city and domestic uses. Whether a satisfactory water in sufficient quantities for this purpose was obtained is not known. Several flowing wells supplying water of good quality were drilled in 1908. Prior to this time water from a small spring was used in part for watering stock, but all the water used by the miners, as well as that used by the town, was shipped in large tanks by rail from Green River. Drilling for water was being conducted systematically at Superior, with the hope of getting an abundant supply of good artesian water from the sandstones of the Mesaverde formation. The first flowing water in this vicinity was obtained in the valley just north of the depot in the course of prospecting for coal with a diamond drill. The water-bearing sandstone at this place gave promise of a source of water sufficient to meet the full demands of the mining camp. Considerable water was also obtained from the white sandstone of the Mesaverde in the vicinity of Emmons Cone, a few miles north of Superior. For deep wells the Mesaverde is the most promising formation and the one most likely to yield a flow. Wells drilled into this formation where it dips away from the central part of the dome should furnish an abundance of water. Whether this water will be suitable for all economic and domestic purposes or be too alkaline to be serviceable is not known at present. The yield and supply of water no doubt will be of about the same grade as that obtained in the wells already drilled at Rock Springs and other places in the field.

AREA WITHIN BAXTER BASIN.

Water for drinking and domestic use is much more difficult to obtain in Baxter Basin than in the area surrounding the basin. The flow of Bitter Creek within this area is much the same as elsewhere along the stream. The water, however, is not fit for domestic or boiler use and at certain times of the year is not very satisfactory for stock. The water flows in intrenched ditches 10 to 15 feet below the flood plain, so that it is difficult to get at and can not readily be raised to the surface or diverted into ditches. Even if the water were raised and diverted into ditches it would soon disappear in the porous sands and clays of the valley, and the entire supply would not be enough to irrigate successfully a single 40-acre tract. Furthermore, the water contains so much alkali that it is not suitable for agriculture.

At the south end of the basin, in the vicinity of Aspen Mountain, where a considerable area of the table-lands is covered by the Bishop conglomerate, a number of springs and small streams occur in the deep, narrow valleys heading on the mountain side. Springs are also found along the contact of the Bishop conglomerate and the underlying formation. The water from these sources is excellent for domestic use and is similar in every respect to that of the area in the vicinity of Little, Miller, and Pine mountains, described above.

The only other water found in Baxter Basin is in sink holes along Salt Wells Creek, where rain water collects during wet weather, and in two intermittent lakes, one north of Bitter Creek in T. 19 N., R. 103 W., the other south of Bitter Creek in T. 18 N., R. 103 W. During wet seasons water stands in these lakes for a considerable part of the year. The water is not satisfactory, however, and can not be depended upon as a source of supply. Baxter Basin is therefore without water facilities except along Bitter Creek and a small area in the vicinity of Aspen Mountain. No water can be obtained by drilling shallow wells in the shale, and all the water used for domestic purposes as well as for drilling must therefore be hauled or piped from the surrounding area. Some of the sandstones of the Colorado group and the Beckwith formation are capable of furnishing large supplies of water, and it is highly probable that flowing water can be obtained from these beds in the central part of Baxter Basin in wells drilled sufficiently deep to tap them.

GEOLOGY.

STRATIGRAPHY.

GENERAL SECTION AND CORRELATION.

The rocks exposed in the Rock Springs uplift range in age from Montana to late Tertiary or early Quaternary. Beds older than Montana are exposed along the east and north flanks of the Uinta Mountains in the vicinity of Vermilion Creek and Henrys Fork, approximately 30 miles southeast and 40 miles southwest, respectively, of the southern part of the Rock Springs uplift; to the west along the Meridian anticline, in western Wyoming, about 70 miles west of Rock Springs; and to the east along the Rawlins dome, approximately 100 miles east of Rock Springs, or 60 miles east of the eastern margin of the Rock Springs uplift. In these fields rocks are exposed ranging in age from late Tertiary or early Quaternary down to the Cambrian and in some localities pre-Cambrian. Although beds of Carboniferous to early Montana age are not exposed in the Rock Springs uplift, some of them are believed to be the source of the oil, if any is present, in the Rock Springs area, and other beds no doubt serve as reservoirs in which the oil has accumulated. Some of the beds will therefore be included in the discussion of the geology of the Rock Springs uplift.

The strata to be considered in a study of the possibilities of obtaining oil from the shale of the area surrounding the Rock Springs uplift belong to that portion of the upper part of the Eocene series of the Tertiary system that is known as the Green River formation. Only two of the lower members of the Green River are known to contain oil shales, and these will be briefly discussed in order to facilitate a further consideration of the distribution and occurrence of oil shale in this part of Wyoming.

The rocks to be directly considered in a study of the oil possibilities in Baxter Basin belong to the upper part of the Cretaceous system. Only the two oldest formations exposed in Baxter Basin need be considered in this discussion and both of these belong to the lower part of the Montana group.

The other beds exposed in the Rock Springs uplift lying between the Montana beds in Baxter Basin and the beds of the Green River formation have been in part briefly described in Bulletins 341 and 381 and will not be further considered in this paper. The general character and succession of the Cretaceous and Tertiary rocks exposed in the Rock Springs uplift are set forth in the accompanying table.

Section of Cretaceous and Tertiary rocks exposed in the Rock Springs uplift, Sweetwater County, Wyo.

System.	Series and group.	Formation and member.		Economic designation.	Thickness (feet).	Character.	Economic value.
		Igneous.		Leucite lava.	0–350	Dikes, flows, volcanic necks, and agglomerate.	Potash niter occurs in some of these rocks. Source of potash and aluminum.
Tertiary or Quaternary.		Bishop conglomerate.		Gravel.	0–200	Waterworn and subangular pebbles and boulders, many of them from 1 to 6 feet in diameter, embedded in finer gravel and sand.	Good water horizon. Supplies many of the springs in southern part of field.
		Unconformity					
Tertiary.	Eocene series.	Bridger formation.		Volcanic ash.	0–2,000	Green and buff tuffaceous shales and sandstones, coarse pumiceous tuffs, marls, and shales, conglomerates, cherts, limestones, and thin beds of lignite. Red, green, and buff gypsiferous tuffs and white marls.	Mostly of volcanic origin, with calcareous component derived from organic source. Moss agate and thin beds of lignite. Considerable gypsum. Chert beds used by Indians for making arrow points.
		Unconformity					
		?	Plant beds and Tower sandstone of Powell.		0–500	Massive, irregularly bedded sandstone; white, yellow, and brown shaly sandstone; some limestone and interbedded shale.	Natural monuments and scenic castle-like structures.
			Unconformity				
		Green River formation.	Laney shale member.	Upper oil shale.	0–950	Thin-bedded shale, sandstone, and limestone (some of which are oolitic); some dark-colored bituminous shale.	Contains traces of oil in bituminous shale. In places rock seems to have been burned in consequence of presence of oil. Upper horizon of oil shale.
			Unconformity				
			Cathedral Bluffs red beds member.		0–1,500	Variegated clay, shale, and sandstone, in places slightly conglomeratic; produces highly colored escarpment of Laney Rim and Cathedral Bluffs.	No economic value so far as known.
			Tipton shale member.	Lower oil shale.	100–325	Thin fissile shale and sandstone; pronounced oolitic limestone, in places 20 to 50 feet thick near base; also other oolitic and concretionary beds locally resembling huge oyster shells scattered on surface.	Oil shale in thin-bedded layers. Some thin coal beds in this lower member of the Green River formation. Lowest horizon of oil shale.
		Wasatch formation.		Black Rock coal group.	1,000–2,500	Alternating layers of white, yellow, and brown sandstones and gray or drab and carbonaceous shales, with coal beds and conglomerate containing granite and quartzite pebbles. Numerous bands of white concretionary sandstone, weathering in irregular shapes. Basal sandstone is conglomeratic. Sandstone hardens locally and weathers into forms resembling large logs or spherical concretions. Large cross-bedded reddish sandstone forms badland topography in Red Creek valley and Fire Hole Basin.	Coal bearing. *Many thin beds of coal and at* least one bed 25 feet thick occur in this group. No large mines opened on this coal. Prospects opened in these beds at many places around the dome.

			Unconformity				
Cretaceous (?).	?		Post-"Laramie" formation.	Knobs-Cherokee coal group.	6,000-9,400	Alternating layers of soft yellowish brown and white sandstones and drab, brown, and black shales.	Coal bearing. Several beds of workable coal occur in the upper portion near Cherokee and in the lower portion near Knobs.
			Unconformity				
Cretaceous.	Upper Cretaceous series.		"Laramie" formation.	Black Buttes coal group.	1,500	Massive basal bed of white and yellow sandstone, showing traces of conglomerate in places; forms prominent scarp; overlain by various sandstone, clay, and coal beds. Fossils abound in places. Exposed only in the northern part of the east side of the dome, and here only lower part is visible. On west side of Rawlins dome this formation is 3,900 feet thick.	Coal bearing. Mines once worked on these beds near Hallville and Black Buttes station. New mine opened in 1907 south of Black Buttes. Prospects at various points. May yield artesian water.
		Montana group.	Lewis shale.		750	Dark gray, drab, and black shales, highly gypsiferous, with some soft shaly sandstone and large concretions; some lenticular beds of white sandstone near base. Produces topography of low relief.	Possible source of clay. Natural routes of travel. Not known to be coal bearing.
			Mesaverde formation.	Almond coal group.	700-950	Soft white and brown sandstones, sandy shale, and clay, with numerous beds of coal and bituminous shale.	Coal bearing. Many coal beds. Numerous prospects throughout the field. Coal from these beds has been mined at Rock Springs and Point of Rocks.
					800-1,000	Massive white and yellowish sandstone. Upper third conglomeratic, with fine black and gray quartz pebbles. Sandstone forms pronounced escarpments and hogback ridges, giving rise to the "white wall."	Water bearing. Yields artesian water in parts of field. Flowing wells at Point of Rocks. Wells northwest of Superior. Water will probably be encountered in these beds back from the outcrop all around the Rock Springs dome.
				Rock Springs coal group.	600-1,400	White to yellow sandstone, interbedded shale and clay with several coal beds. The heaviest beds of sandstone are grouped near the base of the formation. Total aggregate thickness of coal in this group about 90 feet.	Coal bearing. Many large coal beds and numerous smaller beds. Best coal in the Rock Springs field. Important mines at Rock Springs, Sweetwater, Blairtown, Lion, Reliance, Gunn, and Superior. Many prospects and drifts opened. Artesian water zone. Flowing wells at Superior and Rock Springs.
			Blair formation.		1,000-1,200	Drab, yellow, and brown sandstones and interbedded shale and shaly sandstone, with little or no bituminous matter. Massive sandstones are grouped near top of formation, giving rise to the "golden wall."	Water bearing. Important artesian water zone. This formation will probably supply water outside of the ridges and escarpments surrounding Baxter Basin.
			Baxter shale.		1,000+	Black and drab shales, very soft and friable. Shaly sandstones and arenaceous shale, in places highly gypsiferous. Much of it very friable, producing low benches and ridges.	Possible source of clay. Considerable gypsum. In places some sulphur.

As the rocks of the parts of southwestern Wyoming, northeastern Utah, and northwestern Colorado covered by the geologic map accompanying this report have been classified differently in the earlier reports herein referred to, the accompanying correlation table has been prepared, showing the relations of the classification used in this report to the classifications used in the earlier report.

EXPOSED ROCKS CONNECTED WITH OIL POSSIBILITIES IN ROCK SPRINGS UPLIFT.

GREEN RIVER FORMATION (EOCENE).

GENERAL FEATURES.

In the Rock Springs field there are exposed several zones of non coal-bearing rocks associated with four valuable coal groups, named from the bottom upward in the order of their stratigraphic succession the Rock Springs, Almond, Black Buttes, and Black Rock coal groups. Overlying the Black Rock coal group are other coal beds in the basal members of the Green River formation, but thus far none of the coals in this formation have proved to be of commercial importance. The non coal-bearing rocks are found below, between, and above the coal groups. All the beds stratigraphically below the Black Buttes coal group exposed in the Rock Springs uplift form a part of the Montana group of the Cretaceous system, and those stratigraphically above the Black Buttes coal group, of the "Laramie" formation belong to the Eocene series of the Tertiary system. Overlying the Black Rock coal group, which corresponds to the Wasatch formation and forms the basal division of the Eocene in this field, completely encircling the Rock Springs dome and thereby separating the older Cretaceous beds from the later Eocene beds, are the beds of Green River age in which the oil shales are found.

Beds of Green River age (see Pl. III, *B*, *C*) are found everywhere along the west side of the Rock Springs dome in a nearly horizontal position, having very low dips away from the dome toward the central part of the Green River Basin. These beds have been traced northward and eastward across the north end of the Rock Springs uplift out into the Red Desert to a point approximately 20 miles southeast of the Antelope Hills, at the southeastern extremity of the Wind River Mountains. Beds of the same age also occur in the area south and southeast of the Rock Springs dome and are present throughout the area south of the Union Pacific Railroad and north of the Uinta Mountains. The beds here also are nearly horizontal, having a very low dip toward the center of the Washakie Basin. No doubt at one time these beds completely surrounded the Rock Springs dome in much the same way as the Black Rock coal group does at present. Erosion has completely removed these

Correlation table showing different classifications that have been used in the area covered by geologic map accompanying this report.

Age classification recognized in this report.	U. S. Geol. Expl. 40th Par. Atlas, 1876. Includes area mapped in this report.	Powell, J. W., Geology of the Uinta Mountains and Atlas, 1876. Includes area mapped in this report.	Veatch, A. C., U. S. Geol. Survey Prof. Paper 56, 1907. (Southwestern Wyoming, about 60 miles west of area mapped in this report.)	Gale, H. S., U. S. Geol. Survey Bull. 415, 1910. (Northwestern Colorado and northeastern Utah, including Henrys Fork field, mapped in this report.)	Schultz, 1920. (This report.)
Late Tertiary or early Quaternary.	Wyoming conglomerate.	Bishop Mountain conglomerate.	Wyoming conglomerate.	Bishop Mountain conglomerate, 200 feet.	Bishop conglomerate, 0–200 feet.
Tertiary (Eocene ?).	[Mapped as Green River.]	Browns Park group, 0–1,800 feet.		Browns Park formation, 600 feet.	Bridger formation, 0–2,000 feet. (According to author's field tracing, typical Browns Park group of Powell is simply southwestward extension of Bridger formation of Washakie Basin.)
Tertiary (Eocene).	Bridger.	Bridger group, 0–2,000 feet.	Bridger formation, 1,200–1,800 feet.	Bridger formation, 1,000 feet.	
	Green River. [As mapped included Wasatch in some areas and in other areas included beds as young as Bishop conglomerate.]	Upper Green River group, 0–500 feet: Plant beds. / Tower sandstone.	Green River formation, 2,000± feet.	Green River formation, 3,000 feet.	Green River formation: Plant beds and Tower sandstone of Powell, 0–500 feet.
		Lower Green River group, 0–800 feet.			Laney shale member, 0–950 feet.
					Cathedral Bluffs red beds member, 0–1,500 feet.
					Tipton shale member, 100–325 feet.
	Vermilion Creek. [As mapped included in some areas beds as old as Montana.]	Bitter Creek group, 0–3,000 feet. [As mapped included in some areas all beds between upper part of Mesaverde formation and Green River formation.]	Wasatch group: Knight formation, 500–1,500± feet. / Fowkes formation, 0–2,500+ feet. / Almy formation, 2,100–2,200 feet.	Wasatch formation, 4,000 feet.	Wasatch formation, 1,000–2,500 feet.
Cretaceous (?).			Evanston formation, 0–1,600+ feet.	Post-Laramie (Fort Union ?), 1,000 feet.	Post-"Laramie" formation, 6,000–9,400 feet.
Cretaceous. Upper Cretaceous.	Laramie. [As mapped included beds from Wasatch to base of Mesaverde.]		[Absent.]	Laramie formation, 1,200+ feet.	"Laramie" formation, 1,500 feet.
Montana group.	Fox Hill [=Blair and Baxter].			Lewis shale, 1,200 feet.	Lewis shale, 750 feet.
	Colorado. [As mapped=Baxter shale in Rock Springs uplift.] Fort Pierre.	Point of Rocks group, 0–1,800 feet: Sandstones and shales. / Goldenwall sandstone.	Adaville formation, 4,000+ feet.	Mesaverde formation, 3,500 feet.	Mesaverde formation, 2,100–3,350 feet.
			Hilliard formation, 5,500–6,800 feet.	Mancos shale.	Blair formation, 1,000–1,200 feet.
		Salt Wells group, 0–1,800 feet.			Baxter shale, 1,000+ feet.
Colorado group.	Niobrara.	Sulphur Creek group, 0–2,000 feet.			Unexposed shale, 1,800± feet.
	Fort Benton.	Henrys Fork group, 0–500 feet.	Frontier formation, 2,200–2,600 feet.		Frontier formation, 500 feet.
	Dakota.		Aspen formation, 1,500–2,000 feet.		Aspen shale, 200 feet.
Cretaceous (?).			Bear River formation, 500–5,000+ feet. (?)	Dakota sandstone, 200 feet.	Absent.
Jurassic.	Jurassic.	Flaming Gorge group, 0–1,200 feet: White Cliff limestone.	Beckwith formation, 3,800–5,500 feet.	Flaming Gorge formation, 800 feet.	Beckwith formation, 1,000 feet.
			Twin Creek formation, 3,500–3,800 feet.		Twin Creek limestone, 140 feet.
		White Cliff group, 0–1,100 feet. / Vermilion Cliff group, 0–1,100 feet. [Same beds.]	Nugget formation, 1,900 feet: Light-colored sandstones and shales. / Red member, 600 feet.	White Cliff sandstone, 800 feet. / Vermilion Cliff sandstone (?), 600 feet. [Same beds.]	Nugget sandstone, 1,000 feet.
Triassic (?).	Triassic red beds.	Shinarump group, 0–1,800 feet.		Shinarump group, 1,000 feet.	Ankareh shale, 300 feet.
Lower Triassic.			Thaynes formation, 2,400–2,600+ feet.		Thaynes (?) formation, 0–200 (?) feet. (?)
Carboniferous. Permian.	Permo-Carboniferous.	Upper Aubrey group, 0–1,400 feet: Bellerophon limestone, 100–200 feet.	Woodside formation, 500 feet.		Woodside shale, 300 feet.
			Park City formation, 700+ feet.		Park City formation, 200 feet.
Pennsylvanian.		Yampa sandstone, 1,000–1,200 feet.	Weber quartzite, 1,000+ feet.	Weber quartzite, 2,500 feet.	Weber quartzite, 1,000 feet.
	[?] Upper Coal Measures.	Lower Aubrey group, 0–1,000 feet.	Not discussed.		Older Pennsylvanian, 1,000 feet.
Mississippian.		Red Wall group, 0–2,000 feet.		"Wasatch" limestone, 1,000 feet.	Mississippian, 1,000 feet.
Devonian (?).	Weber quartzite.				Devonian (?) to base of Cambrian quartzite undifferentiated, 1,500 feet.
Silurian (?).					
Ordovician (?).					
Cambrian.		[?] Lodore group, 0–465 feet.		Lodore shale not recognized.	
Pre-Cambrian.		Uinta group, 12,500 feet.		Uinta quartzite, 12,000± feet.	Undifferentiated, 13,000 (?) feet.
	Archean.	Red Creek quartzite.			Red Creek quartzite and intrusive schists.

beds, however, over a large part of the Red Desert, in the Great Divide Basin, and to a much smaller extent at the south end of the Rock Springs uplift, along the divide between Sage and Red creeks.

Everywhere along the west side of the Rock Springs uplift the Green River beds consist of two members, defined by Powell, as the "Lower Green River" and the "Upper Green River," the latter including the so-called "Tower sandstone" and the plant beds. East of the north-south anticlinal axis of the Rock Springs uplift, the Green River beds are divided into four distinct members, the upper three of which are not known to be coal bearing in this region. In Bulletins 341 and 381 the lower two members were referred to the Wasatch formation and the upper two to the Green River formation. It is now believed that all four members belong to the Green River and represent the time equivalent of the Green River formation as mapped along the west side of the Rock Springs uplift, on the eastern margin of the Green River Basin. Continuous deposition prevailed on the west side of the Rock Springs uplift during early Green River time, while throughout the remainder of the area deposition was interrupted, and during that part of the epoch represented by the deposition of the third member the conditions that prevailed in the shallow basin east of the Rock Springs uplift were very different from those on the west. The third member on the east side of the Rock Springs uplift represents in fact the recurrence of deposition of sediments similar to those laid down during Wasatch time, and it is highly probable that still farther east and southeast Wasatch deposition was taking place, while farther to the west Green River beds were being deposited, giving rise to the interfingering of these two types of beds, as we now find them in the field. The relation of these beds as far as known is illustrated in figure 2.

Oil shale is found at various horizons in the Green River formation but is not known to be present in the Cathedral Bluffs red beds member, or in the "Tower sandstone" and overlying plant beds.

"TOWER SANDSTONE" AND PLANT BEDS OF POWELL.

The upper beds here tentatively included in the Green River formation consist of massive, irregularly bedded sandstone, sandy limestone, and shale that are well exposed along the crest of White Mountain north of Wilkins, a station on the Union Pacific Railroad a few miles west of Rock Springs; on Wilkins Peak, south of the Union Pacific Railroad in the vicinity of the town of Green River; in Fire Hole Basin; and at other points along Green River. These beds were designated by Powell "plant beds and Tower sandstone," but his "Tower sandstone" was not clearly defined and is not a geographic name. As these beds were not studied in detail, it is not

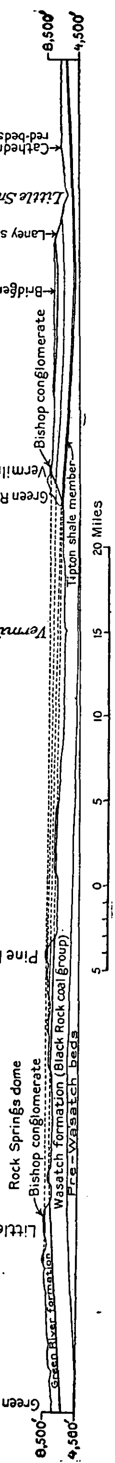
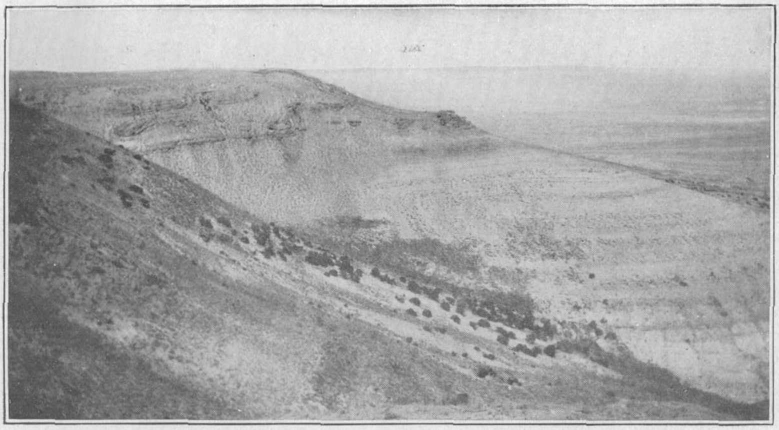


FIGURE 2.—East-west section across the Rock Springs dome, showing the relation of the Wasatch and Green River formations in the Rock Springs area, and the manner in which the Green River formation is divided on the east side of the Rock Springs anticline.

proposed to define them here and introduce a geographic name or names for them. Powell's names are therefore tentatively used, and the beds are also tentatively retained in the Green River formation, where they were placed by Powell, although there is a possibility that they may prove to belong to the overlying Bridger formation. The "Tower sandstone" forms vertical cliffs, and in many places, as in the vicinity of the town of Green River, it rests on irregular surfaces of shale and is itself very much distorted, whereas the shale beneath it is not deformed. Beds of the same sandstone are present in small outliers on the east side of the dome in the vicinity of Pine Butte. The character of these beds and their unconformable relation to the underlying beds are well shown in Plate IV and Plate V, *A*.

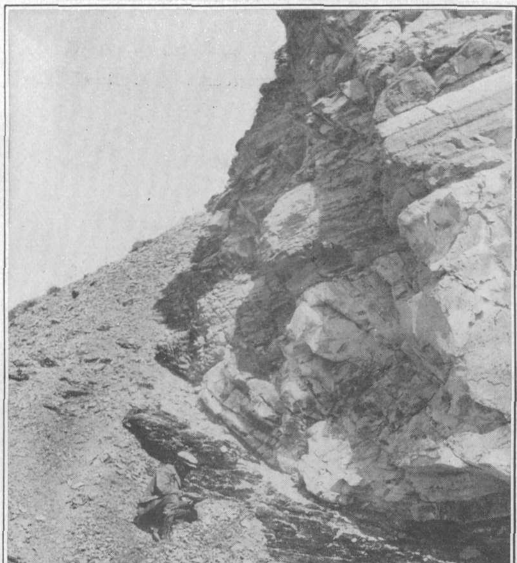
The beds above the unconformity shown in Plate IV represent the "Upper Green River" of the Powell Survey and include the "Tower sandstone" and the overlying plant beds. Stratigraphically above these beds lies the Bridger formation, which is well exposed north, east, and west of the Rock Springs field. The general appearance of the Bridger beds and their method of weathering in these areas are shown in Plate V, *B*, and Plate VI, *A*, *B*.

The relation of the coarse-grained cross-bedded "Tower sandstone" to the underlying and overlying beds suggests that it represents old river-channel deposits or deposits in embayments of the Bridger Lake. As further studies are made of these beds in the areas where they are well exposed it will probably be found that they are contemporaneous with the Bridger beds and represent local deposits laid down under peculiar conditions near the margin of the Bridger Lake. In many of its characteristics the "Tower sandstone" and overlying plant beds represent very typical Bridger deposits, and they are distributed in such a manner as to suggest outliers of the



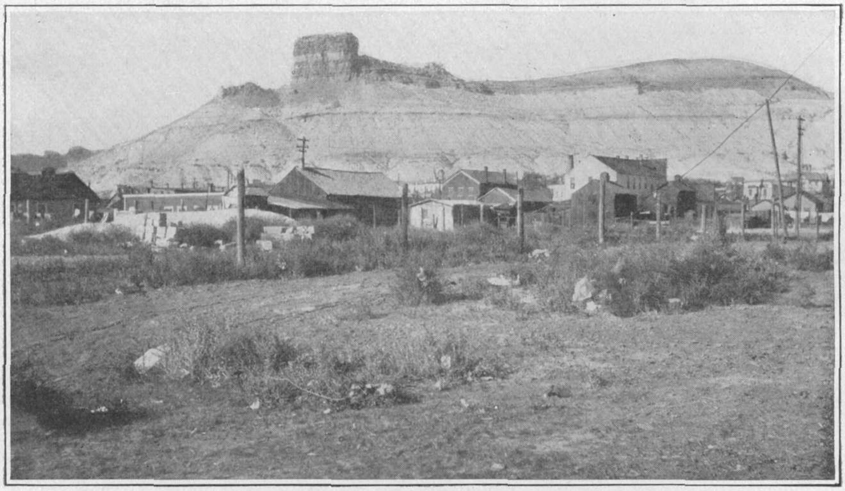
A. CONTACT OF "TOWER SANDSTONE" WITH UNDERLYING LANEY SHALE ALONG EAST FACE OF WHITE MOUNTAIN, IN SEC. 36, T. 19 N., R. 106 W.

Base of Green River formation near lower right corner. Note the unconformable relation of the "Tower sandstone."



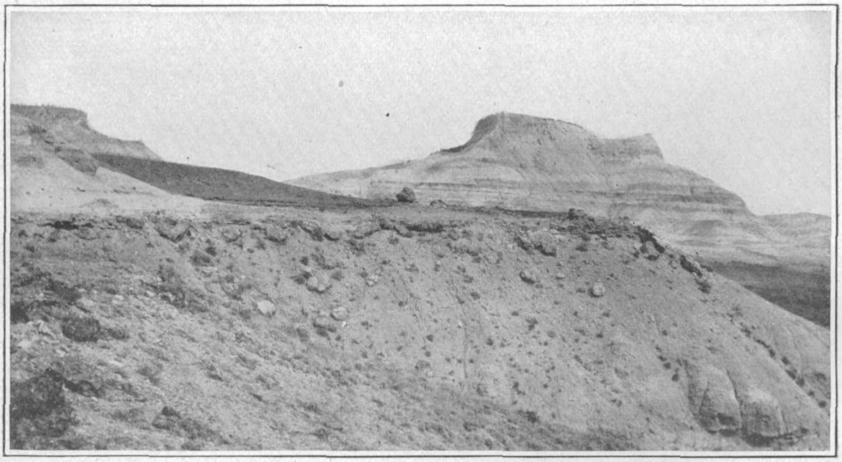
B. CONTACT OF "TOWER SANDSTONE" WITH UNDERLYING SHALES ALONG EAST SIDE OF ROCK SPRINGS UPLIFT IN VICINITY OF PINE BUTTES, IN SEC. 5, T. 15 N., R. 100 W.

Note the unconformable relation and the abrupt change in lithologic characteristics of the overlying beds.



A. "TOWER SANDSTONE" UNCONFORMABLY OVERLYING SHALE AT GREEN RIVER, IN SEC. 15, T. 18 N., R. 107 W.

Green River city in the foreground. (See also Pl. IV.)



B. BRIDGER FORMATION IN TYPICAL EXPOSURE AT OREGON BUTTES, IN T. 25 N., R. 101 W., NORTH OF ROCK SPRINGS UPLIFT.

Note irregular concretionary ledge capping bench in foreground which contains many irregular and cloudy flints and moss agates. Green River shales underlie these beds.

present known Bridger areas. It is the "Tower sandstone" and associated rocks that cap the curious pinnacles which are so conspicuous near the town of Green River and other points along Green River. These beds, as well as those at Pine Buttes, on the east side of the Rock Springs uplift, resemble in their method of weathering and curious shapes the Bridger beds exposed in Oregon Buttes, in Bridger Basin, and in Washakie Basin. The soft shale underlying the masses of hard sandstone softens and crumbles under the influence of the weather and is washed away by rain and melting snow or blown away by the winds, leaving the portions that are protected by the hard capping layers standing as isolated picturesque monuments or precipitous cliffs and escarpments.

LANEY SHALE MEMBER.

The second member of the Green River formation, herein named Laney shale member, from typical exposures along the Laney Rim, lies unconformably below the "Tower sandstone." On the east side of the dome the beds consist of white and green fissile shale, limestone, and sandstone similar to those so characteristic of the lower member, or Tipton shale, of the Green River formation in this part of the field and to the entire Green River formation in other parts of the Green River Basin.

These beds in places lie unconformably upon the third member of the formation, the Cathedral Bluffs red beds, and the relations along this contact indicate that there was an erosional interval in which channels were cut into the red beds before the overlying shale was deposited. In other parts of the field the beds are apparently conformable and seem to grade upward into the shales without a break, although the contact is everywhere well marked by means of a color line. The red beds in the Laney Rim, as described by Emmons,[3]

> are capped by about 100 to 150 feet of an impure concretionary limestone of drab color, having at its summit a seam about 4 inches in thickness of oolitic limestone, which has been, in a great measure, silicified and changed into a dark-gray chalcedony. These upper calcareous beds represent the base of the Green River group (as mapped by King). The oolitic seam is made up of rounded grains from one-thirtieth to one-tenth of an inch in diameter, of a concentric structure, cemented by a cryptocrystalline limy matrix. Examined under the microscope, they show no evidence of organic origin and are seen to be almost identical with the limy sands which are found on the present beaches of the Great Salt Lake. A partial analysis of the agatized portion of this seam gave 74.818 per cent of silica, the remainder being principally carbonate of lime, with some alumina, oxide of iron, and magnesia.

The series of red beds that mark the escarpment around the Washakie Basin and are described below is overlain nearly everywhere by this series of fine, fissile Laney shales, 100 to 800 feet thick, which

[3] Emmons, S. F., U. S. Geol. Expl. 40th Par. Rept., vol. 2, pp. 211, 212, 1877.

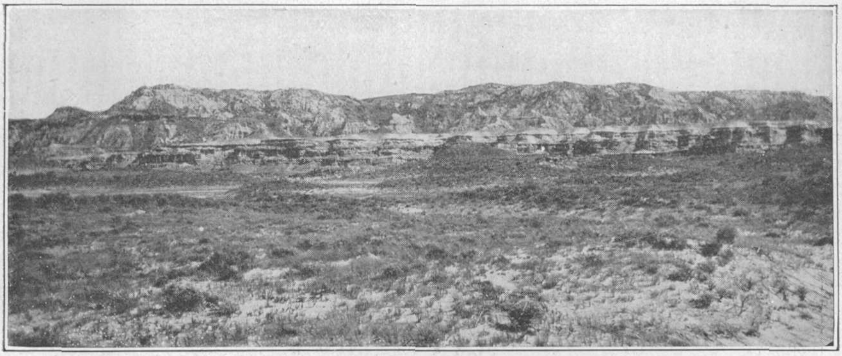
in turn is capped in places, as at Pine Bluff, by reddish or cream-colored coarse-grained sandstone that is probably equivalent to the "Tower sandstone," as shown in Plate IV. The beds generally dip at a low angle toward the center of the basin. In the vicinity of Flat Top (Washakie) Mountain the beds are nearly horizontal. The flat-topped ridge or table-land attains an elevation of about 1,500 feet above the surface of the surrounding plains. It is capped by a remnant of the Bishop conglomerate made up of coarse pebbles of the quartzite, schists, and other rocks of the Park Range, to the east, and the Uinta Mountains, to the southwest. The upper 500 or 600 feet of the peak is composed of yellowish-brown sandstones and thin blue calcareous shales and clays of the Green River formation.

CATHEDRAL BLUFFS RED BEDS MEMBER.

The third member of the Green River formation consists of red or varicolored conglomeratic sandstone, shale, and clay, to which the name Cathedral Bluffs red beds member is here given, as they are well exposed in the Laney Rim and Cathedral Bluffs, southwest of Wamsutter, Wyo. These beds overlie and are conformable with the Tipton shale, described below, and have approximately the same distribution on the east side of the Rock Springs dome. They have been traced northward from Steamboat Mountain to Oregon Buttes and Centennial Peak, on the east side of the Continental Divide, and thence nearly as far east as the Tipton shale. They have also been traced along the west side of the Continental Divide as far north as Oregon Buttes and Pacific, in the vicinity of the Wind River Mountains. How much farther north and west they extend has not been ascertained. These beds have not been found on the west side of the Rock Springs dome. Near the axis of the anticline the red beds lose their characteristics and merge laterally into typical Green River shales so that their identity can no longer be recognized. Some of the characteristic features of these beds are shown in Plate VI, *C*, and Plate VII, *A*, *B*.

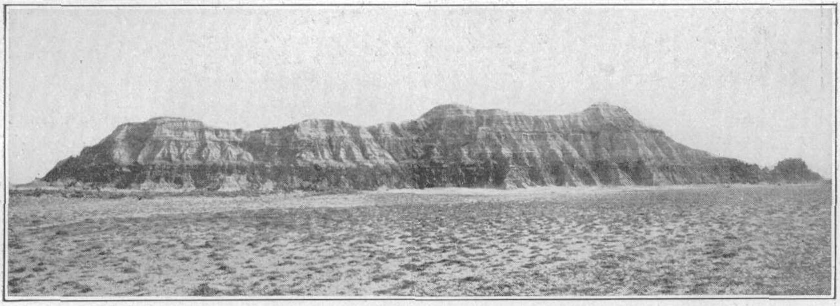
About 4 miles south of the low shale ridge in the vicinity of Red Desert station on the Union Pacific Railroad there is a second line of bluffs, of greater elevation, composed of these striped red beds. To these bluffs Emmons [4] gave the name Cathedral Bluffs, on account of the remarkable buttress-like forms into which their faces have been weathered. A thickness of about 500 feet of these peculiarly variegated beds is here exposed, consisting of fine red, greenish, and purple clays, with a varying admixture of fine white sand. These beds may be traced eastward and southward more or less parallel to the outcrop of the Tipton shale to Little Snake River in northern Colorado. To the east of Flat Top (Washakie) Mountain the Cathe-

[4] Emmons, S. F., op. cit., pp. 211, 212.

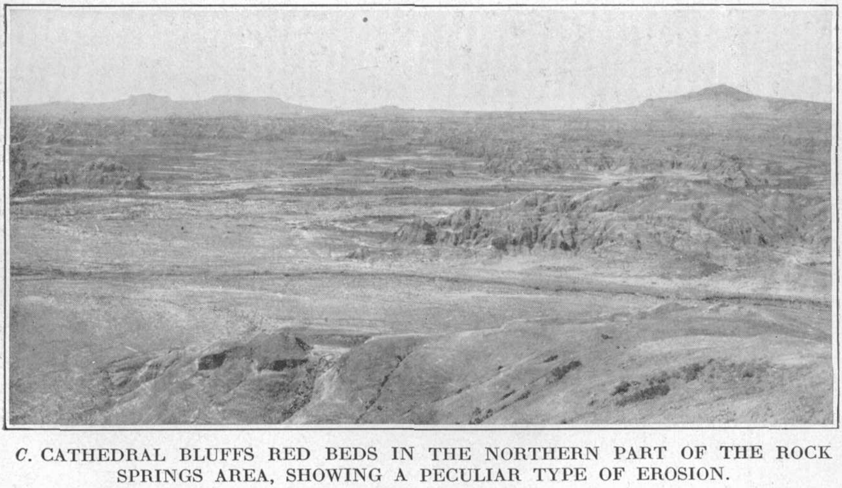


A. TYPICAL EXPOSURE OF BRIDGER FORMATION IN NORTHWEST FACE OF BRIDGER HILL, AT WEST END OF HAYSTACK MOUNTAIN.

The thinly stratified beds in the foreground are a part of the Bridger formation characteristic of the Green River Basin. The beds on the hill in the background belong to the Bridger of the Washakie Basin, east of the Rock Springs uplift.



B. TYPICAL EXPOSURE OF BRIDGER BEDS IN BRIDGER BASIN, ON WEST SIDE OF ROCK SPRINGS UPLIFT, BETWEEN GRANGER AND LYMAN.



C. CATHEDRAL BLUFFS RED BEDS IN THE NORTHERN PART OF THE ROCK SPRINGS AREA, SHOWING A PECULIAR TYPE OF EROSION.

Continental Peak near right margin; Oregon Buttes near left margin. Both of these buttes have Laney shale and Bridger beds overlying the Cathedral Bluffs red beds. (See also Pl. VII.)

A. CHARACTERISTIC EXPOSURE OF CATHEDRAL BLUFFS RED BEDS ALONG EAST SIDE OF ROCK SPRINGS UPLIFT IN LANEY RIM, T. 19 N., R. 96 W.

B. TYPICAL EXPOSURE OF CATHEDRAL BLUFFS RED BEDS IN SEC. 13, T. 25 N., R. 101 W., AT NORTH END OF ROCK SPRINGS UPLIFT.

dral Bluffs red beds dip 4°–5° W. and are of the same appearance as those in the vicinity of Red Desert station. The same beds may be traced southwestward along the Laney Rim to Pine Bluffs, where there are 700 to 800 feet of bright-red and gray clays that resemble more nearly the Wasatch than the Green River formation. The same thickness of red beds prevails along part of the Kinney Rim, to the south, but toward the west, in the vicinity of Pine and Bishop mountains, the beds are much thinner and can be separated from the overlying and underlying shales only with difficulty. Southward along the Kinney Rim the thickness of the red-bed portion of the Green River increases rapidly and attains 1,200 feet at Lookout Mountain (Vermilion Bluff). In this section the Tipton shales are not well exposed, though sufficiently to establish their presence. It seems very probable that farther south the underlying Tipton shale may be absent entirely and the Cathedral Bluffs red beds and the underlying Wasatch may merge into one another much like the Tipton shale and the overlying beds along the west side of the Rock Springs dome. A section of the Green River formation in the vicinity of Lookout Mountain (Vermilion Bluff) is as follows:

Section in vicinity of Lookout Mountain, Wyo.

	Feet.
Formation undetermined:	
Conglomerate composed largely of red conglomeratic quartzite boulders 2 feet or less in diameter but containing also white quartzite, gray siliceous limestone, and soft red sandstone. Material probably ranges from Triassic to Cambrian. Probably part of Bishop conglomerate or of Bridger formation	50
Green River formation:	
Laney shale member. Fissile shales, light gray or yellow in outcrop, darker in place. Contains numerous oolitic bands	700
Cathedral Bluffs red beds member. Brilliantly colored beds of clays and sands, predominantly red or reddish purple but containing light bands which are generally green. Equivalent of the Cathedral Bluffs red beds exposed along the steep escarpment from Laney Rim to Kinney Rim	1,200–1,500
Tipton shale member. Fissile shales resembling characteristic Green River beds in both color and lithology. Thin-bedded shales of gray, white, and brown color, interlaminated with sandstones which merge into greenish clays.	200
Wasatch formation (Black Rock coal group). Gray and lead-colored clays and sandstone; sandstones somewhat irregular and conglomeratic; entire mass coal bearing, being the upper part of Black Rock coal group	400–500

On the cliffs in the vicinity of Sunny Point, west of Snake River, in T. 10 N., R. 96 W., Colo., S. F. Emmons, of the King Survey, measured a section by aneroid barometer and found that the thickness of the beds from Snake River to the summit of the cliff is approximately 2,000 feet. From Emmons's description[5] of the beds given below it appears that the Laney shales here are approximately 350 feet thick and are overlain by beds of Bridger age. Emmons referred the upper 950 feet to the Green River and the remaining 1,050 feet to the "Vermilion Creek group." From present knowledge the section measured by Emmons should probably be subdivided in the following manner:

Section of beds from Snake River to the top of Sunny Point in T. 10 N., R. 96 W., Colo.

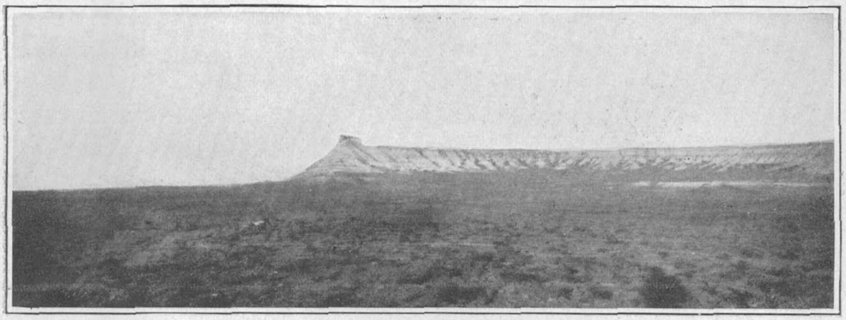
[Measured by S. F. Emmons, of the King Survey. The geologic names are those employed in the present report.]

		Feet.
Bridger formation:		
Coarse brownish sandstone, with intercalated brown calcareous shales		100
Green River formation:		
Laney shale member:		
White calcareous shales, with ½-inch seams of gypsum and a 4-inch seam of agatized unios	45	
Drab concretionary limestone, with brown sandstone shales	85	
White and brown argillaceous shales	120	
Rusty arenaceous shales	100	
Beds of soft light-colored argillaceous and calcareous shales, some of which are impregnated with carbonaceous material and have a light-blue color on the weathered surface, containing also thin seams of gypsum	400	
White sandstones and clays	100	
		850
Cathedral Bluffs red beds member:		
Reddish clayey arenaceous beds		1,050
Base not seen.		
		2,000

TIPTON SHALE MEMBER.

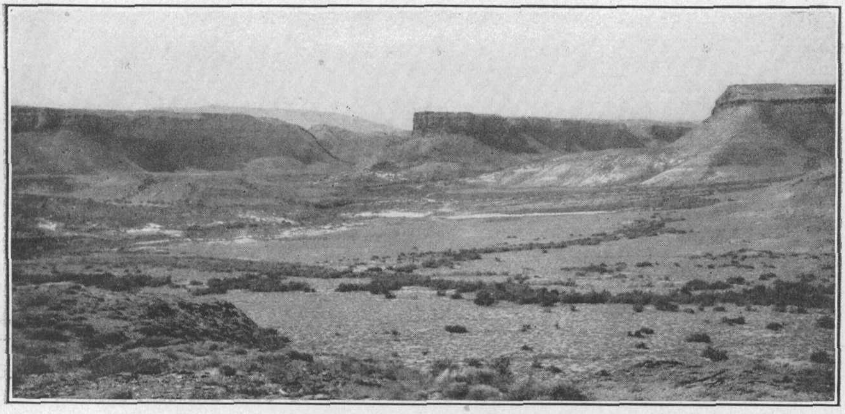
On both the east and west sides of the uplift the beds immediately overlying the Black Rock coal group consist of fissile shale, conglomerate, oolitic limestone, shale, clay, and sandstone. Some of the greenish-white shale of these beds is very fissile and closely resembles the shale in the lower part of the Green River formation in the Green River Basin. At the south end of the dome and in the area between the Rock Springs uplift and the Washakie Basin traces of coal were found near the base of these beds, but throughout the northern part of the field no coal was seen in them. To this member of the formation the name Tipton shale member is here given, as the beds are well exposed in the vicinity of Tipton, a station on the Union Pacific Railroad. (See Pl. VIII, *A*, *B*.)

[5] Emmons, S. F., op. cit., p. 220.



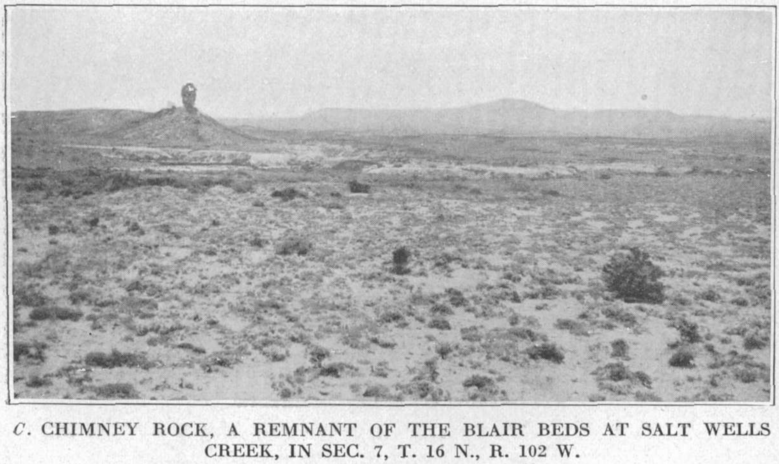
A. TABLE ROCK IN T. 18 N., R. 98 W., AND THE WASATCH ESCARPMENT ON WHICH THE TIPTON SHALE RESTS.

The small dark cap rock of Table Rock is composed of very fossiliferous calcareous sandstone which marks the base of the Tipton shale.



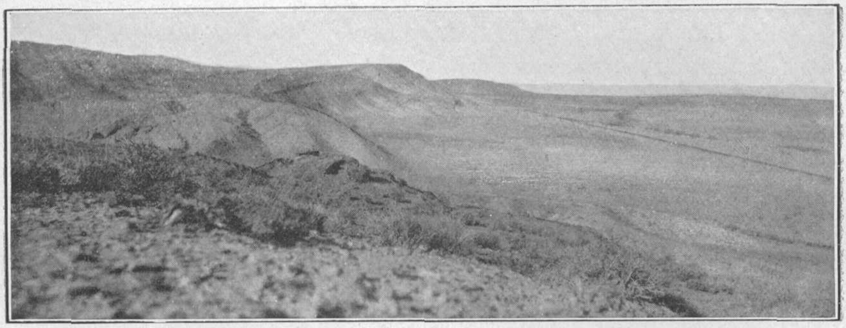
B. EXPOSURES OF TIPTON SHALE AND ASSOCIATED SANDSTONES AT THE MOUTH OF CANYON CREEK, IN T. 12 N., R. 101 W.

The mountain in the background is Diamond Peak, made famous by King in his Fortieth Parallel Survey.



C. CHIMNEY ROCK, A REMNANT OF THE BLAIR BEDS AT SALT WELLS CREEK, IN SEC. 7, T. 16 N., R. 102 W.

Southern part of Aspen Mountain shown in background.

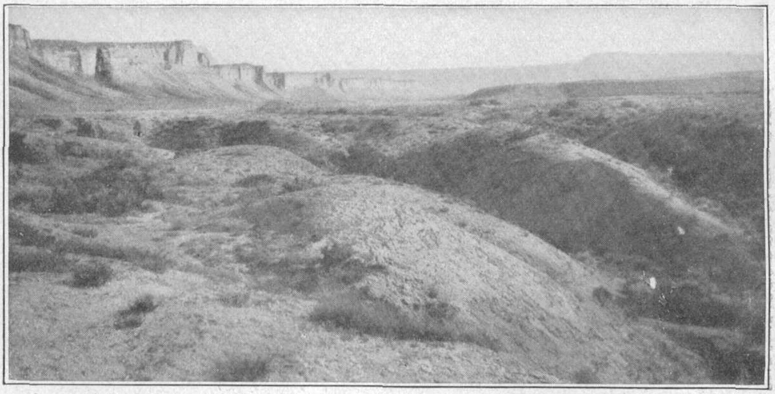


A. CONTACT BETWEEN THE BAXTER SHALE AND THE OVERLYING BLAIR FORMATION, IN SEC. 16, T. 19 N., R. 104 W.

Note the Blair escarpment and ridges surrounding the north end of Baxter Basin.

B. SANDSTONE LENTIL IN THE UPPER PART OF THE BAXTER SHALE.

Note steeper dips on west side of anticline. Black Buttes is hill in background near left of picture and Aspen Mountain is near right of picture. Spur track to Gunn coal mine in foreground and main line of Union Pacific Railroad near center of picture.



C. CONSPICUOUS ESCARPMENT FORMED BY BAXTER SHALE AND OVERLYING BLAIR FORMATION.

The cliff on left of picture extends westward and passes into the table-land south of Aspen Mountain.

TYPICAL EXPOSURES OF BAXTER SHALE.

South of Tipton station the country rises in a series of steps or terraces, the first of which is formed of the whitish shales, clays, and sandstones of the Tipton member, which extend parallel to the railroad toward Wamsutter, on the east, where they swing southward and extend nearly to the edge of the cliffs west of the valley of Little Muddy Creek, approximately 8 miles east of Washakie or Flat Top Mountain, and thence south to Little Snake River. The beds in this part of the field are 200 to 250 feet in thickness. Southwestward from Tipton station these shales, which are lithologically identical with the Laney shale, may be followed along the west base of the Laney Rim past Pine Bluffs to the Kinney Rim and Lookout Mountain and southwestward to Pine and Bishop mountains. The fissile Tipton shale continues along the road south of Rife's ranch and is just cut through in the valley between Coyote and Canyon creeks. In Canyon Creek there are great escarpments of yellow sandstone, about 200 feet high, containing a small amount of conglomerate. The largest pebbles here are but a few inches in diameter. Upstream on Ruby Creek toward the mountains the percentage of conglomerate and the size of the pebbles rapidly increase. Within a mile boulders as large as 2 feet are encountered. These include gray and yellow quartzite and sandstones but practically none of the red quartzites which characterize the Bishop conglomerate.

At a point 14 miles southeast of Pine Butte along the Kinney Rim the fissile Tipton shales are typically exposed. They are here overlain by more than 600 feet of brilliantly colored red beds that mark the escarpment which is so characteristic of the Laney and Kinney rims. The Tipton shale is here 300 feet thick, and the fissile Laney shale, overlying the red beds, is about 600 feet thick. The "Tower sandstone" forms the slopes to the east, and at its base is a vivid green band forming low hogbacks that mark the base of the Bridger formation. Toward the south the Tipton shale is not well exposed, and in the vicinity of Lookout Mountain only enough exposures are seen to establish its presence with certainty. How much farther south or southeast the Tipton shale extends has not been determined.

North of Tipton station the Tipton shale has been removed by erosion over the greater part of the Great Divide Basin. The beds have been traced along the north side of this basin from Steamboat Mountain northeastward to the southeast end of the Wind River Mountains.

MONTANA GROUP, LOWER PART (UPPER CRETACEOUS).

GENERAL FEATURES.

The beds exposed along the central part of the Rock Springs dome all belong to the Cretaceous system. They were mapped in the field as seven distinct lithologic units. The topmost Cretaceous formation exposed is believed to be of Laramie age; the six lithologic divisions underlying it form a part of the Montana group. In this discussion only the two lower non coal-bearing formations of the Montana, or the rocks stratigraphically below the Rock Springs coal group, need be considered, as these two formations are the only ones that have a direct bearing upon the search for oil in Baxter Basin. The lower of these two formations represents clearly a part of the Hilliard shale; the age of the upper formation (herein named Blair formation) is somewhat more in doubt, and it may represent either a part of the Hilliard shale or the basal part of the Mesaverde formation as developed in other areas. If the base of the Mesaverde formation is placed near the lower limit of the coal-bearing beds, as in many of the adjacent fields, it should be drawn at the base of the Rock Springs coal group, and the Blair formation would then represent a part of the Hilliard shale as mapped in Uinta and Lincoln counties, Wyo., the Rock Springs coal group being equivalent to the lower part of the Adaville formation of the same locality.

BLAIR FORMATION.

Below the Rock Springs coal group and above the Baxter shale occur sandstone and sandy shale which form the beds immediately below the Mesaverde as identified in this part of Wyoming. The upper of these beds give rise to the main scarp surrounding Baxter Basin, which is often referred to as the "golden wall" that incloses this structural depression. On account of the pronounced sandstones near the top of the formation the beds have in previous reports been considered a part of the Mesaverde formation. They constitute a distinct lithologic unit, however, and are therefore here named the Blair formation, from typical exposures at Blair ranch, east of Aspen Mountain. The formation occupies a narrow belt between the low shale area of Baxter Basin and the high ridges or hills along which lies the Rock Springs coal group. It consists of an alternating series of thick sandstones and sandy shales. The line marking the base of the formation is drawn on a thin ledge of sandstone that separates the overlying sandstones from the underlying shale. These sandstones are not very resistant, but compared with the underlying shales they form a low escarpment around the basin, and form a convenient marker beyond which drilling for oil in Baxter Basin should not be undertaken.

The beds of the lower part of the formation consist of yellowish-brown and drab sandstones that become thin bedded toward the base and are associated with drab shales. The sandstones are for the most part thin bedded, flaggy, fine grained, and conspicuously ripple marked. Higher up in the series the sandstones become more massive and the color changes from yellowish brown to yellow. Near the middle of the formation is a thin-bedded yellowish-brown sandstone that gives rise in many places to a small escarpment which presents a striking contrast to the prominent escarpment formed by the more massive sandstones in the upper part of the formation. The middle and lower portions are more shaly. Although the sandstones predominate and retain the general yellowish-brown color, they are usually very thin bedded, and the area they occupy has a rather rounded surface.

The top of the formation, or the dividing line between the Blair and the overlying Rock Springs coal group, is drawn at the base of a very prominent and persistent white sandstone that marks the lower limit of the lower coal-bearing member of the Mesaverde. The upper part of the Blair formation is much more sandy than the lower part and consists of massive yellowish sandstones entirely free from carbonaceous matter. These sandstones give rise to the conspicuous escarpment that incloses Baxter Basin. In the southern part of the Rock Springs field, however, the sandstones at the top of the formation lose their massive character, becoming more thin bedded and more easily attacked by erosion. As a consequence the high scarp so conspicuous in other parts of the basin has been cut down completely where this formation crosses Salt Wells Creek, so that it shows only a gentle, rounded topography with a single remnant of the massive sandstone as shown in Chimney Rock (Pl. VIII, *C*). The fossils collected from the Blair formation indicate that the beds are of Montana age. The following species were identified by T. W. Stanton:

Baculites sp.
Cardium sp.
Corbula sp.
Corbula undifera Meek?
Dentalium sp.
Fish scales.
Inoceramus sp.
Inoceramus cripsi var. barabini Morton.
Inoceramus proximus Tuomey.
Leda sp.
Liopistha undata Meek and Hayden.
Lunatia?
Mactra?
Modiola sp.
Ostrea glabra Meek and Hayden.
Syncyclonema rigida Hall and Meek.

BAXTER SHALE.

Below the Blair formation is the dark-gray or drab to black shale of Montana age which occupies the central part of the dome in Baxter Basin. This shale is the oldest rock exposed in the field and is here named the Baxter shale, as fine exposures may be seen in the vicinity of Baxter, a station on the Union Pacific Railroad where this line crosses the axis of the anticlinal fold. The beds are probably equivalent to the lower part of the Steele shale of Carbon County, Wyo.,[6] to a part of the Hilliard shale of Uinta and Lincoln counties, Wyo.,[7]

[6] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Laramie-Sherman folio (No. 173), 1910.
[7] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, p. 69, 1907.

and to a part of the upper portion of the Mancos shale of northwestern Colorado and northeastern Utah,[8] all of which have been mapped at different times as a part of the Pierre shale. The main mass of the formation as here exposed consists of a homogeneous clay shale including some layers of sandy shale and thin beds of sandstone. The greater part of the formation consists of shale in which there are no sandy layers or at least none of sufficient thickness to affect the topography. The upper part of the formation at certain horizons is characterized by belts of thinly bedded sandstone similar to those shown in Plate IX, *A*. At least two such belts are recognizable in the vicinity of Baxter Basin, as may readily be seen on consulting the topographic map of the Rock Springs quadrangle. The lower of these belts forms the top of the anticlinal arch just south of Baxter station and is well shown in Plate IX, *B*. The same belt may readily be traced north of Bitter Creek, where it forms a more or less broken line of low hills near the central part of the basin.

The upper or highest zone of these thin-bedded sandstones occurs near the top of the Baxter formation and forms a nearly continuous line of cliffs around the outer margin of Baxter Basin. These beds form a considerable part of the low, inner escarpment on both sides of the basin and mark in a general way the outer limits of the area within which drilling should be done in the search for oil. These two sandy zones are approximately 360 feet apart, and the upper one forms the rim rock of the central part of Baxter Basin. The beds are somewhat varied in character and form conspicuous low ridges because of the greater erosion of the softer shale and sandstone between them. In many ways this portion of the stratigraphic section resembled very closely the Shannon sandstone member of the Salt Creek field, in central Wyoming. The drab-gray shale of the Baxter formation below the lower sandstone zone is well exposed along the crest of the anticline in the bank south of Bitter Creek a short distance south of Baxter station and represents the lowest beds exposed in the Rock Springs dome.

The work done in this field in 1907 shows that the shales exposed in the basin along the main axis of the anticline are not a part of the Colorado shale, as supposed by Powell and more recently reported by L. W. Trumbull, State geologist of Wyoming, but belong well up in the shale that forms the lower part of the Montana group. Fossils collected from a diamond-drill core at a point 600 feet below the surface in Baxter Basin in sec. 22, T. 19 N., R. 108 W., represent a stratigraphic horizon in marine Montana beds much lower than that of any of the beds exposed along the crest of the dome north of Aspen Mountain. The logs of the wells drilled in the northern part of Bax-

[8] Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, p. 61, 1910.

ter Basin prior to 1907 indicate that the drill did not pass through the beds equivalent to the lower part of the Hilliard shale or enter the Frontier formation below it. Drilling probably stopped within the beds mapped in western Wyoming as the Hilliard shale, the upper part is represented in the Rock Springs field by the Baxter shale in Baxter Basin. All the fossils collected from the Baxter formation in 1907 and 1908 indicate that the beds are of Montana age. The fossils collected in this field and identified by Mr. Stanton include the following species:

Baculites compressus Say.
Crustacean trails.
Inoceramus sp.
Inoceramus proximus Tuomey?
Inoceramus.
Inoceramus cripsi var. barabini Morton.
Ostrea sp.
Fish scales.

UNEXPOSED BUT PROBABLY OIL-BEARING ROCKS PRESENT BENEATH BAXTER BASIN.

The rocks older than the Baxter shale and underlying it are nowhere exposed in the Rock Springs field, and any deduction or inference regarding their character or thickness in this part of Wyoming must be obtained from surrounding areas. Fortunately considerable information has been collected by the writer regarding the older rocks in near-by areas, as along the north flank of the Uinta Mountains in the vicinity of Vermilion Creek, Spring Creek, and Henrys Fork, and in western Wyoming in Uinta and Lincoln counties, so that a fair approximation of the character and thickness of the older rocks can be presented for the Rock Springs locality.

Geologic studies in this part of Wyoming and in northwestern Colorado and northeastern Utah have also been made by other geologists, and the results of these studies have been published in reports which describe the geology, structure, and mineral resources of the region and which afford ground for valuable inferences as to the probable thickness and character of the beds that lie stratigraphically below those exposed along the Rock Springs uplift. These reports, which are listed below, are useful in considering conditions in the Rock Springs field.

King, Clarence, U. S. Geol. Expl. 40th Par. Rept., vol. 1, 1878.

Powell, J. W., Report on the geology of the eastern portion of the Uinta Mountains and a region of country adjacent thereto: U. S. Geol. and Geog. Survey Terr., 2d div., 1878.

Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, 1907.

Schultz, A. R., The northern part of the Rock Springs coal field, Sweetwater County, Wyo.; the western part of the Little Snake River coal field; the eastern part of the Great Divide Basin coal field, Wyoming: U. S. Geol. Survey Bull. 341, pp. 220–282, 1907.

Schultz, A R., The southern part of the Rock Springs coal field, Sweetwater County, Wyo.: U. S. Geol. Survey Bull. 381, pp. 214–281, 1910.

Gale, H. S., Coal fields of northwestern Colorado and northeastern Utah: U. S. Geol. Survey Bull. 415, 1910.

Woodruff, E. G., and Wegemann, C. H., The Lander and Salt Creek oil fields, Wyo.: U. S. Geol. Survey Bull. 452, 1911.

Schultz, A. R., Geology and geography of a portion of Lincoln County, Wyo.: U. S. Geol. Survey Bull. 543, 1914.

Hares, C. J., Anticlines in central Wyoming: U. S. Geol Survey Bull. 641, pp. 233–279, 1916.

As many of the oil fields in central and southwestern Wyoming obtain notable quantities of oil from formations stratigraphically below the Baxter shale, it seems advisable to consider carefully the probable depth to these formations in the Rock Springs dome, where they are sealed beneath impervious rocks but some of them are within reach of the drill. Any anticline or dome where the important oil-bearing formations of the Cretaceous or older rocks are closed beneath thick beds of shale in this part of Wyoming should be considered as a prospective oil field. The accompanying table has therefore been prepared, giving the thicknesses of these older formations in neighboring fields in southwestern and central Wyoming, together with a hypothetical section of the unexposed rocks of the Rock Springs field as interpreted by the writer from surrounding areas. (See also figs. 3, 4.) As none of the formations older than the Baxter shale are exposed in the Rock Springs anticline their description will be deferred to the economic part of the report (pp. 70–83).

STRUCTURE.

ROCK SPRINGS UPLIFT.

The Rock Springs uplift lies north of the Uinta Range near its east end and east of Green River and extends in a north-south direction approximately at right angles to the Uinta uplift. It consists of a huge dome of Cretaceous and Tertiary strata which rise in the midst of the nearly horizontal rocks of the Green River Basin and partly divides the southern portion of the basin into two smaller structural units, the Bridger Basin on the west and the Red Desert Basin on the east. The major axis of the dome is approximately 90 miles long between the extreme north and south limits. The central part of the dome over which beds below the Mesaverde formation crop out is only 40 miles long and 12 miles wide. The major axis lies nearer the west side of the dome as the beds along the west limb dip 10°–20° W. and those on the east limb 5°–10° E. The minor axis is approximately 50 miles long and extends across the dome in a direction north of east and south of west, passing north of Aspen Mountain and through a point 4 miles north of Black Buttes, a station on the Union Pacific Railroad. This minor axis also divides the Red Desert Basin into two parts, the Great Divide Basin on the north end and the Washakie Basin on the south. The dips to the north and the south from this axis are low. Several small anticlines and synclines

Thickness of beds stratigraphically below base of Mesaverde formation as recognized by the author in region around Rock Springs field, Sweetwater County, Wyo.

Age classification of this report.	Western Wyoming. (Schultz, A. R., U. S. Geol. Survey Bull. 680, 1918.)	Lincoln County, Wyo. (Schultz, A. R., U. S. Geol. Survey Bull. 543, 1914.)	Uinta County, Wyo. (Veatch, A. C., U. S. Geol. Survey Prof. Paper 56, 1907.)	Henrys Fork field, Wyo.-Utah. (Schultz, A. R., unpublished notes.)	Rock Springs uplift, Wyo. (This report.)	Vermilion Creek, northwestern Colorado. (Schultz, A. R., unpublished notes.)	Northwestern Colorado. (Schultz, A. R., unpublished notes.)	Rawlins dome, Wyo. (Schultz, A. R., unpublished notes.)	Hanna field, Wyo. (Bowen, C. F., unpublished report.)	Wind River and Green mountains, Wyo. (Schultz, A. R., and Condit, D. D., unpublished notes.)	Big Horn Basin, Wyo. (Hewett, D. F., and Lupton, C. T., U. S. Geol. Survey Bull. 656, 1917.)
Cretaceous. Upper Cretaceous. Montana.	Adaville (?).	Adaville, 2,800 feet.	Adaville, 4,000+ feet.	Mesaverde.	Mesaverde, 2,100–3,350 feet.	Mesaverde.	Mesaverde.	Mesaverde.	Mesaverde, 2,700 feet.	Mesaverde.	Mesaverde, 1,120–1,410 feet.
Cretaceous. Upper Cretaceous. Montana.	Hilliard (?).	Hilliard, 3,000 feet.	Hilliard, 5,500–6,800 feet.	Hilliard, 4,800 feet. (Mancos shale of Bull. 415.)	Blair, 1,000–1,200 feet. (3,800 feet.)	Hilliard, 4,200+ feet.	Hilliard, 4,600 feet.	Hilliard, 5,000 feet.	Steele, 4,000± feet.	Steele, 2,450 feet.	Cody, 1,900–3,400 feet.
					Baxter, 1,000+ feet.				Niobrara, 370± feet.	Niobrara, 420 feet.	
Cretaceous. Upper Cretaceous. Colorado.					Not exposed.				Carlile, 200 feet.	Carlile, 150 feet.	
Cretaceous. Upper Cretaceous. Colorado.	Frontier, 3,000± feet.	Frontier, 2,400–3,800 feet.	Frontier, 2,200–2,600 feet.	Frontier, 125 feet.	Frontier, 500 feet.	Frontier, 235 feet.	Frontier, 250 feet.	Frontier, 500 feet.	Frontier, 700 feet.	Frontier, 460 feet.	Frontier, 494–648 feet.
Cretaceous. Upper Cretaceous. Colorado.	Aspen, 1,000–1,200 feet.	Aspen, 1,200–1,800 feet.	Aspen, 1,500–2,000 feet.	Aspen, 135 feet.	Aspen, 200 feet.	Aspen, 160 feet.	Aspen, 200 feet.	Mowry, 700 feet.	Mowry, 170 feet.	Mowry, 260 feet.	Mowry, 160–375 feet.
								Pink sandstone, 30 feet. Blue shale, 100 feet.	Thermopolis, 140 feet.	Thermopolis, 300 feet.	Thermopolis, 400–800 feet.
Cretaceous. Upper Cretaceous. Colorado. / Lower Cretaceous.	Bear River, 800 feet.	Bear River, 800–1,500 feet.	Bear River, 500–5,500+ feet.	Absent.	Absent.	Absent.	Absent.	Cloverly, 150 feet.	Cloverly, 231 feet.	Cloverly, 150 feet.	Cloverly, 110–300 feet.
Cretaceous (?).			Beckwith, 3,800–5,500 feet.	(?) Beckwith, 1,500 feet.	(?) Beckwith, 1,000 feet.	(?) Beckwith, 840 feet.	(?) Beckwith, 800 feet.	Morrison, 350 feet.	Morrison, 350 feet.	Morrison, 300 feet.	Morrison, 150–580 feet.
Jurassic.	Beckwith, 900–4,000 feet.	Beckwith, 900–2,400 feet.									Apparent conformity
Jurassic.	Twin Creek, 800–1,200 feet.	Twin Creek, 1,600–2,400 feet.	Twin Creek, 3,500–3,800 feet.	Twin Creek, 140 feet.	Twin Creek, 140 feet.	Twin Creek, 140 feet.	Twin Creek, 210 feet.	Sundance, 200 feet.	Sundance, 85 feet.	Sundance, 200 feet.	Sundance, 250–530 feet.
Jurassic.	Nugget, 500–1,000 feet.	Nugget, 500–800 feet.	Nugget, 1,900 feet.	Nugget, 1,600 feet.	Nugget, 1,000 feet.	Nugget, 1,000 feet.	Nugget, 800 feet.	Chugwater (red), 950 feet.	Chugwater (red), 1,000 feet.	Chugwater (red), 1,200–1,400 feet.	Chugwater (red), 700–1,100 feet.
Triassic (?).	Ankareh, 200–500 feet.	Ankareh, 500 feet.		Ankareh, 300 feet.	Ankareh, 300 feet.	Ankareh, 300 feet.	Ankareh, 300 feet.				
Lower Triassic.	Thaynes, 700–1,000 feet.	Thaynes, 1,000–2,000 feet.	Thaynes, 2,400–2,600 feet.	Thaynes (?), 290 feet.	Thaynes (?), 0–200 feet.	Thaynes (?), 200 feet.	Thaynes (?), 200 feet.				
Lower Triassic.	Woodside, 800–1,000 feet.	Woodside, 400 feet.	Woodside, 500 feet.	(?) Woodside, 500 feet.	(?) Woodside, 300 feet.	(?) Woodside, 556 feet.	(?) Woodside, 500 feet.			Dinwoody, 30–200 feet.	Embar, 250–480 feet.
Permian.	Phosphoria, 75–400 feet.	Park City, 1,400 feet.	Park City, 700+ feet.	Park City, 450 feet.	Park City, 200 feet.	Park City, 186 feet.	Park City, 200 feet.	Park City, 160 feet.	Not described.	Park City, 160–300 feet.	
Pennsylvanian.	Wells, 300–1,000 feet.	Weber, 1,000 feet.	Weber, 1,000+ feet.	Weber, 2,000 feet.	Weber, 1,000 feet.	Weber, 2,000 feet.	Weber, 2,150 feet.	Weber, 600 feet.		Tensleep, 300–500 feet.	Tensleep, 30–230 feet.
Pennsylvanian.		Undifferentiated, 9,000 feet.	Not discussed.	Pennsylvanian limestone, 2,100 feet.	Older Pennsylvanian, 1,000 feet.	Pennsylvanian limestone, 2,100 feet.	Pennsylvanian limestone, 2,400 feet.	Carboniferous limestone, 1,100 feet.		Amsden, 200 feet.	Amsden, 150–200 feet.
Mississippian.	Brazer, 200–1,000 feet.			Mississippian limestone, 2,500 feet.	Mississippian, 1,000 feet.	Mississippian limestone, 2,200 feet.	Mississippian limestone, 2,100 feet.			Absent (?).	
Mississippian.	Madison, 1,000 feet.									Madison, 500 feet.	Madison, 600–1,000 feet.
Devonian.	Probably Threeforks, 200 feet.	Probably Threeforks, 80 feet.		Not measured.	Undifferentiated Devonian (?) to base of Cambrian quartzite, 1,500 feet.	Not measured.	Pre-Carboniferous to base of Cambrian quartzite, 2,100 feet.	Absent (?).		Devonian and Silurian, 30–140 feet.	Absent (?).
Devonian.	Probably Jefferson, 150 feet.	Jefferson, 1,000 feet.									
Silurian.	Dolomite, 50 feet.	Probably represented.									
Ordovician.	Bighorn, 250 feet.	Probably Bighorn.								Bighorn, 100 feet.	Bighorn, 150–300 feet.
Cambrian. Upper.	Gallatin limestone, 200 feet.	Undifferentiated.								Gallatin, 250 feet.	Deadwood, 700–900 feet.
Cambrian. Middle (?).	Gros Ventre, 800 feet.									Gros Ventre, 450 feet.	(?)
Cambrian. Middle.	Flathead quartzite, 250 feet.							Quartzite, 250 feet.		Flathead quartzite, 300 feet.	
Pre-Cambrian.	Schists, etc.				Undifferentiated, 13,000? feet.		Red quartzite, 13,000 feet.	Granite.		Granite.	Granite.
					Red Creek quartzite.						

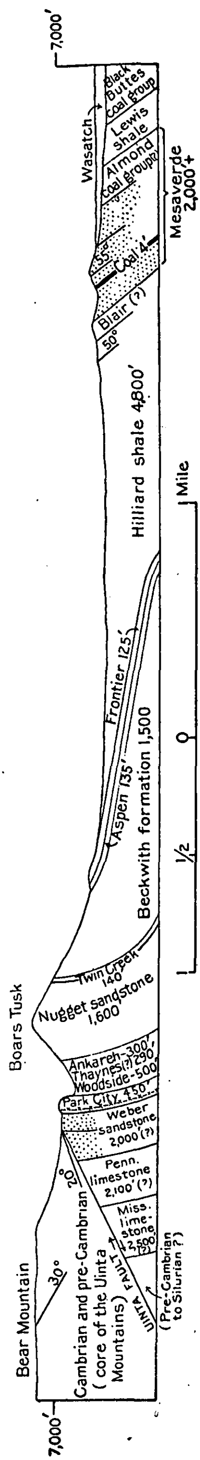


FIGURE 3.—Section of beds from base of Mesaverde formation to Cambrian measured east of Green River, near the mouth of Henrys Fork, in T. 3 N., R. 21 E. Salt Lake meridian, Utah.

are superposed upon the main dome, but for the most part they are not important oil structures. Two of the largest of these cross folds occur near the south end of the dome and are more nearly parallel to the minor axis and to the trend of the Uinta uplift than they are to the major axis. The oldest beds exposed along the crest of the dome are of Montana age. They crop out in the vicinity of Baxter, a station on the Union Pacific Railroad, and extend for a distance of about 30 miles along the crest of the dome. The attitude of the basin is indicated in the three cross sections in Plate X. The anticline plunges both to the north and to the south, so that the highest part of the dome is in the vicinity of Aspen Mountain.

Although at first glance this large dome appears to be perfectly regular and simple, a more careful study reveals many irregularities. It is in fact not a simple north-south fold but one that has been warped and

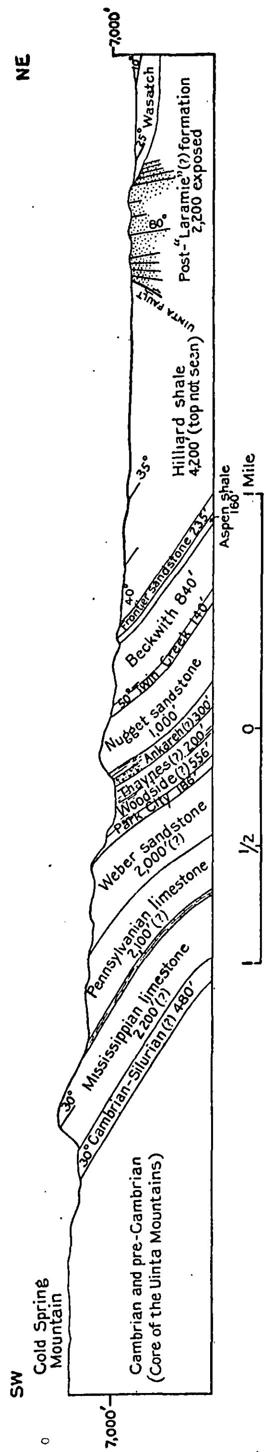
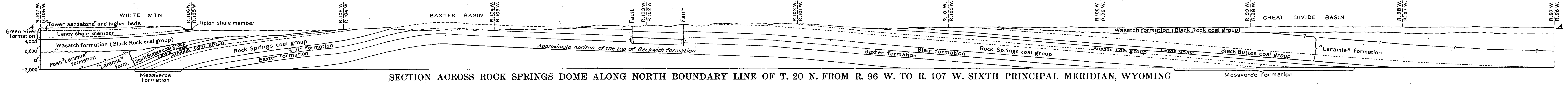


FIGURE 4.—Section of beds from upper part of Hilliard shale to Cambrian, measured in Vermilion Creek area, in T. 10 N., R. 101 W. sixth principal meridian, Colo.

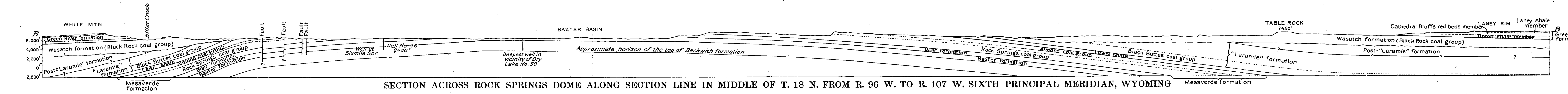
twisted both in a north-south and an east-west direction, so that the course of its major axis varies from place to place, and the variations give rise to minor warps, wrinkles, and folds. A short distance north of Aspen Mountain the major axis slightly changes its course and extends in a north-south line to Baxter station. There is, however, another axis of minor importance that extends in a northeast direction toward Salt Wells, which gives the northward-plunging fold a broad crest whose highest part lies along the major axis. Southward from Aspen Mountain the fold narrows somewhat and then plunges more rapidly toward the south. In the vicinity of the Brooks ranch the crest of the major uplift is again divided into three folds whose axes extend in different directions. The general outline and attitude of the beds in the central part of the dome in which the Baxter shale is exposed suggest the contour of a man's right foot whose heel is placed south of Jacobs ranch, the large toe at the north end of Baxter Basin and the small toe at Salt Wells station, with the arch of the foot covering Aspen Mountain. The part of this fold that is the highest and therefore most favorable for the accumulation of oil lies in the vicinity of Aspen Mountain, and the area that should be drilled is represented in the man's foot by the position of the ankle.

The central part of the Rock Springs dome within the outcrop of the surrounding sandstone ridges of the Rock Springs coal group and the underlying shaly sandstone of the Blair formation is about 30 miles long and 10 miles wide. The dips in this part of the dome are low—about 4° E. and 10°–20° W., although locally they may exceed these amounts. Few structural observations were made within the area of shale outcrop in the center of the dome, as the work on which this report is based was restricted primarily to the overlying coal-bearing formations around the margin of the basin. The attitude of the beds in this part of the field as far as known is indicated by the cross sections shown in Plate XI (p. 40).

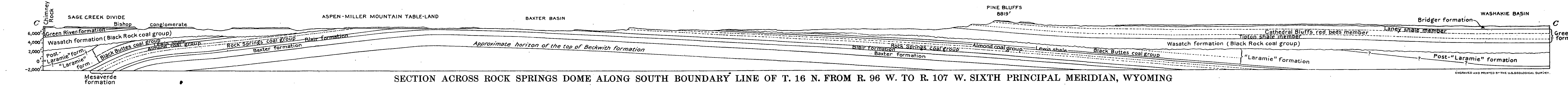
No pronounced folds were observed north of Aspen Mountain, but the occurrence of secondary folds is indicated by the presence of two small anticlines south of Aspen Mountain, near the south end of the dome. The larger of these transverse anticlines, which is in T. 14 N., Rs. 100, 101, 102, 103, and 104 W., is associated with an overthrust fault which is in turn believed to be related to a major overthrust fault along the north flank of the Uinta Mountains, about 20 miles to the south. The structure in this part of the field indicates that the south end of the Rock Springs dome was affected by the uplift of the Uinta Mountains and that by careful search smaller secondary anticlines, somewhat similar to those mentioned above, may be found on the major uplift at least as far north as Aspen Mountain, and perhaps farther north. On the other hand, it is highly probable that there



SECTION ACROSS ROCK SPRINGS DOME ALONG NORTH BOUNDARY LINE OF T. 20 N. FROM R. 96 W. TO R. 107 W. SIXTH PRINCIPAL MERIDIAN, WYOMING



SECTION ACROSS ROCK SPRINGS DOME ALONG SECTION LINE IN MIDDLE OF T. 18 N. FROM R. 96 W. TO R. 107 W. SIXTH PRINCIPAL MERIDIAN, WYOMING



SECTION ACROSS ROCK SPRINGS DOME ALONG SOUTH BOUNDARY LINE OF T. 16 N. FROM R. 96 W. TO R. 107 W. SIXTH PRINCIPAL MERIDIAN, WYOMING

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY.

2 1 0 2 4 6 8 10 MILES

are in this area minor folds which do not reach the surface or which have not been observed in the mass of shale. Such folds or benches may retain oil in sufficient quantity to warrant commercial development after they are located by the drill.

Within the central shale area north of Aspen Mountain in T. 18 N., R. 103 W., according to State Geologist Trumbull,[9] there is a small dome about 6 miles long from northeast to southwest and about 2½ miles wide. The southeast limb of the dome is reported to have a dip of about 5°; the northwest dip averages about 15° and an extreme dip of 20° was measured at one point. To this minor dome Trumbull applies the name Dry Lake dome, after the dry lake or pond that lies almost on its crest. This lake is shown on the United States Geological Survey's map of the Rock Springs quadrangle. The data collected by the writer in 1908 indicate that there may be a minor warping of the beds in this vicinity but not a pronounced secondary dome. It is indeed questionable whether this part of the major fold even represents a favorable locality for the accumulation of oil, if any oil is present in the beds. It is reasonably certain that this area of minor warping does not represent the highest part of the fold or even one of the minor crests along the main axis that should furnish good locations for prospecting for oil. If a crest of a small dome is present here it would follow that similar domes should be found along the major axis both to the north and south, separated from the Dry Lake dome by low saddles or depressions, somewhat as in the Salt Creek field, in central Wyoming, where there are the Salt Creek dome and the two crests on the Teapot dome. Until a great deal more is known regarding the details of structure along the major north-south axis of the Rock Springs dome the most desirable location for an oil prospect can not be selected with any degree of certainty. Considerable drilling may be necessary before the exact location of the oil pool or pools can be accurately determined.

The map accompanying this report (Pl. I, in pocket) shows in a general way the structure of the Rock Springs dome and indicates the position of the main axis, which extends from the southwest corner of T. 24 N., R. 103 W., about 15 miles north of the north end of Baxter Basin, southward through the west tier of sections in T. 103 W. to the north end of Baxter Basin in T. 20 N., R. 104 W., thence nearly southward to Baxter station on the Union Pacific Railroad, thence southward in the same tier of sections to Aspen Mountain, in sec. 14, T. 17 N., R. 104 W., thence southward near Jacob's and Brooks's ranches in Tps. 15 and 16 N., R. 104 W., respectively, to the south end of the dome, in T. 14 N., R. 103 W., near the head-

[9] Trumbull, L. W., Rock Springs uplift and Dry Lake dome, map pl. 12, 1915.

waters of Salt Wells Creek, west of Rife Mountain. About halfway between Aspen and Rife mountains the major north-south fold is divided into three subordinate folds. The westernmost of these subordinate folds extends southward, in line with the major fold, but the other two make sharp bends toward the southeast and form the two transverse anticlinal folds in Tps. 14 and 15 N. These folds plunge steeply toward the southeast and, together with the shallow syncline between them, die out entirely at the Kinney Rim. The shallow synclinal basin a few miles to the north extends to Pine Butte and thence eastward into Washakie Basin, where it merges with the north-south depression of the Red Desert Basin, in which Washakie Basin lies.

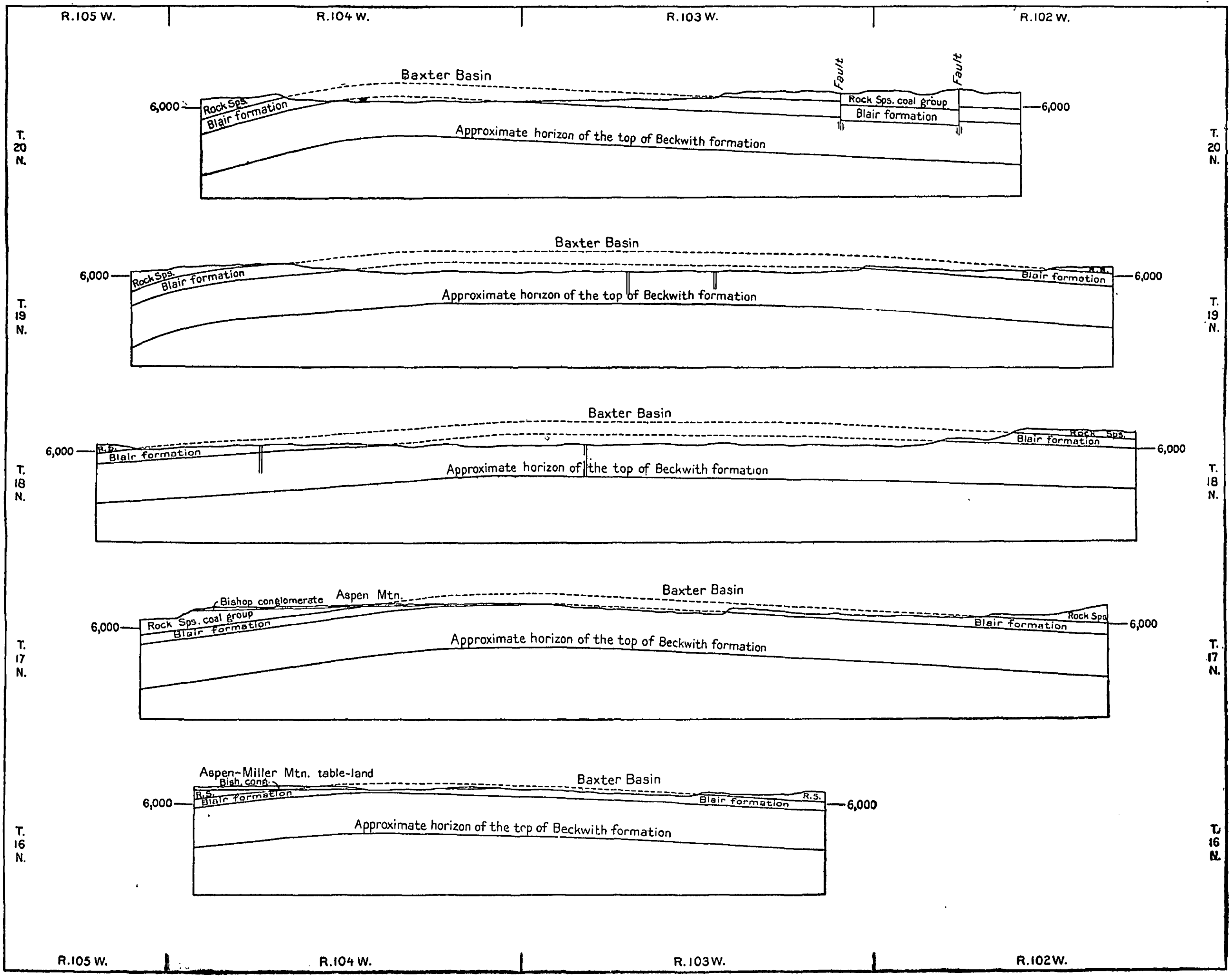
RED CREEK SYNCLINE.

The Rock Springs dome is separated from the Uinta uplift by a narrow and comparatively shallow synclinal depression that trends eastward, parallel to the Uinta fold. The axis of the syncline lies in the southern third of T. 13 N., approximately halfway between the south end of the Rock Springs dome and the Uinta fault, along the north base of the Uinta Mountains, and extends from Little Mountain, in R. 106 W., eastward to the Kinney Rim, in R. 100 W., a distance of nearly 36 miles. A part of the synclinal depression lies in the Red Creek basin, and the eastern part lies in the Vermilion Creek basin nearly parallel to the North Fork of Vermilion Creek, passing a short distance south of Rife's ranch, in T. 13 N., R. 101 W. The dips on the north limb of the syncline range from 2° to 10° and those on the south limb range from 4° to 30°. The dips of the rocks and the location of the axis of the syncline are shown on the map (Pl. I).

RED DESERT SYNCLINE.

GENERAL FEATURES.

East of the Rock Springs dome and parallel to its major axis lies the broad, open, and shallow synclinal basin of the Red Desert. This synclinal depression lies between the Rock Springs uplift, Wind River, and the Uinta Mountains on the west and the Rawlins uplift, the Green Mountains, and the Sierra Madre on the east. The beds in this basin are nearly horizontal but dip at low angles toward the center of the basin. The axis of this synclinal depression is approximately 100 miles long, and the distance across the basin from east to west is about 70 miles. As in the Rock Springs uplift, there are numerous changes in the direction of this syncline, but for the most part the dips are so low and the basin so wide that it is impracticable to locate the axis of the syncline definitely. Here, too, there are numerous warps and wrinkles in the nearly horizontal beds, so that the



SECTIONS ACROSS THE CENTRAL PART OF THE ROCK SPRINGS DOME BETWEEN THE NORTH BOUNDARY LINE OF T. 20 N. AND THE SOUTH BOUNDARY LINE OF T. 16 N., AT INTERVALS OF APPROXIMATELY 7 MILES.

north-south depression is divided into a number of smaller units by the east-west folds that extend across all or a part of it. Some of the more pronounced folds are briefly described below.

WAMSUTTER ARCH.

North of the Laney Rim in the vicinity of Wamsutter, Wyo., and north of the Union Pacific Railroad track is a low arch that divides the Red Desert Basin into two separate basins, the Great Divide Basin on the north and the Washakie Basin on the south. The beds along this arch dip 2°–3° N. and 2°–6° S. This low anticlinal arch probably represents the eastward extension of the minor fold that crosses the Rock Springs dome north of Aspen Mountain. In the area that lies along the crest of this low arch between the Rawlins and Rock Springs domes the beds of the Green River formation have been removed by erosion, and the beds exposed are a part of the Black Rock coal group. The prominent escarpment a few miles south of the Union Pacific Railroad marks the northern limit of Washakie Basin. In the central part of this basin the beds exposed at the surface are a part of the Bridger formation, but the escarpment surrounding the basin is composed of beds of the Green River formation.

CHEROKEE RIDGE FOLD.

At the south end of Washakie Basin, in the vicinity of Cherokee Ridge, approximately 20 miles east of the Vermilion Creek basin, the Bridger and underlying Tertiary beds have been compressed into a comparatively sharp fold, and the beds have been further complicated by considerable faulting. This fold is nearly parallel to the Wamsutter arch and like it separates part of the Red Desert Basin into smaller structural units. The ridge, which received its name from the old Cherokee trail that followed its summit for several miles, forms an anticline whose axis strikes a little south of west and which plunges slightly in this direction. On the south limb of the anticline the beds are very much broken and dip at angles as high as 25° to 30° but on the north the dip is only about 10°. On the north side of Cherokee trail were found beds dipping 7° N. The beds flatten out as they extend northward into Washakie Basin, all of which is underlain by Bridger beds, Laney shales, Cathedral Bluffs red beds, and the Tipton shale. At the east end of the ridge, in the vicinity of Otter Gap, the underlying Cathedral Bluffs red beds are exposed in the deeper valleys along Snake River. The fold becomes less conspicuous toward the west as it passes into the Vermilion Creek basin, where the crest of the arch is broad and low. Along the axis of the fold in the Vermilion Creek basin are exposed the beds of the Black Rock coal group, and in the vicinity of Canyon Creek, on the west side of the basin, coal mines have been opened for local supply.

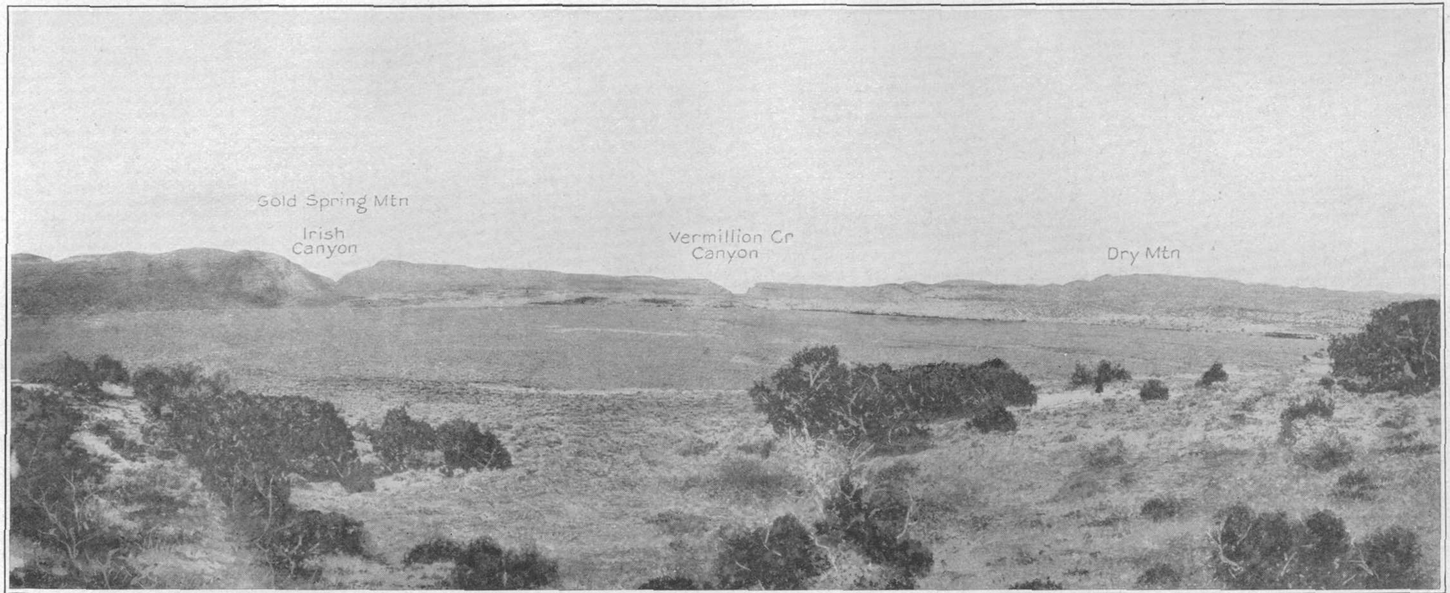
LOOKOUT MOUNTAIN ARCH.

The high table-land east of Lookout Mountain (Vermilion Bluff of the King Survey) and approximately 10 to 15 miles south of the Cherokee Ridge fold represents a low anticlinal fold in the Tertiary beds that crosses nearly at right angles the north-south synclinal valley that extends from the east end of the Uinta Mountains in the vicinity of Little Snake River northward to Wamsutter and thence northward to Green Mountain, forming the depression of the Red Desert Basin in which lie the Great Divide Basin on the north, the Washakie Basin near the center, and several smaller basins near the south end of Red Desert. The strata along the summit of the plateau dip from 1° to 2° toward the north and about the same amount toward the south. The beds on the south side of the plateau dip in accord with the general slope of the surface and form the shallow synclinal basin that lies between Elk Gap, northeast of the 2-Bar ranch, on Little Snake River, and the east end of Cold Spring Mountain. Several miles south of the east end of the ridge in the vicinity of Sunny Point the dip abruptly becomes steeper, and the Green River beds come down to the level of Snake River. From this point to Elk Gap Canyon there seems to have been a local disturbance, resulting in the flexure and probable dislocation of the beds. Not far above the canyon the dips change for a short distance from south to north. At Elk Gap the beds again dip toward the south at an angle of 10° and lie on the south side of another anticline approximately 16 miles south of the Lookout Mountain arch.

The western extension of the anticline observed in the table-land between Sunny Point and Lookout Mountain may be represented by the anticline that passes through Sugar Loaf Butte in T. 11 N., R. 101 W. The beds here dip about 5° N. and 7°–9° S. Farther northwest the fold appears to have died out entirely, and on the north fork of Vermilion Creek it is somewhat disturbed by the movement that took place along the great Uinta fault, which, from Green River eastward, lies along the north base of the Uinta Mountains. In the vicinity of Lookout Mountain the top of the escarpment on the south side of this fold is capped by a remnant of the Bishop conglomerate about 50 feet thick. At this point the beds dip approximately 2° to the east and south, but farther southwest, toward Vermilion Creek canyon, the southeasterly dips gradually steepen to 12° and 15°.

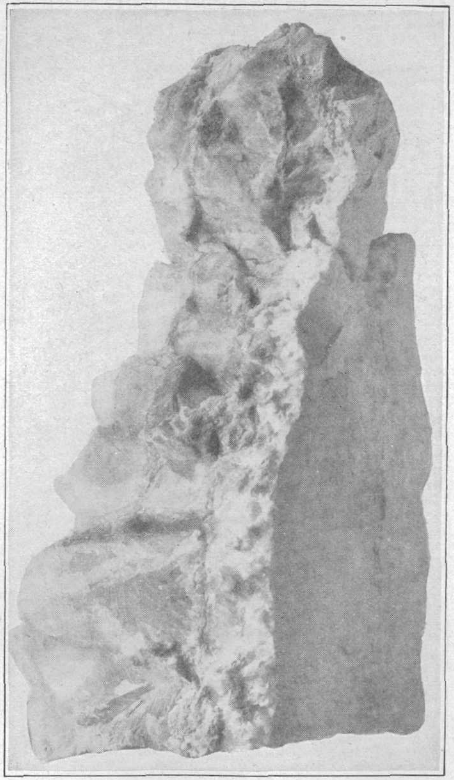
DRY MOUNTAIN ANTICLINE.

In the vicinity of Dry Mountain, 10 to 16 miles south of the Lookout Mountain arch, is another sharp anticlinal fold which may be called the Dry Mountain anticline. The low range composing this fold extends in a southeasterly direction from Vermilion Creek to Snake River and topographically appears to be a continuation of the

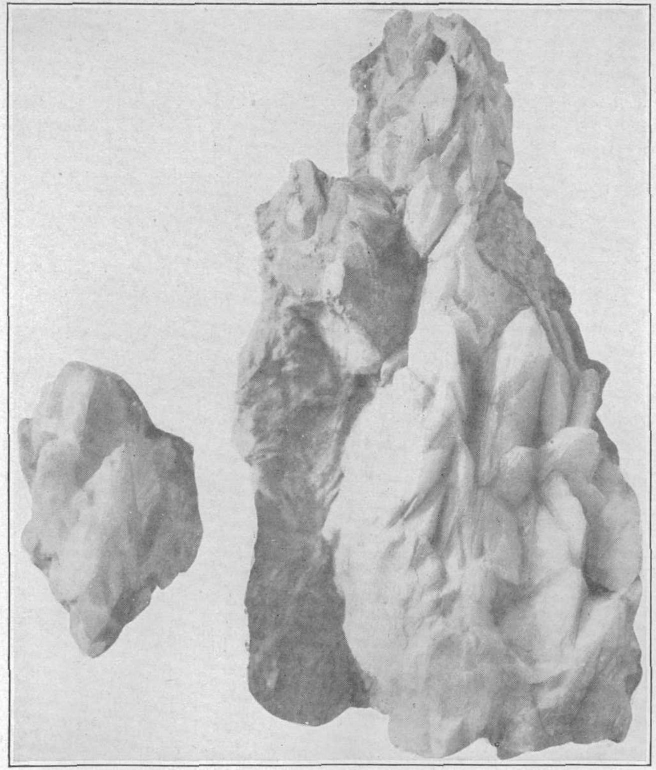


ATTITUDE OF THE TERTIARY BEDS AT THE WEST END OF DRY MOUNTAIN ANTICLINE, IN THE VICINITY OF VERMILION CREEK CANYON.

Beds in the foreground are part of the Browns Park formation of Powell (mapped as Bridger formation in this report).



A. CALCITE FILLING VEIN CAVITY AND WALL OF SHALE TO WHICH IT IS ATTACHED.



B. FRONT VIEW OF CALCITE CRYSTALS FILLING CAVITY ALONG FAULT PLANE.

FRAGMENT OF CALCITE TAKEN FROM VEIN ALONG FAULT CONTACT IN THE NE. ¼ SEC. 36. T. 20 N., R. 104 W., 4 MILES NORTHEAST OF BAXTER STATION AT LOCALITY NO. 53.

monoclinal ridge of Carboniferous and Mesozoic rocks at the east end of Cold Spring Mountain and the anticlinal folds exposed at the lower end of Vermilion Creek canyon. The Dry Mountain flexure, however, is composed at the surface of Tertiary beds covered in places by smaller outliers of the Bishop conglomerate, although beds of Mesozoic age may underlie the Tertiary beds in part of the fold, in the same way as they do for a short distance east of Vermilion Creek canyon. At the edge of the ridge south of the synclinal basin steeply inclined beds are encountered. Here the dip is 20°, and within a short distance it increases to 57°. The slopes are covered with fragments of fine-grained limestone suggesting a Carboniferous deposit, but farther up the ridge Green River clays appear and the ledges of limestone contain *Goniobasis* and *Unio*, which indicate the Tertiary age of these beds. Toward the base the beds are rather more calcareous and sandy than farther east. At several places along the Dry Mountain anticline as far east as Elk Gap the strata have been faulted and dislocated. This anticlinal flexure probably also marks in an irregular manner the eastward continuation of the displacement along the north flank of the Uinta Mountains which has been designated the Uinta fault. The exact location of the fault in the vicinity of Dry Mountain has not been determined, on account of the Tertiary cover. It may extend southeastward and connect with the large faults in the vicinity of Cross and Juniper mountains on Bear River. The dividing line between the Laney shales and the underlying Cathedral Bluffs red beds can be traced along the line of the bluffs from Lookout Mountain to Vermilion Creek canyon, descending somewhat toward the canyon. The summit of the ridge southeast of the canyon, which separates the basin of Vermilion Creek and Browns Park, is made up of beds of white calcareous Tertiary rock that form a part of the Browns Park group of Powell, which in the vicinity of Dry Mountain has been traced by the writer into the Bridger formation of Washakie Basin. These beds slope off on the south of the ridge into the basin of Browns Park at angles of 5° to 7°. On the crest of this ridge, east of the canyon, where the limestones resembling the Carboniferous rocks have been exposed, are patches of conglomerate containing pebbles of red quartzite, which have been referred to the Bishop conglomerate. The general attitude of the beds in this part of the field is shown in Plate XII.

The anticline in the older beds where they are exposed along the canyon of Vermilion Creek in Tps. 9 and 10 N., R. 101 W., is not a simple anticlinal arch but is composed of at least three distinct anticlinal crests parallel with one another. The same folds appear in the overlying Tertiary beds, but the dips apparently are not as steep as in the older rocks. Whether these separate minor folds can be traced for a considerable distance to the east was not determined.

Along Vermilion Creek the oldest rocks are exposed in the anticline farthest to the southwest, where the rocks on the crest of the fold consist of Cambrian quartzite or the red sandstone of the Uinta Mountains. The relations of the folds in the older rocks and the overlying Tertiary beds in the vicinity of Vermilion Creek canyon may best be shown by the accompanying diagrammatic sketch of the beds along the east side of the canyon (fig. 5).

At the east end of the Dry Mountain anticline, on Snake River, in the vicinity of Elk Gap, a singular unconformity exists. The lower beds, which are believed to represent the upper part of the Cathedral Bluffs red beds, dip at an angle of only 10° S. Stratigraphically above them is a series of clays and sandstones, having at the base a prominent seam of red shale, which dip 25°–30° S. Overlying these beds, at some little distance down the river, are apparently conformable beds of fine white calcareous and siliceous material believed to be a part of the Browns Park group of Powell (here mapped as Bridger formation), sloping off gently into the basin of

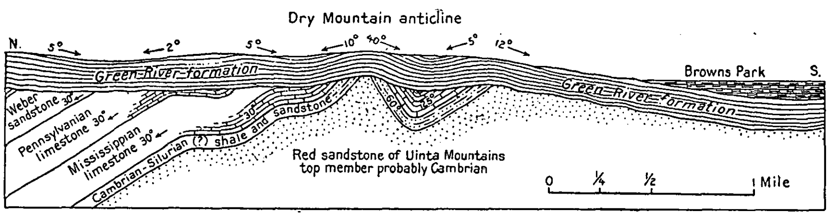


FIGURE 5.—Diagram showing the relation of the Tertiary beds to the underlying older rocks along the Dry Mountain anticline in the vicinity of Vermilion Creek canyon, T. 9 N., R. 101 W., Colo.

lower Snake and Bear rivers, which forms the eastern continuation of the depression in which lies Browns Park.

Southeast of Snake River the ridge is capped by white calcareous beds containing a silicified layer made up of casts of *Goniobasis*, which is so prevalent throughout the Green River beds to the north. The rocks in this locality have a general southward dip, but on the north spurs toward the river incline about 3° N. The white calcareous beds are believed to be the Laney shale and are underlain by the Cathedral Bluffs red beds, which are exposed along the northern flanks of the ridge and extend out into the country to the east, where they have a general dip of 5° N. Southeast of Snake River there is apparently an unconformity between the overlying beds and the Cathedral Bluffs red beds, though much less marked than that observed at Elk Gap. Northwest of Elk Gap the strata descend toward the north, forming the synclinal basin between Elk Gap on the east and Cold Spring Mountain on the west, the Lookout Mountain arch on the north and the Dry Mountain anticline on the south. Between the Dry Mountain anticline and the Uinta Mountains lies the eastward extension of the Browns Park basin.

STRUCTURE CONTOURS.

No attempt was made in the field to work out the details of structure along the central part of the Rock Springs dome, and therefore it did not seem advisable to prepare a structure-contour map on the same scale as that of the geologic map. The data at hand do not warrant the compilation of a carefully prepared structure-contour map drawn on any of the sandstone lentils or geologic contacts that were mapped in the field. It did seem advisable, however, to prepare a small-scale map in order to indicate the probable structure as interpreted from the collected data, and such a map is presented on Plate I (in pocket). The structure contours are drawn on the upper surface of the highest sandstone lentil of the Baxter formation, because this stratum was mapped in the field over a considerable area in the basin and represents one of the lowest beds that is well exposed and sufficiently characteristic lithologically to be identifiable in different parts of the field. This shaly sandstone, because of its lithologic similarity, is believed to represent approximately the horizon of the Shannon sandstone member of the Salt Creek field, in which the upper oil occurs. The structure contours represent the anticline as interpreted from the position of this sandstone before it was partly destroyed by erosion. They have no relation whatever to the present topography but were drawn by means of surface altitudes determined at different points along the outcrops, dip and strike readings, and measurements of stratigraphic distances between prominent overlying and underlying beds of sandstone or characteristic bands of shale. No wells have penetrated this sandstone back from the outcrop, and it is therefore impossible to check the accuracy of the structure mapping or to calculate the depth of the top of the sandstone in any other way than by dips and strikes. The writer believes that minor irregularities are present in the fold, but without additional data obtained by means of drill records such irregularities can not readily be determined and are not indicated on the map. The base of the Rock Springs coal is another important key rock above the datum surface and was used in part of the field in determining the position of the structure contours on the sandstone. As the interval between these two key beds is not everywhere the same, considerable error may have been introduced wherever it was necessary to use the base of the coal group as a level from which to calculate the position of the datum surface. A structure-contour map prepared in this manner is obviously far from accurate, but it is the best representation of the real conditions that can be made from the meager facts at hand and will be distinctly useful.

FAULTS.

The great Uinta fault, along the north side of the Uinta Range, as well as the Red Creek syncline, no doubt separates the greater part of the Uinta anticline from the Rock Springs dome whose major axis is nearly at right angles to that of the Uinta fold. This fault has completely sealed the south end of the Rock Springs dome, so that the oil has not escaped in this direction. The structural relation of the older rocks at the junction of these two folds is entirely concealed by Tertiary beds and can only be inferred from the structure ascertained at more distant points on the folds. The two folds are closely related structurally, however, and the faulting observed elsewhere in the Uinta Range[10] is equally well represented, although on a somewhat smaller scale, in the Rock Springs region.

The general structure of the Rock Springs arch is somewhat complicated by many normal faults of considerable throw. Here and there the horizontal displacement along the fault line amounts to 3 miles; the vertical movement is usually less than 100 feet but in a few localities reaches several hundred feet. Near the south end of the Rock Springs dome, in T. 14 N., R. 103 W., along the crest and south limb of a low anticline that is more nearly parallel to the Uinta uplift, is an overthrust fault which has a vertical displacement of 200 feet. The fault plane dips about 20° to the south, indicating that the thrust came from that direction.

The sandstone ridges that surround Baxter Basin are cut by a number of dip faults, particularly along the eastern and western borders of the arch, and at some places, as in the vicinity of the Union Pacific Railroad, these faults may be continuous across the dome. Whether or not these displacements cut the Frontier or other sandstones near the base of the Colorado group can not be stated positively, but they are probably all taken up in the shale above the Frontier sandstones, or, if continuous, they may make only slight flexures in the sandstones near the base of the Colorado group. Along some of these fault planes in the Baxter shale, notably north of the Union Pacific Railroad northeast of Baxter station, the position of the fault is marked by small, low dikes or veinlike deposits of calcite that stand several inches to a foot above the decomposed shale. Where the dike or vein material, which is from half an inch to 12 inches in thickness, does not rise above the surface the line of the fault can be traced by the fragments of calcite strewn along it. Two of the fault contacts where a vein deposit of this type can best be studied lie approximately 3 and 4 miles north of Baxter. The material may readily be picked up along the fault in sec. 1, T. 19 N., R. 103 W.,

[10] Schultz, A. R., A geologic reconnaissance of the Uinta Mountains, northern Utah, with special reference to phosphate: U. S. Geol. Survey Bull. 690, pp. 31-94, 1918.

in sec. 6, T. 19 N., R. 104 W., and in sec. 36, T. 20 N., R. 104 W. The appearance of some of this calcite, filling fissures along fault planes, is well illustrated in Plate XIII, showing material obtained at locality 53. (See Pl. I.)

These dikes or veins of calcite, as well as the fragments strewn along the surface, represent vein deposits of calcite that fill or partly fill the fissures produced by faulting. Careful search was made along some of these dikes to ascertain whether or not ozokerite, or mineral wax, was associated with the calcite, but none was found. Certain of the faults in the shale may extend down to a sand in which oil may be stored and afford passages through which oil in the sand under great pressure may be forced upward to the surface. If the faults do not cut an oil sand or if the fissures are completely recemented with calcite or other material so that the oil could not reach the surface, no ozokerite would be found associated with the vein deposit.

The ozokerite that in some fields is associated with the calcite which fills all fault fissures at the surface is produced by the evaporation of oil which has risen in these fissures and long remained there. It is noteworthy that most deposits of ozokerite in calcite veins appear to be confined to the area immediately above the oil pool and are not found in the adjoining areas, perhaps because the gas pressure immediately over the oil pool is the greatest and the oil is forced close to the surface, whereas at greater distances from the pool the pressure is not so great and the oil is not forced upward to produce seepages and deposits of mineral wax. The absence of mineral wax in calcite veins does not prove the absence of oil in a fold; it may indicate that the fissures or veins do not cut an oil sand or that the oil pool lies in some other part of the fold not cut by faults.

In the Rock Springs region some of the faults extend across the dome, others cut one limb or part of one limb, and still others extend for a few hundred feet or a mile or two and then die out. Some of the larger faults have been traced for more than 20 miles. The general trend of the faults is nearly at right angles to the strike of the rocks, or across the major axis of the dome. In some places, however, the angle of departure is large and the fault more nearly parallels the strike than the dip of the beds. This is well illustrated near the north end of the dome, where the faults cut some of the rocks at right angles to their strike but before dying out continue approximately along the strike of the underlying beds. The position of the larger faults is shown on the map accompanying this report (Pl. I). In addition to the larger faults that are readily detected on the surface, numerous small faults are encountered in coal-mine workings, and similar faults no doubt are also present in the shale areas. In the Rock Springs coal group, from the Van Dyke or lowest coal bed upward, there is at many places a system of characteristic joints or slips that cut the coal at short intervals from floor to roof. These slips incline toward the south, and along many of them the displacement is half an inch to a foot or more. The exact period of the faulting is not known. It may have occurred at different times during the gradual uplift of the dome, after the end of the epoch of Cretaceous deposition. It is believed, however, that most if not all of the faulting in the Rock Springs area occurred at the time the leucite lava flows at its north end were poured out and was associated with the movements that gave rise to the renewed uplift in the Uinta Mountains immediately before the period of deposition of the Bishop conglomerate, which, so far as known, is nearly independent of the faults and folds in the underlying rocks and is either of Bridger or post-Bridger age. Both minor folding and faulting, however, have taken place in different parts of the field since the deposition of the Bridger formation.

OIL-BEARING ROCKS.

TYPES.

In the Rock Springs field the rocks from which oil can be extracted are of two very distinct types, having a different distribution and geologic history. Oil can be obtained by distillation from the oil shale that is found in certain beds of the Green River formation of Tertiary age. The rocks containing these oil-shale beds are distributed around the central area of the Rock Springs dome and form a part of the Tertiary table-lands and escarpments. Practically no attention has been given to these beds by oil prospectors, and no attempt has been made to extract oil from them in commercial quantities. The rocks of the other type range in age from Cretaceous to Cambrian and form the central dome of the Rock Springs uplift. With the exception of the upper strata of the Cretaceous these beds have not been exposed in this part of the State by erosion. It is believed that some of them contain sands in which oil and gas have collected and that careful and thorough prospecting will prove the presence of oil and gas in parts of this fold as it has in other folds in many fields in Wyoming. Each of these types of oil-bearing rocks will be discussed more fully in the subsequent pages.

OIL SHALE EXPOSED IN ROCK SPRINGS UPLIFT.

GENERAL FEATURES.

The Green River beds, of early Tertiary (Eocene) age, from which oil is distilled in Sweetwater County, Wyo., consist predominantly of shale. The oil shale of the Green River formation is confined to two distinct members, the lower or Tipton shale member and the upper or Laney shale member. The Laney overlies the Cathedral Bluffs red beds member near the middle of the Green River formation. On the west side of the Rock Springs uplift the Tipton and Laney members are not distinct, as in this part of the field the Cathedral Bluffs red beds, which separate them, lose their characteristics and resemble typical Green River beds, so that the entire formation is lithologically alike. It represents both the lower and upper members of the oil shale, but by earlier writers it has been correlated with the upper oil-shale member on the east side of the Rock Springs dome. The oil shale in the lower or Tipton member is more likely to be of the papery variety, and that in the upper member is more likely to be of the hard, massive type, although it includes also considerable papery shale. The oil shale in this part of Wyoming appears to contain somewhat less oil than the shale farther south, in northwestern Colorado and northeastern Utah, but it is apparently about the same in the vicinity of Green River, on the west side of the Rock Springs dome, as along the western margin of Washakie Basin in the Red Desert, on the east side of the dome. The shales range from very lean beds, yielding less than 1 gallon of oil to the ton of shale, to fairly thick beds, yielding 30 to 35 gallons to the ton. Four of the best shale samples upon which tests were made were obtained from the upper member of the Green River formation, and yielded 29, 30, 32, and 34 gallons of oil to the ton of shale. The remainder of the samples yielded from 3 to 20 gallons of oil to the ton and gave about the same returns, irrespective of whether they came from the lower or the upper member. The total number of samples tested in this field is 37, of which 12 yielded less than 10 gallons to the ton of shale and 25 yielded 10 gallons or more to the ton. The average yield for the 37 samples was a little more than 14 gallons. All the samples from both the lower and upper members were collected in the southern part of the Rock Springs field, and no tests have been made of the shales of either member in the northern part of the field.

CHARACTER OF OIL-SHALE BEDS.

The first sample of oil shale from the Green River beds observed by the writer was collected by him in 1905 in Lincoln County at Fossil Butte, north of Fossil, Wyo., within a few miles of the Oregon Short Line Railroad, in T. 21 N., R. 117 W., while he was making a study of the coal deposits of southwestern Wyoming.[11] In the face of this butte are exposed two zones of oil shale that have weathered

[11] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming: U. S. Geol. Survey Prof. Paper 56, 1907. Schultz, A. R., Geography and geology of a portion of Lincoln County, Wyo.: U. S. Geol. Survey Bull. 543, 1914.

blue and are very conspicuous in the white Green River beds. These oil shales on fresh surfaces have a brown to black color. A sample of shale from the upper zone at this locality, tested by D. E. Winchester in 1915, yielded 50 gallons of oil to the ton of shale. In the Rock Springs field the formation exhibits on the weathered outcrop a more or less white color, but closer examination reveals an alternation of gray, bluish-gray, and white bands. Some of the shale is light brown when fresh and weathers to nearly white with a yellowish to bluish coating in places. The shale breaks up into thin laminae or flakes resembling manila paper. It contains an abundance of vegetable and animal remains and some well-preserved fossil leaves and small fishes. Fish remains, including many complete skeletons, are numerous in many of these beds. The shale in some of the beds has very much the aspect of an ordinary carbonaceous shale, such as is commonly associated with coal beds.

Hayden,[12] while making a study of the beds in western Wyoming from Laramie westward to Bear River along the Union Pacific Railroad, observed the oily material in these shales. He says:

Very soon after leaving Rock Springs station the Green River group is seen on the bluff hills on either side of the road to the entrance of Bitter Creek into Green River. In the Green River valley are seen remarkable sections of strata. I have called this group the Green River shales, because it is composed of thin layers, varying in thickness from that of a knife blade to several inches. The rocks all have a grayish-buff color on exposure, sometimes with bands of dark brown. These darker bands are saturated with an oily substance, which causes them to ignite readily. At one time this material was used as a fuel in stoves and burned well, giving off a good supply of heat; but it was found that the bulk of earthy matter, after the combustible portion was burned out, was as great as the original mass and rendered it too inconvenient. One of the cuts along the railroad passes through a layer of the cream-colored chalky limestone. There were one or two beds of this petroleum earth.

During the progress of the excavations the workmen built a fire by the side of one of the walls, and this oily earth ignited and burned for several days, giving light to the workmen by night and filling the valley with a dense smoke by day. * * * There are also seams of very fine limestone that are quite black, so thoroughly is the rock saturated with petroleum. The combustible shales vary in thickness from two to several feet. Near the summit of the hill, under the yellow calcareous sandstone, there are 50 feet of the shales that contain more or less of the oily material.

Lesquereux,[13] in discussing the Green River shales in the vicinity of the town of Green River, where he measured a section 548 feet thick from the top of Pilot Hill downward to the bed of Green River, makes the following statement:

This section indicates a thickness of about 40 feet of bituminous matter distributed in thin beds, besides the 70-feet-thick bed No. 8, composed of alternate layers of calcareous and bituminous shales. All these shales are more or less impregnated by bitumen and sometimes so much charged with it that it percolates through rocks of sandstone under them. As atmospheric action vaporizes and dissolves the bitumen,

[12] Hayden, F. V., U. S. Geol. and Geog. Survey Terr. Fourth Ann. Rept., p. 142, 1870.
[13] Lesquereux, Leo, U. S. Geol. and Geog. Survey Terr. Sixth Ann. Rept., pp. 336, 337, 1872.

the exposed faces of the strata are generally whitish and do not show on the outside the appearance of their composition. But when cut into a few feet deep the shale are found as hard and as black as cannel coal, breaking in even fracture without marks of lamination. This has caused a great deal of useless researches, borings, and tunnelings, from unreliable reports on the presence of true coal at various localities around Green River station. From my own exploration of these formations, I am satisfied that they do not have any bed of true lignite. The shales are, however, valuable and may yield by distillation an amount of bitumen large enough to be remunerative, when this matter becomes available to some purpose in the distant localities where it is found. This bitumen appears to be essentially the result of the decomposition of animal matter. I have looked in vain in the shales for remains of vegetables. In the lowest stratum only—No. 16 of the section—I have found an obscure impression resembling a leaf of grass or a narrow flattened stem, rather referable to some fresh-water plant than to a marine vegetable. From the thinness of the strata of the Green River group, their extreme diversity, their multiplication, and their compounds, they seem to be the result of deposits in shallow lakes where materials were originated and mixed. These lakes were inhabited by a prodigious quantity of fishes, which, destroyed at repeated periods by drought, have partly furnished the bitumen to the shales where their skeletons are preserved. Whenever I had time to search for them, I have scarcely failed to find traces of fish remains in the numerous beds of bituminous shale which I have examined.

The shale that yields the most oil when subjected to distillation[14] is that which weathers into massive benches of grayish-blue color but which is dark brown to black on a freshly broken surface. After this tough rich shale, which appears to be without bedding planes or laminations, is heated and the oil driven off it crumbles easily and exhibits true shale structure. Where thin benches of rich shale are interbedded with lean or barren shale, the former, being resistant, weathers to projecting ledges. The massive shale is exceedingly tough, resists erosion to a remarkable degree, and weathers bluish white. Fragments of this rock as well as the papery shale particles will burn when ignited, and in a number of places large banks of the Green River shale have been baked as a result of the burning of rock in place. Although oil may be obtained from shale by destructive distillation, it does not appear that more than a small percentage exists in the shale as oil, for free oil in commercial quantities has not been found in wells drilled into the shale in southern Wyoming, particularly in the vicinity of the town of Green River,[15] where 13 wells have been drilled through the Tipton shale or lower part of the Green River formation, or in northwestern Colorado. Small quantities of free oil are present, however, as shown by several oil seeps on the old grade just below the present roadbed 3 miles west of Green River, where the Union Pacific Railroad passes through Fish Cut. That some oil must be present or be distilled by the heat of the sun is indicated by the extensive burns observed in the shale at Antelope Springs, in T. 16 N., R. 99 W., and at several places along Green

[14] Winchester, D. E., Oil shale in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, p. 162, 1916.

[15] Schultz, A. R., Deposits of sodium salts in Wyoming: U. S. Geol. Survey Bull. 430, pp. 583–587, 1910.

River, where the white shale has been baked and the iron content oxidized so that the rock has the appearance of a partly burned brick. When freshly broken, the shale gives off an odor of petroleum. All gradations exist between this hard, tough, massive rock and the papery shale which weathers to curly forms. The papery shale is in a few places black but usually light brown, and the thin plates of weathered shale are remarkably flexible, a characteristic which distinguishes this rock from ordinary carbonaceous shale. Weathering affects the papery shale to a distance of more than 20 feet back from the outcrop, but except along joint planes the hard, massive shale shows little evidence of weathering for more than a quarter of an

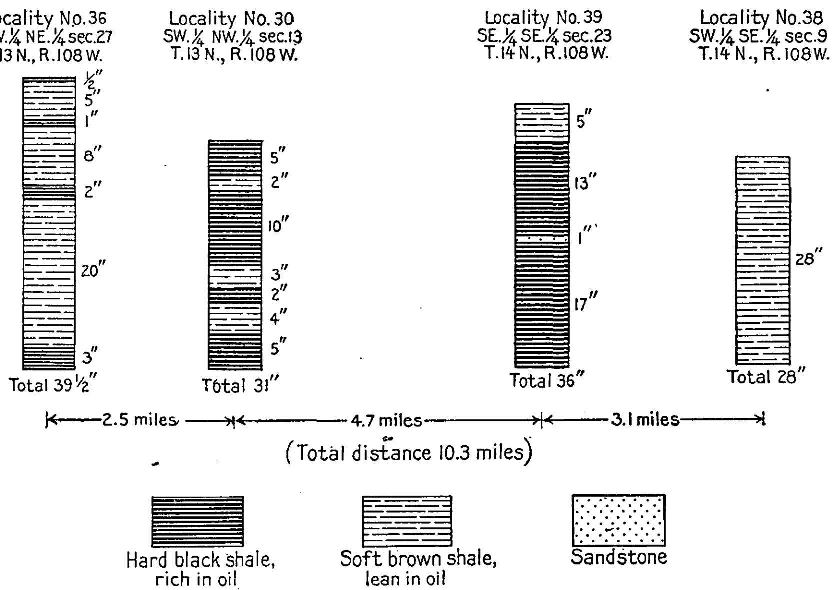
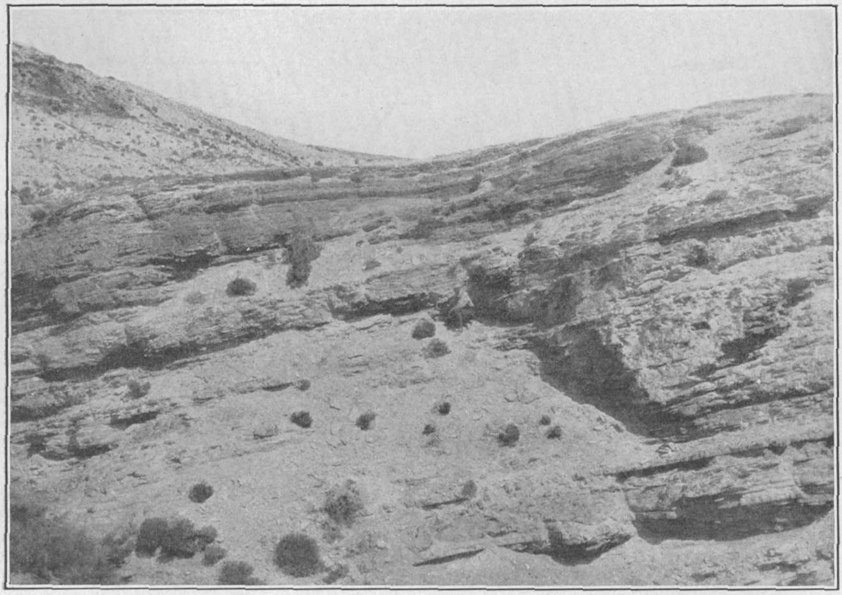


FIGURE 6.—Diagram showing variation in an oil-shale zone in the upper part of the Green River formation on the west side of Green River, in Tps. 13 and 14 N., R. 108 W., Wyo., where a single bed or zone is exposed continuously for a distance of nearly 12 miles.

inch from the exposed surface. Oil has been distilled from the papery shale as well as from the hard, massive variety. In Wyoming the quantity of oil obtained from some of the massive shale has been about the same as that obtained from the papery variety, whereas in Colorado and Utah the yield of the massive variety is greater. The productive shale beds, however, vary from place to place both in thickness and the amount of oil they contain.

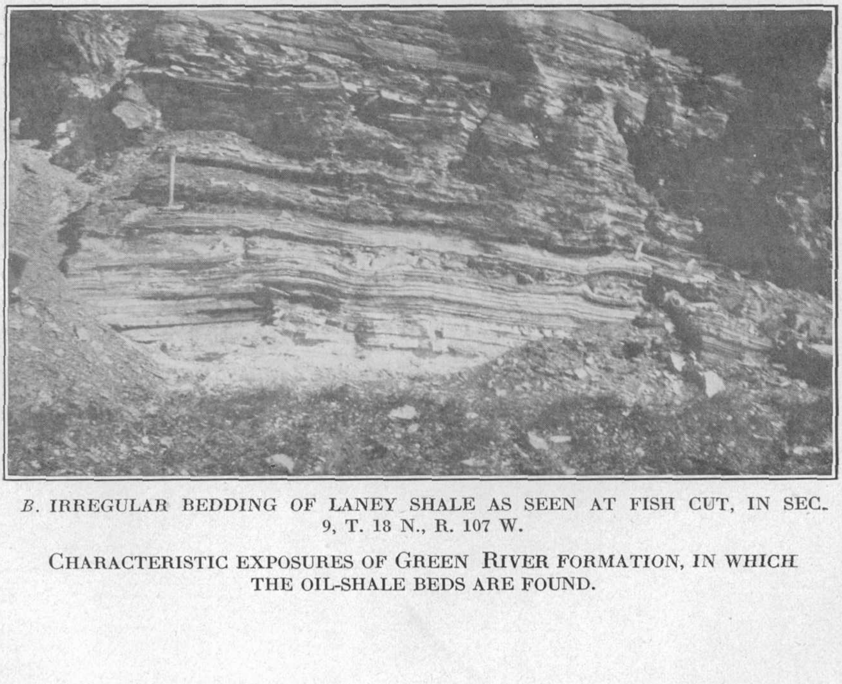
In 1915 a careful study was made of the oil-shale strata [16] exposed along the west side of Green River in southwestern Wyoming in Tps. 13 and 14 N., R. 108 W., for a distance of about 10 miles, and it was found that although the formation appears to be remarkably regular

[16] Winchester, D. E., op. cit., pp. 168, 169.



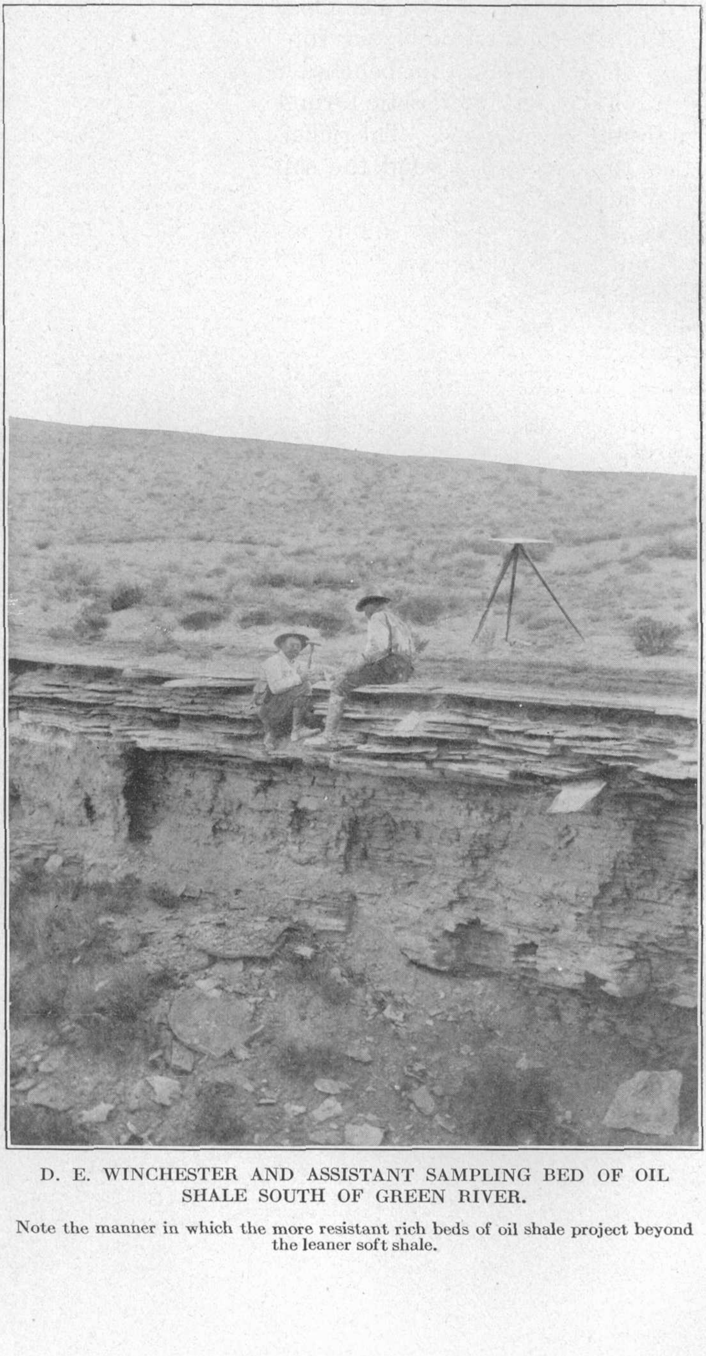
A. TIPTON SHALE NORTH OF FOURTEENMILE SPRING, ON EAST FACE OF WHITE MOUNTAIN, IN SEC. 33, T. 21 N., R. 105 W.

Note the thin-bedded character of the shales near the center of the picture. Characteristic weathering of the oil-yielding paper shales.



B. IRREGULAR BEDDING OF LANEY SHALE AS SEEN AT FISH CUT, IN SEC. 9, T. 18 N., R. 107 W.

CHARACTERISTIC EXPOSURES OF GREEN RIVER FORMATION, IN WHICH THE OIL-SHALE BEDS ARE FOUND.



D. E. WINCHESTER AND ASSISTANT SAMPLING BED OF OIL SHALE SOUTH OF GREEN RIVER.

Note the manner in which the more resistant rich beds of oil shale project beyond the leaner soft shale.

in thickness individual beds vary greatly from place to place and a single bed several feet thick at a certain place may change to comparatively thin-bedded shale within half a mile or less. Along both sides of Green River in the area a single zone of rich oil-yielding shale is exposed in almost continuous outcrop for several miles. The bed is made up of alternating thin benches of rich and lean shale which weather into a most characteristic form so that the bed can be easily identified from place to place. The richer benches weather to grayish-blue ledges that project beyond the softer lean shale, as shown in Plates XIV and XV.

In places slabs 3 or 4 feet square and only an inch thick have weathered out and lie scattered over the surface. The variability of the different parts of the bed is shown graphically in figure 6, based upon the measurement of four sections made by Winchester in 1915.

At the localities of the four measured sections samples of shale were collected by Winchester from the same bed for distillation and showed a wide range in the yield of oil and ammonium sulphate per ton of shale. The results of the field distillation of the samples are given in the following table and further emphasize the variation in the oil-shale bed illustrated in figure 9.

Results of distillation of samples of oil shale from four localities along the outcrop of a single bed in Tps. 13 and 14 N., R. 108 W., Wyo.

Locality No. on Plate I.	Total thickness sampled.	Yield of oil per short ton of shale.	Gravity of oil.		Yield of ammonium sulphate per short ton of shale.
			Specific.	Baumé.	
	Ft. in.	*Gallons.*		°	*Pounds.*
36	3 3½	19	Not determined.		9.3
30	2 7	34	0.8994	25.65	5.7
39	3 0	32	.8818	28.77	6.6
38	4 2	7	.8885	27.56	2.5

The irregularity of the oil shale is set forth in more detail in the following stratigraphic sections, which were measured in this part of Wyoming by the writer and his assistants in 1907, 1908, and 1915 or by D. E. Winchester in 1915, at the places indicated on the map (Pl. I), and which illustrate the variation in the character of the rocks exposed in different parts of the field. The beds of shale that are known by testing or are estimated to yield oil are indicated by heavy type in the sections.

Sections of parts of Green River formation in southwestern Sweetwater County, Wyo.

West face of Kinney Rim, T. 13 N., R. 99 W.

[No. 1, Pl. I.]

		Ft.	in.
Laney shale member:			
Sandstone, coarse grained, not massive		50	
Sandstone, containing fossil shells			4
Sandstone, coarse grained, thin bedded		10	
Covered, probably sandy shale		35	
Sandstone, coarse		8	
Covered, mostly shale		30	
Shale, papery, drab, lean		5	
Shale, thin, barren, and sandstone		72	
Shale, drab, thin, lean		3	
Shale, thin, drab, barren		20	
Shale, thin, lean		30	
Sandstone, concretionary		1	
Shale, thin, lean		14	
Oolite and chert.			
Shale, thin bedded, lean		14	6
Shale, thin bedded; weathers blue; rich	(sample 1; 30 gallons)	2	
Shale, gray, sandy (not included in sample)		1	7
Sandstone, yellow (not included in sample)			1
Shale, thin bedded; weathers blue; rich		3	
Shale, yellow, sandy		28	
Shale, papery, lean		40	
Shale, drab, fissile		10	
Sandstone, concretionary		1	
Shale, drab, papery		13	
Oolite			6
Shale, drab, papery		10	
Sandstone, oolitic			4
Shale, drab, fissile		12	6
Sandstone, micaceous		1	
Sandstone, yellowish		3	
Shale, drab, thin sandstone lenses		26	
Sandstone, shaly, yellowish		1	
Shale, drab, papery, barren		5	
Sandstone, shaly, yellowish		1	6
Shale, greenish drab		37	
Cathedral Bluffs red beds member:			
Maroon clay shale, base not seen.		489	4

Southeast of Black Buttes, station on Union Pacific Railroad, in sec. 14, T. 17 N., R. 100 W.

[No. 2, Pl. I.]

	Ft.	in.
Green River formation:		
"Tower sandstone," massive, irregular bedded	75	
Laney shale member: Shales resembling bed on west side of Rock Springs dome	385	
Cathedral Bluffs red beds member: Very prominent red clays and sandstones forming largest escarpment around Washakie Basin	740	

Green River formation—Continued.

Tipton shale member:

	Ft.	in.
Sandstone, slightly yellowish, very fossiliferous, (*Goniobasis*, *Unio*, and *Viviparus*)	10	
Sandstone, shaly, yellow, very fossiliferous	4	
Shale, brown, fissile toward top	1	
Shale, hard, slate-colored	5	
Sandstone, hard, yellowish gray, micaceous, massive (two very thin shale bands)	18	
Shale, hard, slate-colored, calcareous	2	6
Sandstone, massive, yellow, micaceous	14	
Sandstone, soft, yellow, with thin layers of slate-colored sandy shale	13	
Sandstone, hard, yellow; *Goniobasis*, *Unio*, fragments of bones and hard shale pebbles one-half inch in diameter	1	9.6
Shale, slate-colored to yellow, sandy	6	
Sandstone, soft, massive, micaceous, yellow	11	
Sandstone, slate-colored, sandy	7	
Sandstone, massive, micaceous, yellowish gray	17	
Shale, soft, slate-colored	3	
Sandstone, soft, yellow, micaceous	17	
Shale, soft, slate-colored	6	
Sandstone, soft, yellow	2	
Shale, soft, slate-colored	4	
Sandstone, soft, white to yellow	4	
Sandstone, yellow; hard ledges	1	
Sandstone, soft, thin bedded, yellow, micaceous; several very thin beds of slate-colored sandy shales	15	
Shale, soft, slate-colored	3	
Sandstone, soft, yellow, micaceous	9	
Shales, soft	5	
Shale, calcareous, hard, yellow	1	
Shale, slate-colored	2	
Sandstone, yellow, micaceous	6	
Shale, slate-colored	4	
Sandstone, soft, yellowish, micaceous, with thin beds of sandy shales	32	
Shales, slate-colored to yellow, with carbonaceous matter near top	13	
Sandstone, soft, drab to yellow, micaceous, with thin beds of slate-colored clays and shales	33	
Shale, drab, with some siliceous limestone (limestone conglomerate)	2	
Sandstone, soft, drab, with thin layers of sandstone	7	
Shale, soft, slate-colored	5	
Sandstone, soft, yellow	14	
Sandstone, thin bedded, yellowish gray, micaceous; weathers with brownish-black specks	7	
Sandstone, soft, yellow, with some compact slate-colored clay	13	
Shales, fissile, slate-colored	22	
Sandstone, soft, gray	1	

Green River formation—Continued.

Tipton shale member—Continued.

	Ft.	in.
Sandstone (?) and shale; weathered surface of soft sandstone and shale, mostly covered. Upper 10 feet fissile slate-colored shales, carbonaceous and fossiliferous	49	
Limestone, very fossiliferous, yellow, siliceous; contains *Goniobasis*, *Unio*, and *Viviparus;* dip 3° SE.	2	
Shale, fissile, slate-colored. Massive yellow limestone, tends toward concentric concretionary structure. Caps rim of lower escarpment		9.6
Shale, fissile, slate-colored	5	
Limestone, yellow, oolitic		6
Shale, fissile, dark, slate-colored	2	
Limestone, yellow, oolitic		2.4
Shale, fissile, dark, slate-colored	32	
Shale, fissile, dark, slate-colored or brown, calcareous and fossiliferous	3	
Sandstone, white; upper 5 inches hard and contains shells	1	
	386	9.6

Wasatch formation (Black Rock coal group):

	Ft.	in.
Clays, shales, sandstones, impure limestones, carbonaceous shales, and coal beds	1,715	

Tps. 23 and 24 N., R. 101 W., east of Steamboat Mountain.

[No. 3, Pl. I.]

Green River formation:

	Ft.	in.
Laney shale member: Shales, thin bedded, white	90	
Cathedral Bluffs member:		
Clays, pale green and reddish purple	6	
Clay, yellow; calcitic, and shaly limestone	2	
Shale or clay, spongy, pale green	4	
Limestone, with chert veins and concretions	2	6
Shales, spongy, containing calcitic concretions, varying horizontally in color through pale green (prevailing), dirty yellow, pink, and rose madder	15	
Shale, sandy, pale yellow	2	
Shales or clays, spongy, containing calcitic concretions; surface strewn with numerous small fragments of bones. Near base is small lens of coarse-grained conglomeratic gray sandstone, with matrix of quartz and feldspar grains, containing sandstone, quartz, and schist pebbles as much as half an inch in diameter. Lower portion is of shale and rests, apparently conformably, upon the upper concretionary ledge of the Tipton shale	28	
Tipton shale member:		
Sandstone, shaly, yellow to drab. This ledge forms a cap on the series of buttresses to the east, the most prominent ledge on the escarpment in T. 24 N., R. 100 W., and caps the southernmost butte in the same township	5	

Green River formation—Continued.

Tipton shale member—Continued.	Ft.	in.
Limestone, conglomeratic; lower part soft and contains numerous *Goniobasis* and fragments of *Unio;* upper part hard, forms slabs, and contains *Goniobasis* and *Unio*. This ledge is very fossiliferous to the east. It contains basalt and sandstone pebbles one-quarter inch in diameter, and one bone pebble was found in it		9. 6
Shale, slate-colored, with 3-inch layers of cadmium-orange near top	2	
Sandstone, soft, yellow	2	
Shale, slate-colored	16	
Sandstone and shale, soft, shaly, yellow to slate-colored	12	
Sandstone, yellow	3	
Shale, slate-colored	2	
Sandstone, yellow, concretionary, micaceous	5	
Shale, slate-colored	14	
Sandstone, yellow, concretionary	5	6
Shales, slate-colored and pale green	3	
Sandstone, yellow, concretionary, micaceous; contains shale pebbles in lenses	6	
Shales, slate-colored and drab	27	
Sandstone, yellow, cross-bedded; weathers pinkish-brown on surface. This ledge becomes very fossiliferous 4 miles to the east and forms prominent series of low buttresses. It is the lowest fossil ledge at Luman ranch	3	
Shales, slate-colored, drab, pale green	18	
Sandstone, soft, yellow, micaceous, as below but not concretionary. Forms crest of hill and of escarpment, with thin cap of fragmentary limestone, oolite, and limestone concretions. This ledge swings to the northeast on a broad curve, concave toward the south, and forms the low outlying buttresses and escarpment until it turns back northeast again. It is capped by a 3-foot ledge of hard sandstone	15	
Sandstone, soft, yellow, micaceous. Forms many large cross-bedded pinkish-brown concretions	4	
Shales, drab, green, slate-colored, and rose madder	5	6
Sandstone, soft, yellow, micaceous, locally concretionary	6	
Shales, predominatingly slate-colored to drab; thin beds of green, red, purple, all pale; sandy toward top	16	
Sandstone, yellow, micaceous, soft, conglomeratic	8	
Shale, drab to slate-colored, soft, with thin layers of shaly sandstone	7	
Sandstone, yellow, micaceous, with black particles	4	
Shale, drab to slate-colored, soft, with thin layers of shaly sandstone	14	
Limestone, concretionary; surface of thin concretions at base is covered with flaxseed bumps	4	
Shales, fissile, slate-colored	8	

	Ft.	in.
Green River formation—Continued.		
Tipton shale member—Continued.		
Oolites, yellow; lower 4 feet slabby; upper 1 foot white and size of millet seed	5	
Shale, fissile, slate-colored, with two thin beds of concretionary limestone near base	55	
Limestone, concretionary, with quartz, chert, and sandstone pebbles one-half inch in diameter	2	
Shales, fissile, slate-colored through yellow to brown; contains two beds of concretionary yellow limestone as much as 9 inches thick and one thin-bedded oolite ledge 8 inches thick	9	
Oolite, yellow; solid ledges 1 to 10 inches in thickness interspersed with thin layers of fissile shale, most of which is largely oolitic. One bed of yellow limestone near center is 10 inches thick. *Goniobasis* in beds near base; also layers of selenite	3	6
Sandstone, hard, thin bedded, fine grained, gray, interbedded with fissile shales; probably base of Tipton shale	4	6
Wasatch formation (Black Rock coal group):		
Shales, drab to slate-colored	3	6
Sandstone, rusty yellow, high color	3	
Shale, slate-colored	19	
Sandstone, rusty, yellowish brown, with small lenses of shale conglomerate	38	
Sandstone, shaly; ½-inch shale pebbles on top	1	
Shale, slate-colored	11	
Sandstone, yellowish and micaceous, in places slightly shaly	5	
Shales, soft, slate-colored	7	
Sandstone, soft, yellowish	4	
Shales, soft, slate-colored, with thin beds of shaly sandstone	48	
Sandstone, soft, yellow	4	
Shales, soft, slate-colored	25	
Sandstone, soft, yellow	6	
Shales, soft, slate-colored	23	
Sandstone, massive, yellow	4	
Shale, soft, and shaly sandstone, thin bedded, slate-colored to yellowish	11	
Shales, slate-colored, hard; look like small concretions	5	
Sandstone, yellow, micaceous, massive at top	11	
Shale, slate-colored, grading into overlying ledge	5	6
Sandstone, yellow, micaceous; middle and upper parts hard, breaking into chunks	15	
Shales, soft, yellow and slate-colored; sandy near top and bottom; thin bed of carbonaceous matter near center; little shale below top	5	
Sandstone, hard, yellow, concretionary and pinkish-brown on surface; cross-bedded; forms slabs	1	

Sec. 18, T. 24 N., R. 103 W., on divide between Killpecker Valley and Jack Morrow Creek.

[No. 5, Pl. I.]

	Ft.	in.
Green River formation:		
Tipton shale member:		
Limestone, concretionary, oolitic, having concentric layers and appearance of huge shells; some layers show small stalactites at right angles to concentric layers on concretions. This ledge forms the upper limestone and capping of many of the hills on divide between Jack Morrow and Killpecker creeks	15	
Clays, greenish, rather compact beds one-fourth to one-half inch thick; weather readily	33	7.2
Sandstones, yellowish gray, and thin-bedded shales containing many concretions and irregular bands, in places light-gray cherty bands, green and white shales, and sandstones	28	
Shales, gray, thin bedded, very fissile; layers about one-eighth inch thick	6	
Shales, dark colored, bituminous, very fissile; thin like Laney shales	11	2.4
Sandstone, thin bedded, calcareous, shaly, in places almost fissile	5	
Shales, soft, grayish brown, sandy; weather easily	5	7.2
Limestone, oolitic, full of gastropods and shells; much calcite replacement. Concretionary oolites one-fourth to one-half inch in diameter	22	4.8
Shales, greenish drab	20	
	146	9.6
Wasatch formation (Black Rock coal group):		
Shales and clays, reddish	10	
Clay, reddish or greenish brown; yellow massive sandstone to base of cliff	150+	
	160+	

East face of White Mountain north of Sixmile Spring, in sec. 8, T. 19 N., R. 105 W.

[No. 7, Pl. I.]

	Feet.
Green River formation:	
"Tower sandstone:" Sandstone similar to that on Wilkins Peak and on White Mountain in vicinity of town of Green River	115
Shales, white and gray, and shaly sandstones, with beds of oil **shale** and interbedded sandstones. (See detailed section measured in sec. 36, T. 19 N., R. 106 W., No. 24, Pl. I.) (Represents Laney shale member and probably upper part of Cathedral Bluffs red beds member.)	685
Shales, bluish gray, drab, and white, very fissile and paper-like in places. The upper third of these beds forms the lower falls. Ledge makes nearly vertical cliff at Sixmile Springs. Upper part of beds contains numerous fish remains. Rock contains some bituminous matter and on weathering becomes brownish blue. (Probably represents lower part of Cathedral Bluffs red beds member.)	65

	Feet.
Green River formation—Continued.	
Tipton shale member (top boundary somewhat indefinite):	
Limestone, bluish brown, somewhat cherty, containing many gastropods and Unios. May represent same horizon as upper concretionary limestone farther north that marks the top of the Tipton shale in the vicinity of Steamboat Mountain and Jack Morrow Creek. Contains some oolite and weathers white to gray, with some dark-brown bands	2
Limestone, oolitic, forming hard band of rock	1
Shale, brown and gray, very fissile, with flaxseed-like oolite bands. (Some of these shales estimated to yield 10 to 15 gallons to the ton)	7
Shale, greenish brown and drab	50
Shales, bluish green and white, fissile in places, papery shales in layers. Some of the beds are chiefly clay, changing in places to yellowish-brown sandstones that closely resemble sandstones in the Wasatch formation	100
Wasatch formation (Black Rock coal group): Clays and sandstones, pinkish, reddish, and yellow, to base of hill at foot of White Mountain	200

East face of White Mountain near south line of sec. 10, T. 21 N., R. 105 W.

[No. 8, Pl. I.]

	Ft.	in.
Green River formation:		
Shales containing fish remains. Alternating shales and sandstones, becoming brownish toward the top and grading into limestones. Shales varying in color from white to dark brown. Papery shales at certain horizons. Forming east scarp of White Mountain. (Represent Laney shale member and Cathedral Bluffs red beds member)	600	
Tipton shale member (top boundary somewhat indefinite):		
Limestone, oolitic, with quartz nodules	1	
Shale, brown, calcareous	40	
Limestone, gray and brown, siliceous	15	
Shales, brown, fissile	22	
Limestone conglomerate, brown, oolitic	2	
Shales, yellow	60	
Limestone, brown, micaceous	1	3
Shale, red	20	
Sandstone, yellow, cross-bedded, and volcanic ash	25	
Limestone, conglomerate, micaceous	2	
Wasatch formation (Black Rock coal group):		
Clays, alternating red and bluish, with a few calcareous sandstone layers 1 foot or more in thickness.		

Firehole Basin, secs. 17 and 19, T. 17 N., R. 106 W.

[Nos. 19-21, Pl. I.]

	Ft.	in.
Green River formation:		
"Tower sandstone": Sandstone, massive, brown, coarse.	125	
Beds representing Laney shale member and Cathedral Bluff red beds member:		
Sandstone, thin bedded	35	
Shale, papery, gray	25	
Sandstone, shaly, gray	32	
Shale, sandy, lean	65	
Shale, hard; contains fish remains (sample 20; 14 gallons)	5	
Shale, lean	20	
Shale, thin with lenses of very rich waxy shale	55	
Shale, hard	15	
Shale, hard (sample 19; 12 gallons)	5	
Shale, hard, lean	12	
Shale, gray, sandy	20	
Shale, hard, rich	1	4
Shale, gray, sandy, thin sandstones, and a few 1 to 3 inch beds of rich shale	90	
Shale, hard, thin, medium rich	1	6
Shale, barren	15	
Shale, medium, with large gypsum crystals	1	6
Shale, thin, barren	80	
Shale, medium, with gypsum crystals		8
Shale, gray, sandy	26	
Shale, medium, with gypsum crystals	1	6
Shale, hard, rich		10
Sandstone, thin, gray	8	
Shale, hard, rich		10
Shale, gray, sandy	17	
Shale, hard, rich		2
Shale, thin, gray, sandy	9	2
Shale, hard, rich.		
Shale, sandy	118	
Sandstone, gray	4	
Shale, sandy, greenish	6	
Sandstone, gray, thin bedded	1	
Shale, sandy, green	27	
Shale, sandy, thin bedded, gray	21	
Sandstone and shale, green, in beds 2 feet thick; sandstone concretionary	58	
Shale, sandy, gray, slope	97	
Sandstone, massive, cross-bedded, forming ledge and capping hill	5	
Shale, forming slope	43	
Sandstone, rather massive, forming ledge	10	
Shale, soft, thin, platy, barren	30	
Shale, medium hard, rather thin, very lean	4	11
Shale, medium hard (sample 18; 4 gallons)	4	10
Shale, sandy, lean to barren	70	
Shale, medium hard, very lean	10	
Shale, lean	4	6

	Ft.	in.
Green River formation—Continued.		
Beds representing Laney shale member and Cathedral Bluffs red beds member—Continued.		
Sandstone, brown persistent		8
Shale, lean	3	6
Tipton shale member (top boundary somewhat indefinite):		
Shale, hard to medium hard (sample 17; 9 gallons)	4	6
Shale, lean to barren	75±	
Shaly sandstone, barren	15	
Shale, sandy, forming slope, lean	47	
Shale, hard (sample 16, lower 4½ fe t; 11 gallons)	5	6
Shale, hard (sample 15; 10 gallons)	5	3
Shale, hard	1	4
Sandstone (sample 14; 9 gallons)		3
Shale, fairly soft, thin bedded	2	9
Shale, hard	1	
Shale, hard, rich (sample 13; 19 gallons)	5	4
Shale, hard, rich (sample 12; 19 gallons)	6	3
Shale, soft		7
Shale, hard, rich (sample 11; 11 gallons)	2	5
Shale, soft		6
Shale, hard, rich	2	3
Base not seen.		
	1,360±	

Firehole Basin, sec. 27, T. 17 N., R. 106 W.

[Nos. 22-23, Pl. I.]

	Ft.	in.
Green River formation:		
Tipton shale member:		
Shale, drab	45	
Sandstone, platy	16	
Shale, lean	22	
Sandstone, brown, platy	7	
Shale, hard, not so rich as underlying beds	24	
Shale, hard, thin, platy (sample 23; 14 gallons)	5	6
Shale, hard, dark	2	3
Shale, hard, dark, rich (sample 22; 19 gallons)	8	1
Shale; weathers to thin plates; part of member will yield small amount of oil	120	
Covered, mostly light-colored shale or clay	75	
	324	10
Wasatch formation (Black Rock coal group):		
Clay, mostly gray, with some red	80	
Clay, gray, yellow, green, and red, with beds of yellow sandstone. All beds very lenticular. A 40-foot bed of massive sandstone at one place splits and within 100 yards along its outcrop is represented by variegated clay beds, with a few thin sandstones	75	
	155	
	479	10

East escarpment of White Mountain, sec. 36, T. 19 N., R. 106 W.

[No. 24, Pl. I.]

	Ft.	in.
Green River formation:		
"Tower sandstone:" Sandstone, brown, coarse, unconformable on underlying beds	245	

	Ft.	in.
Green River formation—Continued.		
Beds representing Laney shale member and Cathedral Bluffs red beds member:		
Shale, gray, sandy, and shaly sandstone, with three beds of rich shale each 3 inches thick in lower part..	265	
Shale (estimated yield, 12 to 15 gallons)...........	3	
Shale, gray, sandy, and thin sandstone with two or three 1-inch beds of rich shale..................	37	
Sandstone, gray, ripple marked....................	1	
Shale, sandy, gray, and shaly sandstone............	22	
Sandstone, shaly, yellow..........................	2	
Shale, sandy, and clay, with a few thin sandstone beds; color predominantly white.................	133	
Sandstone, green, shaly...........................	33	
Shale, gray, sandy, and thin sandstone............	58	
Shale, green, sandy, and green sandstone...........	17	
Shale, greenish drab, sandy........................	35	
Sandstone, chalky, cross-bedded, brown............	2	
Shale, drab, sandy................................	95	
Sandstone, ferruginous............................		4
Shale, sandy, gray-green, and shaly sandstone......	75	
Tipton shale member (top boundary somewhat indefinite):		
Sandstone, shaly.................................	2	
Shale, papery, lean, with 2-inch beds of rich shale and some thin beds of sandstone.................	87	
Sandstone, with clay balls........................		6
Shale, papery, lean...............................	26	
Shale, sandy, gray................................	24	
Sandstone, shaly, gray, fossiliferous...............	2	
Shale, carbonaceous...............................	8	
Clay, sandy, gray.................................	40	
Wasatch formation (Black Rock coal group):		
Sandstone, coarse, gray................................	1	
Clay, somewhat sandy, gray............................	55	
Shale, clay, variegated, red at top.....................	33	
Sandstone, yellowish green, friable.....................	30	
	1,331	10

East side of Green River at town of Green River, in T. 18 N., R. 107 W.

[Nos. 28–29, Pl. I.]

	Ft.	in.
Green River formation:		
"Tower sandstone:" Sandstone, massive, brown	135	
Beds representing Laney shale member and Cathedral Bluffs red beds member:		
Shale, lean to barren..............................	3	
Shale, hard..	6	
Sandstone, brown, massive..........................	1	
Shale, lean to rich..............................	1	
Sandstone, brown, massive..........................	5	
Shale, lean, papery................................	11	
Sandstone..		2
Shale, hard, rich................................		6
Sandstone..		8

	Ft.	in.
Green River formation—Continued.		
Beds representing Laney shale member and Cathedral Bluffs red beds member—Continued.		
Shale, hard, dark (sample 29; 7 gallons)		8
Shale, brown, tough (sample 29; 7 gallons)		4
Shale, hard, rich, dark (sample 29; 7 gallons)	1	4
Sandstone		3
Shale, hard, rich	2	6
Shale, hard, rich (sample 28; 18 gallons)	6	3
Sandstone		6
Shale, hard, rich	6	2
Sandstone, hard, massive		6
Shale, hard, gray, sandy, lean to barren	13	
Shale, soft, greenish, lean	15	
Partly masked barren gray shale and sandstone, with some lean papery shale	55	
Sandstone, platy	2	
Shale, lean, soft	2	6
Shale, greenish gray	21	6
Sandstone, thin bedded	11	
Covered, mostly barren gray sandy shale, with a few ledges of gray shaly sandstone	128	
Sandstone, platy	3	
Shale, greenish	7	
Covered, mostly barren gray sandy shale, with a few ledges of gray shaly sandstone	110	
Shale; weathers papery	1	6
Sandstone		6
Shale; weathers papery	2	
Shale, gray, sandy, with layers of shaly sandstone	21	
Shale, greenish	20	
Shale, gray, sandy, with layers of shaly sandstone	17	
Shale, greenish, with brown sandstone lentils	20	
Sandstone, brown, with some clay shale	35	
Sandstone, thin, platy	4	
Sandy shale and shaly sandstone, gray, barren	85	
Base not seen.		
	755	5

West side of Green River, T. 13 N., R. 108 W.

[Nos. 32–37, Pl. I.]

	Ft.	in.
Laney shale member:		
Sandstone, ferruginous, containing fossil shells		6
Shale and sandstone	500±	
Shale, thin, brown	5±	
Shale, thin, brown (sample 37; 3 gallons)	5	
Shale, thin, brown	2	6
Shale, hard, black, rich (sample 36; 19 gallons)		½
Shale, brown, soft (sample 36; 19 gallons)		5
Shale, hard, black, rich (sample 36; 19 gallons)		1
Shale, brown, soft (sample 36; 19 gallons)		8
Shale, hard, black, rich (sample 36; 19 gallons)		2
Shale, brown, soft (sample 36; 19 gallons)	1	8
Shale, hard, black, rich (sample 36; 19 gallons)		3

Laney shale member—Continued.	Ft.	in.
Shale, light brown, lean (sample 35; 3 gallons)	5	
Interval	25	
Shale, lean (?)	10±	
Shale, dark brown (sample 32; 13 gallons)	5	
Shale, thin bedded, tough	10	6
Shale, thin bedded, tough (sample 33; 4 gallons)	5	4
Shale, thin bedded, tough	2	6
Shale, massive, light brown	2	6
Shale, massive, light brown (sample 34; 6 gallons)	4	10
Shale, lean; base not seen.		
	587±	

SOURCE OF OIL AND AMMONIA.

The oil-shale deposits in different parts of the United States have until recently received very little attention, chiefly because petroleum has been abundant and, owing to the prices at which crude oil and its derivatives have been placed on the market, oil distilled from shale could not compete successfully with it. Before petroleum was discovered in Pennsylvania the Mormons distilled oil from shale near Juab, Utah, where the ruins of an old still can yet be seen. Many attempts have also been made to distill oil from cannel coal, and a few experiments were made with the Devonian black shale in the Ohio Valley, in Kentucky and Ohio, before the cheap Pennsylvania oil flooded the markets, but no oil-shale industry had been established in America up to July 1, 1917. According to Baskerville[17] there were 55 oil-distilling companies in the United States in 1860. "Many of the companies were of small capacity, and most of them were not more than fairly started when the discovery of petroleum paralyzed the industry."

It has long been known that some of the shale in the Green River formation in northwestern Colorado, northeastern Utah, and southwestern Wyoming would yield petroleum when it was subjected to destructive distillation. Petroleum has been obtained from the oil fields, however, in quantities so great and at a cost so low that its production in the United States from shale by distillation has not seemed to be commercially feasible, despite the fact that oil from this source was produced many years ago in the United States and that in Scotland such an industry has long been paying dividends on a large investment and, in fact, according to current report, is now supplying a high-grade fuel oil for the British Navy.

Most of the oil obtained by the distillation of oil shale from the Green River formation is reddish brown and at ordinary temperatures ranges from semisolid vaseline-like products to a thin liquid. Oil has been distilled from 37 samples of the shale collected by D. E. Winchester

[17] Baskerville, Charles, Economic possibilities of American oil-shales: Eng. and Min. Jour., vol. 88, pp. 149-154, 195-199, 1909.

and the writer in 1915 at different points in the area south of the central part of the Rock Springs dome. These samples were not all selected because they were supposed to be rich in oil but to determine the amount of oil certain types of rock would furnish. As all the samples were collected near the outcrop, it is probable that some of the more volatile constituents of the oil had been lost by evaporation, and the results of distillation tests may not show the maximum amount of oil that can be obtained from fresh shale. Although the writer has studied the oil shales in the different parts of the field, he collected only two of the samples—Nos. 4 and 6—from the Tipton shale; the others were sampled by Mr. Winchester.[18] The results of the tests are set forth below.

Results of distillation of samples of oil shale collected in the Rock Springs field, Wyo. in 1915.

Rock sample locality.	Location.			Thickness of shale sampled.	Gravity of oil at 60° F.		Yield of oil per short ton of shale.	Yield of ammonium sulphate per short ton of shale.
	Sec.	T. N.	R. W.		Specific.	Baumé.		
				Ft. in.		°	*U. S. gals.*	*Pounds.*
1	9	13	99	5 0	0.8709	30.79	30	3.94
2	24	17	100	....	....	....	....	....
3	34	24	101	....	....	....	....	....
4	19	13	103	4 0	.8760	29.81	11	4.88
5	18	24	103	....	....	....	....	....
6	25	13	104	2 0	.8937	26.65	15	5.91
7	8	19	105	....	....	....	....	....
8	10	21	105	....	....	....	....	....
9	9	17	106	7 3	.9077	24.23	14	4.27
10	9	17	106	6 6	.9197	22.22	19	2.74
11	17	17	106	5 9	.8798	29.12	11	5.51
12	17	17	106	6 3	.9190	22.34	19	9.82
13	17	17	106	5 4	.9111	23.66	19	8.81
14	17	17	106	5 1	.9075	24.26	9	7.59
15	17	17	106	5 3	.9050	24.69	10	5.10
16	17	17	106	4 6	.9143	23.12	11	3.86
17	17	17	106	4 6	.8848	28.22	9	2.28
18	17	17	106	4 10	....	....	4	3.02
19	19	17	106	5 0	.8963	26.19	12	7.17
20	19	17	106	5 0	.8702	30.88	14	7.93
21	19	17	106	4	.9456	18.05	14	11.19
22	27	17	106	8 1	.9003	25.50	19	8.68
23	27	17	106	5 6	.9120	23.50	14	5.50
24	36	19	106	....	....	....	....	....
25	8	18	107	5 9	.9027	25.09	13	5.80
26	8	18	107	3 3½	.8800	29.09	6	3.73
27	8	18	107	1 8	.9182	22.47	29	11.71
28	8	18	107	Fragment	.9130	23.30	29.2	9.00
29	24	18	107	6 3	.9148	23.03	18	7.27
30	24	18	107	2 4	.8862	27.97	7	5.65
31	13	13	108	2 7	.8994	25.65	34	5.70
32	13	13	108	4 0	.9060	24.52	15	8.50
33	26	13	108	5 0	.9496	17.43	13	7.49
34	26	13	108	5 4	.9277	20.91	4	12.69
35	26	13	108	4 10	.9062	24.49	6	4.71
36	27	13	108	5 0	....	....	3	7.18
37	27	13	108	3 3½	....	....	19	9.32
38	27	13	108	5 0	....	....	3	9.52
39	9	14	108	4 2	.8885	27.56	7	2.47
40	23	14	108	2 11	.8818	28.77	32	6.62
41	23	14	108	11	.8892	27.44	20	4.39
42	11	15	108	7 2	.9183	22.45	9	11.14
43	36	16	108	5 3	.9022	25.18	21	5.69
44	36	16	108	6 0	.8925	26.86	13	5.06

[18] Winchester, D. E., Oil shales in northwestern Colorado and adjacent areas: U. S. Geol. Survey Bull. 641, p. 154, 1916.

A study of the table indicates that there is a considerable variation in the yield of both oil and ammonium sulphate, and this variation is in a large measure due to the variety of shale beds sampled. The yield of oil from the distilled samples ranges from 3 to 34 gallons to the ton of shale, and that of ammonium sulphate from 2.28 to 12.69 pounds to the ton.

Much of the Tipton shale in this field is a fine paper-like dark-brown to black shale which weathers to a bluish gray on exposure to the air. As land containing deposits of oil shale that yields less than 15 gallons of oil to the ton is not at present classified by the Survey as mineral land, and as the tests above reported show that many of the shales in the Rock Springs field will yield less than 15 gallons of oil to the ton, the lands as a whole have not been classified as mineral lands. The distribution of the lower member or Tipton shale and the upper member or Laney shale is well known, however, and a careful and detailed study of the oil content of the beds in different parts of the field may prove that some of the richer beds will yield much more than 15 gallons to the ton, like those in the classified area along Green River, and that the lands should in fact be classified as mineral land valuable for the oil in the shale. Until further tests of these shales have been made and more is known regarding the richest beds a mineral classification is unwarranted. As shown by Winchester, the Green River formation includes in some areas a vast quantity of shale that will yield a barrel (42 gallons) or more of oil to the ton, and shale from a thin bed at one locality in northeastern Utah, south of this field, yielded 90 gallons to the ton, or nearly four times as much as is obtained from the average Scotch oil shale. Tests made in the laboratory of the Bureau of Mines show that the quantity of oil that can be derived from such shale ranges from less than 1 gallon to 90 gallons to the ton.

Winchester [19] states that a study of the results obtained by him in the field and laboratory "reveals a fairly uniform quantity of products from the different samples, the gasoline ranging from 6 to 12 per cent, the kerosene from 28.5 to 49 per cent, the paraffin from 1.63 to 7.70 per cent, and the sulphur from 0.41 to 1.42 per cent. The samples for fractionation were chosen to illustrate both range in physical character of the shale and wide geographic distribution."

In order to determine the behavior of shale oil when subjected to the Rittman process [20] of refining two samples of oil were tested at the Pittsburgh laboratory of the Bureau of Mines. From the results obtained Winchester [21] concludes that the tests of two samples of shale oil do not furnish adequate data for generalization but merely

[19] U. S. Geol. Survey Bull. 641, p. 156, 1916.

[20] Rittman, W. F., Dutton, C. B., and Dean, F. W., Manufacture of gasoline and benzine-toluene from petroleum and other hydrocarbons: Bur. Mines. Bull. 114, 1916.

[21] Op. cit., p. 158.

indicate that under proper treatment shale oil may be made to yield a much larger percentage of gasoline than that shown by the figures quoted above.

In discussing the amount of nitrogen in the shale and the amount of ammonium sulphate that can be produced by steam distillation, Winchester[22] concludes that

The average amount of ammonium sulphate produced from the shale by steam distillation was about two and one-half times the amount obtained from the same samples by dry distillation, thus providing a factor for the conversion of the figure for ammonium sulphate by dry distillation to ammonium sulphate which may be obtained with steam distillation (the method practiced in the oil-shale industry of Scotland and France).

In the six samples tested an average of 37.8 per cent of the nitrogen in the shale was accounted for in the ammonium sulphate obtained by steam distillation, compared with an average of 15.7 per cent recovered by dry distillation. During the two seasons the yield of ammonium sulphate was determined for 57 of the samples that yielded more than 15 gallons of oil to the ton of shale. In these samples an average of 6.7 pounds of ammonium sulphate to the ton was obtained. This multiplied by 2.5, the factor mentioned above, gives an average of 16.7 pounds of ammonium sulphate to the ton, which seems to be a fair estimate of the quantity that may be produced in commercial practice from shale of the area examined in 1914 and 1915.

Investigations made by the United States Geological Survey have shown that whenever economic conditions necessitate or justify the distillation of oil shales for their products and by-products the shales of the Green River formation in Colorado, Utah, and Wyoming can be made to yield vast quantities of oil, gas for use in the process of distillation, and fertilizer enough to enrich a large number of the farms of the Middle West. Under present economic conditions, when large quantities of petroleum are required, an effort is being made to utilize the oil shales, and in the near future an oil-shale industry will be firmly established in the United States.

Very rough but cautious calculations of the contents of the shale in parts of the area examined indicate that the distillation of shale from beds over 3 feet thick in Colorado, where the first testing plants are being installed, alone will yield more than 20,000,000,000 barrels of crude oil, which is more than five times the total quantity of petroleum marketed in the United States prior to 1917 and from which more than 2,000,000,000 barrels of gasoline can be extracted by ordinary methods.

In Utah there is probably nearly three times as much shale just as rich as that in Colorado, so that the total production from Utah will probably be at least three times as great as that in Colorado. In Wyoming, where the Green River formation has a wide distribution, much of the shale is known to be less productive than in the other two States, although one bed 2 feet thick yields as much as 50 gallons to

[22] Op. cit., p. 160.

the ton of shale and is apparently of as good quality as the shale farther south, so that the total yield for the State may equal that in Colorado. This shale oil will yield 10 to 15 per cent of gasoline by ordinary methods of refining. The oil shale in these States should produce not only the oil but also, with only a moderate added cost, large quantities of ammonium sulphate, a compound especially valuable as a fertilizer. The industry requires a large and costly equipment of retorts, condensers, and oil refineries, as well as of mining machinery, so that it probably can not be profitably organized on a small scale.

In view of the ever-increasing demand for gasoline and the increase in price of crude oil, from which it is obtained, it is of interest to know that an almost inexhaustible supply of oil may be obtained from the shale of the Green River formation in northwestern Colorado, northeastern Utah, and southwestern Wyoming, just as soon as a permanent oil-shale industry has been established in these States. The high cost of distilling oil from shale as compared to the cost of producing oil from wells has thus far prevented the development in this country of such an industry, but sooner or later it may be found commercially profitable to utilize some of the enormous supply of petroleum and associated by-products to be derived from the distillation of these shales, to supplement the decreasing production from the oil fields.

The oil derived from the shale is similar to that which is being produced from wells in the United States at the rate of more than 250,000,000 barrels a year. The ammonia is a most valuable by-product of the distillation and may be utilized in the manufacture of commercial fertilizer or other nitrogen compounds, as the market demands. The development of this enormous reserve simply awaits the time when the price of petroleum and gasoline or the demand for other products of distillation warrants the utilization of the oil shale as an additional source of supply. At all events these shales are likely to be drawn upon long before the exhaustion of the petroleum fields in Wyoming or other oil-producing States.

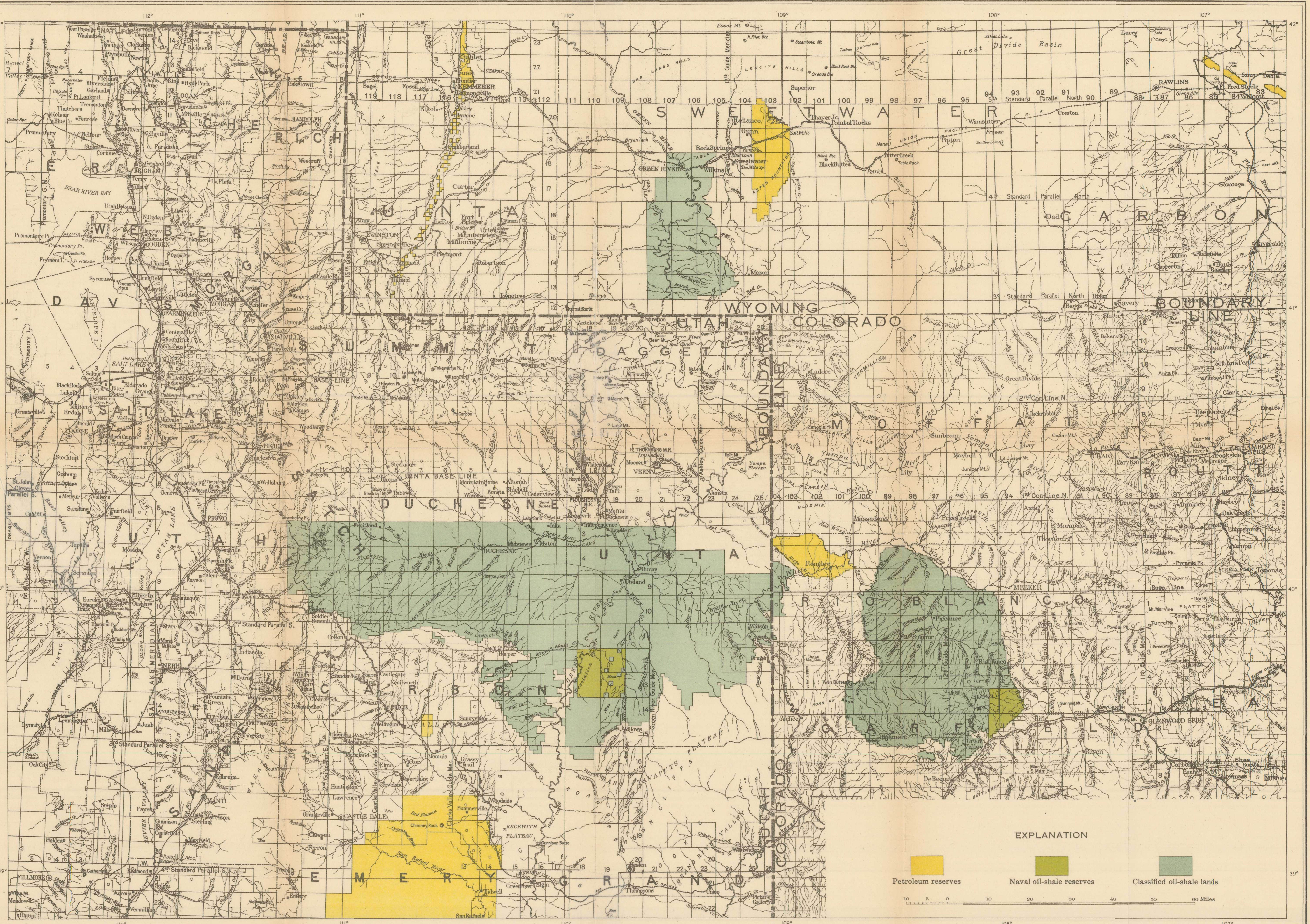
OIL-SHALE LAND CLASSIFIED AS MINERAL LAND.

In 1916, after the completion of field work in the oil-shale region of Colorado, Utah, and Wyoming by the Geological Survey, large areas of land in this region were designated as mineral land valuable for oil shales. Prior to this time no attention had been given to the lands on which oil shale was found, but as soon as it was known that the lands possessed mineral value rumors became current that all the oil-shale land was to be withdrawn from entry. The Survey received numerous requests for information regarding such withdrawals, but there proved to be no basis for the rumors, as no withdrawal of oil-shale land was contemplated by the Government. As a result of the field examinations made from 1913 to 1916 it has been clearly demonstrated that the latent potentiality of the oil shale of this region as a source of petroleum is enormous. It is also known that there is locked up in these shales a vast amount of nitrogen which can be recovered as a by-product in the refining of the shale and used in the manufacture of fertilizers and explosives. With all this information at hand the Government has consistently held that the oil-shale land should not be withdrawn but should be classified as mineral land and made available to the public under the United States mining laws. In accordance with this policy the first classification of oil-shale lands was transmitted to the Commissioner of the General Land Office by the Geological Survey May 23, 1916. On July 1, 1917, the area classified as oil-shale lands amounted to 3,636,036 acres, of which 896,018 acres lies in Colorado, 2,636,000 acres in Utah, and 460,000 acres in Wyoming. The lands so classified, except two small areas, one each in Colorado and Utah, which have been set aside as naval oil-shale reserves, are open to mineral entry under the mining laws of the United States or to nonmineral entry in accordance with the provisions of the act of July 17, 1914, the oil-shale deposits in all entries so made under this act being reserved for separate acquisition under the mineral-land laws. The only classified oil-shale lands that have been withdrawn for Government purposes are those included in Naval Oil Shale Reserve No. 1, Colorado No. 1, and Naval Oil Shale Reserve No. 2, Utah No. 1, approved December 6, 1916. The naval reserve in Colorado comprises 45,440 acres in Tps. 5 and 6 S., Rs. 94 and 95 W., sixth principal meridian; and the naval reserve in Utah includes 86,584 acres in Tps. 12 and 13 S., Rs. 18 and 19 W. Salt Lake meridian. These two reserves, comprising approximately 0.033 per cent of the total classified oil-shale area, were set aside for the Government's use, and no additional reserves are now contemplated. Should at any time in the future additional naval reserves be required, they would comprise only a fractional part of the total area yet to be classified as oil-shale land. The location of the two naval oil-shale reserves with respect to the classified oil-shale lands in Wyoming and the other two States is shown in Plate XVI.

OIL-BEARING FORMATIONS PROBABLY PRESENT BENEATH BAXTER BASIN.

GENERAL FEATURES.

In the fields surrounding the Rock Spring region in Wyoming, Colorado, and Utah some of the formations from the Cambrian to the Cretaceous contain sandstone members or strata which in places contain traces of oil or produce oil and gas. These formations may



Base, General Land Office maps

MAP SHOWING THE LOCATION OF THE PETROLEUM RESERVES, NAVAL OIL-SHALE RESERVES, AND CLASSIFIED OIL-SHALE LANDS IN PARTS OF WYOMING, UTAH, AND COLORADO

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

therefore contain oil or gas in the Rock Springs field. The lowest of these favorable oil sands or prospective oil reservoirs are more than 5,000 feet below the surface in Baxter Basin, and some of them lie too deep for commercial exploitation and are of interest only as possible sources of oil to supply the overlying sands that lie near enough to the surface to be within practicable reach of the drill. That some of the shales associated with the sandstones contain oil pools is not considered probable, although it is recognized that oil in small quantities may be present in shale here as it is in some of the other Rocky Mountain fields. Its commercial importance, however, is negligible. A brief review of the oil-bearing formations in this part of the Rocky Mountain province is given below.

HILLIARD SHALE.

The name Hilliard shale was proposed by Prof. Wilbur C. Knight in a paper read before the Geological Society of America in 1901. The name was derived from the small town of Hilliard, which stands on the shales of this formation a few miles west of Kemmerer, Wyo. The formation consists of dark-colored sandy shales containing a few sandstone layers. It is limited below by the coal-bearing Frontier formation, of Colorado age, which crops out at Kemmerer, and above by the coal-bearing Adaville formation, of Montana age, which is well exposed at the east portal of the Oregon Short Line tunnel at Hodges Pass. The Adaville beds are probably equivalent to the lower part of the Mesaverde formation of the Rock Springs field, of which the Rock Springs coal group forms the lower part. The upper part of the Hilliard shale in Lincoln and Uinta counties[23] is clearly equivalent in part to the Baxter shale and may include a part or all of the Blair formation of the Rock Springs area. In the field in 1907 and 1908 it was thought more probable that the Blair should be correlated with the sandstones at the base of the Adaville formation and that both of these formations represent the lower part of the Mesaverde in this part of Wyoming. Later work in different parts of Utah and Wyoming, however, leads the writer to believe that the base of the Mesaverde should be placed at the base of the Rock Springs coal group and that the Blair is equivalent to the upper part of the Hilliard. If this correlation is correct the character of the remainder of the Hilliard formation as known in Lincoln and Uinta counties and in the Uinta Mountain localities will serve as a clue to the character of the beds below the Baxter shale in the Rock Springs field. In northwestern Colorado and northeastern Utah the Hilliard shale is represented in the upper part of the Mancos shale,

[23] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, 1907. Schultz, A. R., Geology and geography of a portion of Lincoln County, Wyo.: U. S. Geol. Survey Bull. 543, 1914.

which also includes equivalents of the Frontier and Aspen formations, and in central Wyoming the Hilliard is in part represented by the Steele shale.

The deposits (chiefly shale) of Montana and Colorado age in northern Colorado and northeastern Utah are about 5,000 feet thick; in western Wyoming, in Uinta and Lincoln counties, they are 5,500 to 6,800 feet thick; in the Rawlins field, east of the Rock Springs dome, and in the Vermilion Creek and Henrys Fork fields, south of the dome, they are about 5,000 feet thick. Although the thickness of these shales in the Rock Springs field can be determined only by the drill, it seems reasonable to assume that they are at least 4,500 to 5,000 feet thick. In Lincoln and Uinta counties these shales contain a series of pronounced white sandstone lentils, which range in thickness from 50 to 100 feet and occur through about 800 feet of strata approximately 3,000 feet above the base of the series. These sandstone lentils are very conspicuous on Hams Fork and extend 2 miles northward to a point where they are replaced by a clay ridge covered with very large *Ostrea soleniscus*. The clay beds in no way suggest the sandstone layers, though grading directly into them. The fossils collected from these beds indicate that the rocks are of Niobrara age and are a part of the Colorado group. The lower 3,800 feet of the Hilliard formation is therefore a part of the Colorado; the upper 3,000 feet may be in part or wholly of Montana age. Somewhat similar beds in the Salt Creek field in Central Wyoming are described by Wegemann[24] as Niobrara shale. In the Salt Creek field the beds lie approximately 220 feet above the top of the Wall Creek sandstone, the most prominent sandstone of the Frontier formation, and range in thickness from 735 to 1,025 feet. At what depth below the surface the beds of Niobrara age lie in the Rock Springs field is not known, but the evidence in the surrounding fields indicates that they are probably near the center of the series of beds of Montana and Colorado age, or approximately 2,500 to 3,000 feet below the base of the Mesaverde or the Rock Springs coal group. A great thickness of underlying beds is also of Colorado age.

In the Rangely field, in Rio Blanco County, Colo., wells that have been drilled in the Mancos shale have discovered one or more oil-bearing sands in the main body of the shale. Some of these wells yielded several barrels of oil a day. Some indications of a similar field have been noted on Black Gulch, 40 miles east of Rangely, in the White River valley, in the Wolf Creek area, northeast of Rangely, and in the vicinity of the Toe Creek anticline, in Routt County.

The Frontier, which so far as known is the principal oil-bearing formation in Wyoming, lies about 5,000 feet below the base of the

[24] Wegemann, C. H., The Salt Creek oil field, Natrona County: U. S. Geol. Survey Bull. 452, pp. 45–46, 1911.

Mesaverde in this region and is therefore near the drilling limit in anticlines in which the Mesaverde is the oldest formation exposed. About 2,000 feet above the horizon representing the top of the Frontier in the Salt Creek and Big Muddy fields is the Shannon sand. This sand contains oil at Salt Creek and is thought to have been the source of the first oil produced in the Big Muddy field. Above the horizon supposed to be the equivalent of the Shannon the writer has observed sandstone beds capable of acting as oil reservoirs in the Blair formation in Baxter Basin and in the Steele shale in the Rawlins field, and it is believed that the oil discovered at Lost Soldier, northeast of Baxter Basin, comes from one of these sands. It is apparent, therefore, that there are in the Montana and Colorado deposits of this region sands that may serve as oil reservoirs within a short distance below the base of the Mesaverde. As all the beds down to and including a part of the Baxter shale have been removed by erosion in Baxter Basin no attention need be given to the sands of the upper part of the Montana group in prospecting for oil in the central part of the basin.

FRONTIER FORMATION.

The Frontier formation underlies the Hilliard shale and, with the Aspen shale, described below, contains the sands that are supposed to carry oil in this region. Here, as in other parts of Wyoming, the Frontier probably consists of a series of shales and interbedded sandstones. The coals that are present in the western part of the State have probably thinned out and disappeared, as they have along the north and south flanks of the Uinta Mountains. Observations made in Uinta and Lincoln counties indicate that some of the sandstones of the Frontier in the Rock Springs dome are lenticular and that others are continuous over large areas, like those in the Big Horn Basin and other parts of the State. The persistent sandstones of the Frontier formation in southwestern Wyoming, such as the Oyster Ridge and associated sandstones, resemble the Wall Creek sandstone of the same formation in the Salt Creek field, the Big Horn Basin, and other places in central Wyoming. In western Wyoming the Frontier formation is 2,000 to 3,000 feet thick, but toward the east it thins rapidly and does not retain the characteristic sandstones like that of Oyster Ridge in Lincoln and Uinta counties.[25]

It is less than 400 feet thick at many points along the north and south flanks of the Uinta Mountains, 500 to 700 feet thick in the Rawlins field, and probably not far from 500 feet thick in the Rock Springs dome. The character of the Frontier beds in this field is

[25] For a description of the Frontier formation in these counties see U. S. Geol. Survey Prof. Paper 56, pp. 65–69, 1907; U. S. Geol. Survey Bull. 543, pp. 60–63, 1914.

probably more nearly like that of the beds in the Henrys Fork, Vermilion Creek, and Rawlins fields than like that of the beds in Lincoln and Uinta counties. In central Wyoming, as shown by Hares,[26] the Frontier formation includes three distinct sandstones which correspond in ascending order to the Peay, an intermediate sand, and the Wall Creek. All of them are of medium to fine grained gray, somewhat massively bedded sandstones from 20 to 200 feet thick. The entire formation attains a maximum thickness of 1,000 feet. The intervening shale, which makes up more than half of the formation, is dark and sandy. The lowest sandstone member, corresponding to the Peay, is persistent and characterized by large brown concretions, especially in the Emigrant Gap and Oil Mountain anticlines and the Pine dome. The middle sandstone is commonly characterized by small black chert pebbles about the size of peas, which usually distinguish it from the other two sandstones, though in a few places the Wall Creek contains similar pebbles. The upper or Wall Creek sand is the main productive oil sand in the Salt Creek field, 25 miles northeast of the North Casper Creek anticline,[27] but the Peay and Torchlight are important producing sands in the Big Horn Basin.[28] The Wall Creek sandstone may correspond to the Torchlight, as shown by Hintze, for it is stratigraphically at about the same position.

ASPEN SHALE.

In western Wyoming the Aspen shale [29] underlies the Frontier formation in a position stratigraphically similar to that occupied by the Mowry and Thermopolis shales in other parts of the State. Like the Mowry it is light colored and fissile and contains numerous fish scales. Toward the bottom of the Aspen the shales are dark in color, which suggests their possible equivalence to the Thermopolis shale of central Wyoming and the Big Horn Basin. Unlike the Thermopolis shale, however, the lower part of the Aspen contains fish scales. Observations on these beds in surrounding areas and along the north side of the Uinta Mountains make it appear probable that the Aspen shale, from which the oil in the Spring Valley field is obtained, is at least 200 feet thick in the Rock Springs field and may be much thicker. Until a test well has penetrated these formations in the Rock Springs field no more definite statement as to their thickness in this part of Wyoming is justified. In central and southern Wyoming the Mowry shale is normally about 300 feet thick and is an exceptionally good

[26] Hares, C. J., Anticlines in central Wyoming: U. S Geol. Survey Bull. 641, p. 246, 1916.

[27] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 71-75, 1911.

[28] Washburne, C. W., Gas fields of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 340, pp. 348-363, 1908. Hintze, F. F., jr., The Basin and Greybull oil and gas fields, Big Horn County, Wyo.: Wyoming State Geologist's Office Bull. 10, pp. 41-47, 1914. Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p 65, 1914.

[29] U. S. Geol. Survey Prof. Paper 56, p. 64, 1907; U. S. Geol. Survey Bull. 543, p. 59, 1914.

key rock, as it consists of a hard, fissile dark shale that weathers white and contains abundant fish scales, vertebrae, and fins. It is in many localities immediately overlain by a bed of bentonite. No traces of oil were seen oozing from this formation in the fields examined, but oil was produced from it in the Big Horn Basin,[30] at Lander,[31] and at Spring Valley,[32] and it is the probable source of the oil in the Wasatch formation at Labarge.[33] Oil is reported to occur in the Mowry shale in the unproductive Powder River field.[34] Hares in his work in central Wyoming collected two specimens of Aspen or Mowry shale on which tests were made in order to throw light on the possible origin of the Wyoming oil, but the results were negative. One of two samples of the Mowry shale tested by distillation yielded about 2 gallons of oil to the ton, and the other, which contained the greater quantity of fish remains, a mere trace.

BECKWITH FORMATION.

Directly below the Aspen shale in the Rock Springs field lies the group of beds that in western Wyoming constitutes the Beckwith formation.[35]

The Bear River formation, which in western Wyoming lies between the Aspen shale and Beckwith formation, thins rapidly toward the east and is entirely absent along the north flank of the Uinta Mountains in the regions of Henrys Fork and Vermilion Creek and is presumably therefore also absent in the Rock Springs field. Along the north side of the Uinta Mountains the Beckwith formation consists of four rather distinct members. Directly below the Aspen shale is a fine-grained brown to gray quartzitic sandstone and sandy shale with some conglomerate or conglomeratic sand. This sandstone is considered by the writer equivalent to the upper part of the Beckwith formation of western Wyoming and to the beds occurring elsewhere in this part of the Rocky Mountain States that are mapped as the Dakota. It is believed to be the same as the Dakota as mapped in some reports on the Lander field and northern Utah and northwestern Colorado and the same as the upper member of the Cloverly

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[30] Lupton, C. T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621, pp. 157-190, 1916.

[31] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, p. 27, 1911.

[32] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, p. 158, 1907.

[33] Schultz, A. R., The Labarge oil field, central Uinta County, Wyo.: U. S. Geol. Survey Bull. 340, pp. 367-371, 1908. Trumbull, L. W., Prospective oil fields at Upton, Buck Creek, Rattlesnake Mountains, and Labarge: Wyoming State Geologist's Office Bull. 5, pp. 14-15, 1913.

[34] Wegemann, C. H., The Powder River oil field, Wyo.: U. S. Geol. Survey Bull. 471, p. 71, 1912.

[35] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, pp. 57-59, 1907. Schultz, A. R., Geology and geography of a portion of Lincoln County, Wyo.: U. S. Geol. Survey Bull. 543, pp. 52-54, 1914. Mansfield, G. R., and P. V. Roundy, Revision of the Beckwith and Bear River formations of southeastern Idaho: U. S. Geol. Survey Prof. Paper 98, pp. 75-84, 1916.

formation of some authors. It may correspond to the Greybull sand of the Big Horn Basin.[36] In the Uinta Mountain region and at the south end of the Rattlesnake Mountains or near Garfield Peak, in central Wyoming, this sandstone, so far as known, contains no oil, but at numerous places on Wallace Creek and the creeks to the north it is saturated with dark asphaltic oil and, with the lower conglomerate, equivalent to the middle part of the Beckwith formation, furnishes the asphaltum found in that district. The upper sandstone of the Beckwith shows no trace of oil along the outcrop throughout the western part of Wyoming, but it may furnish the lower oil encountered in Pittsburg-Salt Lake Oil Co.'s well 2 miles south of Spring Valley, in the NW. ¼ NE. ¼ sec. 10, T. 14 N., R. 118 W.[37] The higher oils at this locality probably came from the Bear River formation. The upper sandstone of the Beckwith is so variable in thickness and so unfavorably situated in most of the folds of this region that it is considered unimportant as a reservoir for oil.

The second and fourth (lowest) members of the Beckwith are very much alike and lithologically resemble the Morrison of Wyoming. These rocks consist of indurated clays of dark-greenish cast, together with some shaly sandstone beds, white clays, and clays of mottled colors such as green, purple, maroon, gray, red, and pink. The two members are separated by a conglomeratic sandstone member which in places is from 150 to 200 feet thick; the shale above it is approximately one-fourth to one-third as thick as the lowest member. The entire group of four members, which are probably in part unconformable, is about 850 feet thick on the north side of the Uinta Mountains, in the Henrys Fork field, and in the Vermilion Creek area. It should be noted that these beds are much thinner in this part of Wyoming than in the western part and differ very decidedly from the exposures as described in the reports above referred to. These beds in the Rock Springs area probably very closely resemble those in the Vermilion Creek and Henrys Fork fields. The entire thickness of the Beckwith formation, including the upper sandstone member and the three underlying members, probably does not exceed 800 to 1,000 feet in the Rock Springs field. The conglomerate member of the Beckwith is the only member below the upper sandstone that may serve as a reservoir for the accumulation of oil in this part of Wyoming. In the opinion of the writer it is probably equivalent to the basal conglomeratic sandstone of the Cloverly formation of the Big Horn Mountains, the lower member of the Cloverly formation of the Basin and Greybull oil and gas fields,[38] and the Dakota (?) of the

[36] Lupton, C. T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621, pp. 157-190, 1916.

[37] See U. S. Geol. Survey Prof. Paper 56, p. 149, 1907.

[38] Hintze, F. F., jr., The Basin and Greybull oil and gas fields, Big Horn County, Wyo.: Wyoming State Geologist's Office Bull. 10, pp. 16-17, 1914.

Salt Creek field,[39] and is identical with the conglomerate described as of Lower Cretaceous age (?) in the Lander field.[40] In central Wyoming Hares [41] found that beds equivalent to this formation contain dark-colored, well-rounded chert pebbles, commonly about the size of small marbles but reaching a maximum diameter of 1½ inches, firmly cemented. Usually the cement is silica, but in some places it is lime. The coarse basal conglomerate that constitutes the lower half of the formation grades upward into a slightly conglomeratic sandstone and the whole attains a thickness of about 60 feet. It varies little from this thickness throughout the eastern part of the area, though in the Conant Creek anticline it is only 8 feet thick. The formation where upturned forms small hogbacks, a feature which, with the lithologic character, makes its identification easy.

Though the conglomerate is mentioned by Knight[42] as showing traces of oil in the Dutton "anticline," none were noticed in it there by Hares or in the other exposures of the conglomerate except along the Rattlesnake Mountains. It is probably the source of the oil at the seep in sec. 28, T. 33 N., R. 82 W., at the north end of Oil Mountain. Small quantities of dark, thick oil ooze from it near the Lew Smith Spring, at the head of Horse Creek, in sec. 26, T. 32 N., R. 86 W., on the southwest side of the Rattlesnake Mountains. About 2 miles south of Oil City a few sections of land have been patented as oil placer land because dark asphaltic oil seeps from the conglomerate beds that occur in that locality. Northwest of Oil City and south of Garfield Peak the conglomerate contains little if any oil, but in places on Wallace Creek and on the small creeks near by it is saturated with dark asphaltic oil. The light volatile parts have evaporated from the oil that seeps out here, and the heavy dark residue, mixed with soil and dead vegetation, has accumulated on the creek bottoms to a thickness of a foot or more and covers many square rods. This deposit is used locally for fuel, chiefly for engines drilling prospect holes. Strong sulphur water was found in the conglomerate in the Ohio well, on Poison Spider Creek, and in the Guthery, Monongahela, and Toltec wells, and similar water issues from the conglomerate in sec. 15, T. 33 N., R. 81 W. The Ohio and Guthery wells struck traces of oil in the conglomerate.

TWIN CREEK FORMATION.

Below the Beckwith beds lies the Twin Creek formation, equivalent to the Sundance formation of central Wyoming. The thickness

[39] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, p. 44, 1911.

[40] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, pp. 18–19, 1911.

[41] Hares, C. J., Anticlines in central Wyoming: U. S. Geol. Survey Bull. 641, p. 244, 1916.

[42] Knight, W. C., Wyoming Univ. School of Mines, Petroleum ser., Bull. 4, pp. 17–19, 1901.

of these beds along the north side of the Uinta Mountains south of the Rock Springs field is about 140 feet, and their thickness in the Rock Springs field is probably about the same.

Hares [43] states that along the east flank of the Rattlesnake Mountains north of Garfield Peak there are places where the sandstones in the Sundance (Jurassic) and especially the Morrison (Cretaceous?) formations show signs of oil. Oil seeps from the Sundance and Morrison formations have been noted in the unproductive Powder River oil field.[44] These formations in some areas, as in Lincoln County and central Wyoming, contain thin and thick sandstones that in favorable folds might serve as reservoirs for oil, but it is believed that they are of little value as oil reservoirs in the Rock Springs field. The most favorable horizon for the accumulation or storage of oil below the Frontier sands is the conglomeratic member of the Beckwith, but the prospects for striking oil in commercial quantities in this member is slight.

NUGGET SANDSTONE.

The Nugget sandstone consists essentially of 1,000 feet of massive white to red sandstone that is finely banded and intricately cross-bedded. At the east end of the Uinta Mountains the sandstone is chiefly white; at the west end it is almost entirely red. This sandstone is equivalent to the "White Cliff" sandstone of the Uinta Mountain section, to the Nugget sandstone as mapped by Boutwell in the Park City district of Utah, and probably to the upper or more sandy portion of the Chugwater formation of central Wyoming. The thickness on Henrys Fork and Vermilion Creek is approximately 1,000 feet, and that is its probable thickness in the Rock Springs uplift. Hares [45] points out that in places in central Wyoming, as on the east flank of the Rattlesnake Mountains, these beds show signs of oil. Indications of oil have also been observed by the writer in these beds at several points along the Uinta Mountains. The white sandstones are infiltrated with oil so that on breaking the fresh surfaces have a dark color and the rock gives off a strong odor of oil. The weathered rock has a bluish-white appearance and does not on first glance show the amount of oil the rocks contain. At a number of places along the outcrop on the south side of the Uinta Mountains some of the oil has escaped to the surface and formed small asphaltic deposits on the ground. In the Rock Springs uplift the Nugget sandstone probably lies too deep to be commercially exploited, even if the oil has collected in these beds.

[43] Op. cit., p. 243.
[44] Wegemann, C. H., The Powder River oil field, Wyo.: U. S. Geol. Survey Bull. 471, p. 71, 1912.
[45] Op. cit., p. 243.

PARK CITY FORMATION.

As originally defined by Boutwell (in the Park City district of Utah) the Park City formation was described as "calcareous, with interbedded quartzite, sandstones, and some shale," 590 feet thick, overlying the Weber quartzite and underlying the Woodside shale. In 1914 the upper or phosphate-bearing part of the formation as developed in southeastern Idaho was separated by Richards as a distinct geologic unit to which he applied the name Phosphoria formation, the lower part of the Park City being mapped with all the underlying Pennsylvanian beds, including those equivalent to the Weber quartzite, as the Wells formation. In the area covered by the present report, however, the Weber quartzite and Woodside shale are recognized and mapped, as is the Park City formation, the upper part of which represents the Phosphoria formation of northeastern Utah, eastern Idaho, western Wyoming and Montana, as well as a part of the Embar formation of central Wyoming.

Almost everywhere in the Rocky Mountain States where the Park City formation, or the equivalent beds, have been studied in detail, they show indications of oil and may some day prove to be the source of much of the oil in overlying sandstones. Indications of oil were seen in the Phosphoria formation in many places in Wyoming, Utah, Idaho, and Montana, and equivalent beds in the Lander field constitute one of the main oil-producing formations. In central Wyoming the Embar formation overlies the Tensleep sandstone and is composed of 225 feet or more of light-gray fossiliferous limestone, shale, chert, and beds of phosphate. It is typically developed in the western part of the area, where it is equivalent to the Park City and Dinwoody formations, but in the eastern part the equivalent beds are of an entirely different character, taking on the lithology of the Chugwater formation and consisting mostly of red shale with some limestone, fossiliferous red and gray chert, and gypsum but containing no thick beds of sandstone. It was reported that the well of the Pine Dome Oil Co. obtained its flow of gas from the Embar, but it is fully as probable that the gas comes from the Tensleep sandstone. The presence of oil seeps in the Red Springs dome at the south end of the Big Horn Basin, and on the north flank of the Owl Creek Mountains near the M-bar ranch indicates that the Embar is oil bearing in those regions as well as at Lander. At the west end of the Green Mountains the Park City formation is 160 feet thick. At the east end of the Uinta Mountains it is only about 200 feet thick; and probably the thickness is the same in the Rock Springs field.

Throughout the Uinta Mountain uplift the entire phosphatic series of the Park City formation is approximately 35 feet thick and varies from place to place, but there is a single phosphatic zone which may represent all or a part of the Phosphoria of eastern Idaho and in which the various thick and thin, rich and lean beds of phosphate occur. Some of the beds that are several inches in thickness consist almost entirely of phosphatic material; others are composed chiefly of chert nodules and lenses with a little phosphate material. The thicker beds consist of cherty limestones, shales, sandstones, and phosphate beds from 1 to 6 feet thick. Individual layers or beds in this series of limestone, shale, and sandstone contain more or less phosphatic salts ranging from 1 to 70 per cent tricalcium phosphate, the maximum being equivalent to 32 per cent phosphoric acid. When compared over large areas these layers have been found to be variable, not only vertically but horizontally, both as to character of bed and as to the quantity of phosphoric acid present, and yet in many respects they are rather uniform and constant in character and have throughout the field many common characteristics.

The richest portion of the phosphatic zone is generally a dark-gray oolitic sandy limestone thickly speckled with black phosphatic granules and containing in places small particles of tarlike gilsonite and other hydrocarbon compounds. When the phosphate rock is dissolved in nitric acid it leaves a copious residue of fine sand with a tarlike oily substance which probably represents the material that gives the fetid or petroliferous odor readily noted when the rock is broken with the hammer. The indications of oil in these beds, together with the oil that has seeped into the overlying sandstones so that in places they are completely impregnated with asphaltic material, seem to indicate that the Park City formation may be a source of oil. Oil is also known to be present in rocks of Permian age in the Virgin River oil field, in southwestern Utah near the town of Virgin. The first well drilled there yielded 10 barrels of oil a day from a depth of 566 feet. No commercial oil has been produced in this field up to the present time.

Rock samples collected from the Phosphoria formation in different parts of the Rocky Mountain States and tested for oil indicate that this formation contains oil over large areas. The following table indicates the amount of oil and phosphate obtained from these specimens:

Tests of phosphate rock containing oil in northwestern Colorado, eastern Idaho, western Utah, and western Wyoming.

[Chase Palmer, U. S. Geological Survey, and C. S. Reeve, Office of Public Roads and Rural Engineering, analysts.]

No.	Location.	Laboratory No. (Office of Public Roads and Rural Engineering).	Phosphorus pentoxide (P_2O_5).	Tricalcium phosphate ($Ca_3(PO_4)_2$).	Specific gravity.	Petroleum.		
						Dry distillation (gallons per ton).	Carbon tetrachloride extraction.	Carbon disulphide extraction (per cent).
E....	Trail Creek, Wyo., NE. ¼ sec. 16, T. 41 N., R. 118 W.	12781	Trace.	Trace.	1.93	A little oil[a]..	Little.......	0.34
G....	Palisade Creek, Idaho, sec. 25, T. 2 N., R. 45 E.	12782	12.69	27.8	2.33	Little oil distillate.[a]	Very little...	.79
H....	South Fork of Raney Creek, Idaho, sec. 16, T. 2 N., R. 45 E.	12783	31.69	69.4	2.24	A little oil[a]..	.....do.......	.98
I.....	North Fork of Raney Creek, Idaho, sec. 8, T. 2 N., R. 45 E.	12784	17.08	37.4	2.64	.....do.[a]	.....do.......	1.19
X....	Young's ranch, southwest of Lander, Wyo., sec. 8, T. 31 N., R. 99 W.	12785	24.3	53.16	2.31	3.17.........	Some........	4.89
14....	Wolf Creek, Utah, NE. ¼ sec. 18, T. 1 N., R. 9 W.	12771	16.76	36.70	2.23	Oil[a].........	Little.......	.95
16....	Lake Fork, Utah, SW. ¼ sec. 27, T. 2 N., R. 5 W.	12772	12.28	26.89	2.55	.....do.[a]	.....do......	1.00
18....	Whiterocks River, Utah, NE. ¼ sec. 18, T. 2 N., R. 1 E.	12773	26.39	57.79	2.90	No oil[a]	None........	.34
20....	Deep Creek, Utah, NE. ¼ sec. 8, T. 3 S., R. 21 E.	12774	26.40	57.82	2.90	.....do.[a].....	.....do.......	.43
30....	Lodgepole Creek, Utah, SW. ¼ sec. 3, T. 2 N., R. 18 E.	12775	30.72	67.28	2.77	0.36.........	.....do.......	.61
38....	Green River, Utah, sec. 30, T. 4 S., R. 24 E.	12776	4.84	10.68	2.64	0.50.........	.....do.......	.28
42....	Disappointment Creek, Colo., sec. 31, T. 6 N., R. 99 W.	12777	Trace.	Trace.	2.17	No oil[a].....	.....do.......	.89
44....	Vermilion Creek, Colo., sec. 36, T. 10 N., R. 101 W.	12778	4	8.76	2.35	2.34.........	Some.......	6.79
A....	Baxter Basin, Wyo., sec. 36, T. 20 N., R. 104 W.	No number.	0	0	2.00	No oil[a]......	None........	None.
B....	Disappointment Creek, Colo., sec. 31, T. 6 N., R. 99 W.	12779	Trace.	Trace.	2.30	.....do.[a]....	Some........	4.48
C.....	Whiterocks River, Utah, sec. 18, T. 2 N., R. 1 E.	12780	23.48	51.42	2.33	1.64.........	.....do.......	5.04

[a] Mr. Reeve omitted the dry distillation of these samples because so little material was submitted as to make it practically impossible to obtain results of any value.

That the Embar or equivalent rocks (including the Phosphoria formation) in Idaho, Montana, Utah, and Wyoming contain petroleum at Lander and give evidence of the presence of petroleum elsewhere has long been known. This fact has been emphasized recently, however, by Bowen's examination in 1916 of the oil shale at Dillon and Dell, Mont.[46] The reports of oil in the Phosphoria formation in Montana and Idaho and in equivalent rocks in the Wind River and Owl Creek mountains in Wyoming and the Uinta and Wasatch mountains in Utah suggest that these rocks should be geologically examined. The results of an examination of the oil possibilities of these beds in the Rocky Mountain region will be of scientific interest, and if they are favorable they will constitute an important factor in oil-land classification. Should such an examination determine that these rocks are to be considered as a source or reservoir for oil an entirely new field of investigation, embracing folds in which these beds may constitute the objective oil sands, will be opened.

TENSLEEP SANDSTONE.

The Tensleep sandstone, which is equivalent to the Weber quartzite of Pennsylvanian age, is the lowest formation that shows signs of oil in central Wyoming in the area between Casper, Lander, and Lost Soldier. According to Hares[47] the Tensleep sandstone is approximately 200 feet thick in the Rattlesnake Mountains. An exposure of a few square rods in the SW. ¼ sec. 13, T. 33 N., R. 90 W., in the Dutton anticline, contains some oil, but so far as observed none escapes. At all other localities where the formation was examined by Hares it is barren. The rock is a medium-grained, highly cross-bedded, firmly cemented quartz sandstone which is of sufficiently open texture to allow the free circulation of water, as shown by the Ohio well, on Poison Spider Creek. No indications of oil were observed in this sandstone in western Wyoming, in the Rawlins dome, or along the Uinta Mountains.

CARBONIFEROUS LIMESTONE.

The reports of oil in the Madison and associated rocks in the Big Snowy Mountains, Mont., in the northern part of the Big Horn Basin, Wyo., and at several places in Utah south of the Uinta Mountains render these older formations also proper objects of scientific study. In the Rock Springs field these beds, as well as the overlying Tensleep or Weber sandstones, lie at too great a depth to be exploited. Unless the oil has migrated upward and is now confined in some member nearer the surface it will be of no avail to the prospector.

South of the Uinta Mountains considerable drilling for oil and gas has been done at several localities in Utah, but very little oil in commercial quantities has been found. The San Juan field, in the south-

[46] Bowen, C. F., Phosphatic oil shales near Dell and Dillon, Beaverhead County, Mont.: U. S. Geol. Survey Bull. 661, pp. 315-320, 1918.

[47] Hares, C. J., Anticlines in central Wyoming: U. S. Geol. Survey Bull. 641, p. 243, 1916.

Sections showing occurrence of oil and gas in some of the Rocky Mountain fields.

[Correlations approximate and sections incomplete. O, oil; G, gas; +, seeps and small production of oil and gas.]

Boulder, Colo. [a]	Laramie Fox Hills Pierre O (Hygiene sandstone member O G) Niobrara O? Benton O? Dakota Morrison Absent Lykins Lyons Fountain
Florence, Colo. [b]	Laramie? Trinidad? Pierre O Niobrara Carlile Greenhorn Graneros "Dakota" + Morrison + Absent Fountain Millsap
De Beque, Colo. [c]	Green River Wasatch Absent Absent Mesaverde O
Rangely, Colo. [d]	Green River Wasatch Fort Union (?) Absent Absent Mesaverde Mancos O Dakota "Flaming Gorge" or McElmo "White Cliff" or La Plata "Red Beds"
Green River, Utah [e]	Absent Mancos: Ferron O G Dakota McElmo La Plata
San Rafael, Utah [e h]	McElmo La Plata Vermilion Cliff Permian? O
San Juan, Utah [f]	La Plata Dolores shale Moencopie (Oljato sandstone member) Goodridge O
Virgin, Utah [g]	Eocene Upper Cretaceous Jurassic Triassic Permian O Upper Carboniferous
Castle Valley, Utah [h]	Green River (?) Wasatch Absent Absent Mesaverde Mancos: Ferron Dakota McElmo La Plata Vermilion Cliff + Permian
Spring Valley and Labarge, Wyo. [i]	Green River Wasatch +O Evanston Absent (?) Adaville Hilliard O Frontier O Aspen O Bear River O Absent (?) Beckwith O Twin Creek
Rock Springs, Wyo. (This report)	Leucite lava Bishop conglomerate Absent Bridger Green River Wasatch Post-"Laramie" "Laramie" Lewis Mesaverde Blair Baxter Not exposed Frontier Aspen Absent (?) Beckwith Twin Creek Nugget Ankareh Thaynes (?) Woodside Park City Weber Older Pennsylvanian Mississippian
Lander, Wyo. [j]	Wind River Absent or concealed Absent Mesaverde Mancos +O Dakota Lower Cretaceous (?) Morrison Sundance Chugwater +O Embar O
Central Wyoming [k]	White River + Wind River +? Fort Union Lance Lewis Mesaverde: Teapot +, Parkman Steele: Shannon Niobrara Carlile Frontier: Wall Creek +, +, Peay + Mowry Thermopolis Dakota Lower Cretaceous: Shale Conglomerate + Morrison + Sundance + Chugwater + Embar Tensleep + Amsden Madison
Big Muddy, Wyo. [l]	White River Lance Fox Hills Pierre: Teapot, Parkman, [Shannon] Niobrara Benton: Wall Creek O, Mowry "Cloverly" Morrison Sundance
Douglas, Wyo. [m]	White River O G Fort Union (?) Lance Fox Hills Pierre: Parkman ?, Shannon ? + Niobrara Benton O G: Wall Creek (?), Mowry, (O ?) "Cloverly" O+ Morrison Sundance Chugwater Forelle (?) Satanka (?) Casper +
Salt Creek and Powder River, Wyo. [n]	Wasatch Fort Union Lance Lewis Mesaverde: Parkman Steele: Shannon O Niobrara O Benton: Wall Creek O, Mowry + Cloverly + Morrison + Sundance +
Wyoming [o]	White River Bridger Green River Wasatch + Fort Union (?) Laramie Fox Hills Fort Pierre Niobrara + Fort Benton Dakota + + Como Shirley Triassic Permian Carboniferous
Moorcroft and Newcastle, Wyo. [p]	Fox Hills Pierre Niobrara Carlile Greenhorn Graneros: Mowry O, O Dakota + Fuson + Lakota Morrison Sundance Spearfish
Shoshone River, Wyo. [q]	Wasatch Fort Union Ilo (Lance) Meeteetse Gebo Colorado + + O O "Cloverly" G Morrison G Sundance
Grass Creek, Oregon Basin, and other anticlines, Wyo. [r]	Wasatch Fort Union Lance Meeteetse Mesaverde Cody Frontier O Mowry O Thermopolis O G Cloverly O G Morrison Sundance Chugwater Embar Tensleep Amsden Madison
Basin, Wyo. [s]	Fort Union and Lance undifferentiated Mesaverde Cody Frontier: Torchlight +, (+), Peay + G Mowry +O Thermopolis + Cloverly Morrison
Greybull, Wyo. [t]	Ilo Montana undifferentiated Eagle Pierre Basin Benton: Torchlight, Peay, O G Cloverly O G: Greybull Morrison
Elk Basin, Wyo. [u]	Wasatch Fort Union Lance Bearpaw Judith River Claggett Eagle Niobrara Carlile Frontier O Mowry Thermopolis Cloverly O: Greybull Morrison Sundance Chugwater Embar Tensleep Amsden Madison

[a] Fenneman, N. M., Geology of the Boulder district, Colo.: U. S. Geol. Survey Bull. 265, pp. 76–98, 1905.

[b] Washburne, C. W., The Florence oil field, Colo.: U. S. Geol. Survey Bull. 381, pp. 517–544, 1910.

[c] Woodruff, E. G., Geology and petroleum resources of the De Beque oil field, Colo.: U. S. Geol. Survey Bull. 531, pp. 54–65, 1913.

[d] Gale, H. S., Geology of the Rangely oil district, Rio Blanco County, Colo., with a section on the water supply: U. S. Geol. Survey Bull. 350, 1908.

[e] Lupton, C. T., Oil and gas near Green River, Grand County, Utah: U. S. Geol. Survey Bull. 541, pp. 115–133, 1914.

[f] Woodruff, E. G., Geology of the San Juan oil field, Utah: U. S. Geol. Survey Bull. 471, p. 76, 1912.

[g] Richardson, G. B., Petroleum in southern Utah: U. S. Geol. Survey Bull. 340, p. 343, 1908.

[h] Lupton, C. T., Geology and coal resources of Castle Valley in Carbon, Emery, and Sevier counties, Utah: U. S. Geol. Survey Bull. 628, pp. 20-21, 1916.

[i] Veatch, A. C., Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil: U. S. Geol. Survey Prof. Paper 56, pp. 157–158, 1907. Schultz, A. R., The Labarge oil field, central Uinta County, Wyo.: U. S. Geol. Survey Bull. 340, pp. 364–365, 1908; unpublished notes.

[j] Woodruff, E. G., The Lander oil field, Fremont County, Wyo.: U. S. Geol. Survey Bull. 452, 1911.

[k] Hares, C. J., Anticlines in central Wyoming: U. S. Geol. Survey Bull. 641, pp. 233–279, 1916.

[l] Barnett, V. H., The Moorcroft oil field and Big Muddy dome, Wyo.: U. S. Geol. Survey Bull. 581, pp. 83–117, 1915. Darton, N. H., Preliminary report on the geology and underground-water resources of the central Great Plains: U. S. Geol. Survey Prof. Paper 32, pp. 334, 364, 379–388, 1905.

[m] Barnett, V. H., The Douglas oil and gas field, Converse County, Wyo.: U. S. Geol. Survey Bull. 541, pp. 49–88, 1914.

[n] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 670, 1918.

[o] Knight, W. C., A preliminary report on the artesian basins of Wyoming: Wyoming Univ. Exper. Sta. Bull. 45, 1900. Knight, W. C., and Slosson, E. E., The Dutton, Rattlesnake, Arago, Oil Mountain, and Powder River oil fields: Wyoming Univ. School of Mines Petroleum Series, Bull. 4, 1901.

[p] Barnett, V. H., The Moorcroft oil field and Big Muddy dome, Wyo.: U. S. Geol. Survey Bull. 581, pp. 83–117, 1915.

[q] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, pp. 89–113, 1914.

[r] Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 656, 1917.

[s] Lupton, C. T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621, pp. 157–190, 1916.

[t] Hintze, F. F., The Basin and Greybull oil and gas fields: Wyoming State Geologist's Office Bull. 10, 1915.

[u] Hares, C. J., unpublished data; also Anticlines in central Wyoming: U. S. Geol. Survey Bull. 641, p. 238, 1916.

eastern part of the State, has probably produced more oil from this geologic stratum than any other localities that have been drilled, but only 1 of the 30 wells drilled there from 1907 to 1910 yielded more than a good showing of oil. The oil in this field is believed to come from the Goodridge formation, of upper Pennsylvanian age. Several wells have been drilled east of the San Rafael Swell, of which only one, drilled to a depth of 2,715 feet, encountered oil. The oil was struck in the Carboniferous rock at depths of 2,175, 2,530, and 2,655 feet below the surface. In the Green River region several deep wells have been drilled in the McElmo formation, and a few penetrated the underlying La Plata sandstone but have not tested the Permian or Pennsylvanian rocks. None of the wells have obtained oil in commercial quantities. Several oil seeps from rocks of Carboniferous age have been reported along Colorado River in southeastern Utah.

CAMBRIAN AND PRE-CAMBRIAN FORMATIONS.

Oil-bearing beds of Cambrian and pre-Cambrian age are described by Trumbull.[48] The beds of this age in central Wyoming, according to reports, are saturated with oil near Copper Mountain, on the south side of the Owl Creek Mountains, near T. 39 N., R. 92 W. The Wind River formation (Eocene), which overlies the Cambrian at this locality, is also said to show traces of oil. No indications of oil, however, were observed in the Cambrian or pre-Cambrian formations in southwestern Wyoming or along the Uinta Mountains. As a source of oil or a reservoir for the accumulation of oil these formations are of no value in the Rock Springs uplift, for they lie at too great a depth below the surface.

The accompanying table indicates the stratigraphic position of the oil and gas bearing beds and oil shale in Wyoming and adjacent fields.

WELLS DRILLED IN OR NEAR BAXTER BASIN.

HISTORICAL SKETCH.

The petroleum resources of Wyoming have engaged the attention of many persons since the days of Capt. Bonneville's travels in the last century, when he described for the first time some of the tar springs of the region in central Wyoming east of the Wind River Mountains.

In southwestern Wyoming, west of the Rock Springs uplift, oil springs were known to the trappers and frontiersmen who built the trading post of Fort Bridger, and to the Mormons at the time they made their pioneer journey to Great Salt Lake in 1847, as they used

[48] Trumbull, L. W., Petroleum in granite, part 1: Wyoming Geol. Survey Bull. 1, Scientific series, pp. 5-16, 1916.

some of the oil for their wagons and stock and carried small quantities with them to Salt Lake. From that time to the present more and more active work has been undertaken, so that many of the oil fields in Wyoming have been studied and are now producing large quantities of petroleum. The two years, 1917 and 1918, were the busiest the State has ever seen so far as oil development is concerned, and the year 1919 promises to see more active drilling than that completed in 1918, when the supply of well tubing and casing was difficult to obtain, and the work was greatly interfered with as a result of the war.

During 1916 there were rushes to three new fields—Pilot Butte, Lost Soldier, and Big Muddy. In each of these three fields oil has been obtained at shallow depth, probably in the equivalent of the Shannon sand of Salt Creek. At Big Muddy several deep wells have obtained oil in the Wall Creek sand, 2,000 feet stratigraphically below the Shannon. At Pilot Butte and Lost Soldier the lower sands have not been tested. In the Salt Creek field sands below the famous Wall Creek sand have been developed. The so-called "Lower Wall Creek" has been tested and is reported to contain oil distributed over a larger area than the overlying sand. It is also reported that there are other sands below the "Lower Wall Creek."

Oil has also been obtained at shallow depth and at a high geologic horizon on Dry Piney Creek, in Lincoln County, and gas and a little oil were struck in sands in Baxter Basin, southeast of Rock Springs.

In the Rock Springs area no surface indications of oil have been observed other than the oil shale. At Fish Cut, a short distance west of the town of Green River, the surface in several places is kept moist by oil that oozes from the shale on the old Union Pacific Railroad grade just below the present road. Rock from Fish Cut that gave no outward sign of the presence of oil yielded on distillation 29.4 gallons of oil, 9 pounds of ammonium sulphate, and 2,978 cubic feet of gas to the ton of shale. On the east side of the Rock Springs dome, in Tps. 17 and 18 N., R. 92 W., along Muddy Creek east of Washakie Basin, the presence of oil is indicated by outcrops of oil-saturated sandstones from 20 to 30 feet thick near the base of the Wasatch formation or the Black Rock coal group. No oil and gas seeps have been reported from the Baxter shale or the overlying Blair shale, and no mineral wax or ozokerite has been found associated with the calcite deposits filling veins along fault planes. Nevertheless search is being made for oil along the Rock Springs uplift, and small showings of oil and gas have been made in some of the wells drilled on this fold. The wells which have been drilled in or adjacent to Baxter Basin and which have some value in determining the character and oil possibilities of the beds beneath the surface in the Rock Springs dome may be classified into three groups—the wells drilled by the Union Pacific Railroad Co. for the purpose of obtaining suitable water for use in its locomotives; those drilled in the first attempt by oil prospectors to find commercial oil in Baxter Basin, in 1900–1903; and those drilled in the second attempt by prospectors to find oil in Baxter Basin, in 1915–16.

WELLS DRILLED BY UNION PACIFIC RAILROAD CO.

ROCK SPRINGS.

The first deep well put down in the vicinity of the Rock Springs dome was drilled by the Union Pacific Railroad Co. at Rock Springs in 1872. The well was on the west limb of the dome, in sec. 35, T. 19 N., R. 105 W., and proved at this early date the prolific character of the Rock Springs coal group. No oil or gas was reported from the coal beds or from the interbedded sandstones. The following log of this well was furnished by the Union Pacific Railroad Co.:

Log of railroad well at Rock Springs, Wyo.

	Thickness.	Depth to top.		Thickness.	Depth to top.
	Ft. in.	*Feet.*		*Ft. in.*	*Feet.*
Coal	11	4	Black sulphate alumina		563
Quicksand		39	Coal	3	577
Hard sand rock.			Sand rock		583
Coal	6	117	Coal	3	597
Coal	1	149	Coal	3	606
Coal	1 8	175	Coal	3	616
Brown shale		180	Slate and sand rock		640
Coal	2	209	Coal	3 9	668
Coal	5 5	268	Slate rock		683
Coal	3 7	317	Coal	3	694
Coal	4 8	377	Coal	1	
Sand rock		400	Coal	2	728
Coal	2 6	420	Shale		
Sand rock		427	Sand rock		1,034
Coal	3	473	Shale		1,067
Coal	2	485	Sand rock		1,129
Soft aluminous stone		500	Shale		1,145
Coal	1 6	543	Water		1,145

POINT OF ROCKS.

In 1873 the railroad company drilled its first well at Point of Rocks, in sec. 27, T. 20 N., R. 101 W. The well was started in the middle member of the Mesaverde formation and drilled to a depth of 1,000 feet. It is on the east limb of the dome, much farther from the major axis than the wells at Rock Springs or Salt Wells. A trace of oil was reported at a depth of 351 feet, and immediately below this the log shows 37 feet of petroleum shale. In 1901 the company drilled a second well at Point of Rocks to a depth of 1,002 feet, and in 1910 a third well to a depth of 1,009 feet. The material penetrated is much the same in all three wells, and an abundant supply of good water was obtained from each well. The log of the well drilled in 1910, which is similar to the other two, is as follows:

Log of railroad well No. 3 at Point of Rocks, Wyo.

	Thickness.	Depth.		Thickness.	Depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Clay	50	50	Shale	15	564
Sand rock	43	93	White sand rock	8	572
Gravel	5	98	Red sand rock	68	640
Sandy shale	45	143	Shale	6	646
White shale	6	149	White sand rock	14	660
Sand rock	45	194	Red shale	40	700
Sandy shale	25	219	Shale	63	763
Sand rock	115	334	Sand rock	12	775
Red shale	22	356	Shale	20	795
Sand rock	40	396	Sand rock	89	884
Red shale	12	408	Shale	3	887
Sand rock	50	458	Sand rock	45	932
Shale	40	498	Shale or fire clay	46	978
Coal dirt	1	499	Sandy shale	31	1,009
Sandy shale	50	549			

BITTER CREEK.

A well was drilled by the railroad company in 1873 at Bitter Creek, in sec. 10, T. 18 N., R. 99 W. This well, like those at Point of Rocks, is on the east limb of the dome but is much farther from the crest and was started in beds of the Black Rock coal group, of Tertiary (Wasatch) age. The well went only to a depth of 696 feet and probably was drilled all the way in Tertiary rocks. A rich petroleum shale 9 feet thick was reported at a depth of 546 feet, and flowing water was obtained at 395 feet. The following record of this well was furnished by the Union Pacific Railroad Co.:

Log of water well of Union Pacific Railroad at Bitter Creek, Wyo.

Water	57	Vein of sand	320
Waterworn pebbles	63	Very hard shale	350
Coarse gravel	76	Water rising within 2 feet of surface	378
Hard sandstone	100	Water flowing at surface	395
Light shale	100	Light shale	408
Hard shale stone	170	Fine sandstone	495
Black sulphate of alumina and iron	194	Coarse sandstone	510
Thin stratum of sandstone changing to light shale	224	Rich petroleum shale 9 feet thick	546
Black sulphate of alumina		Light shale	550
Very hard shale	300	Light shale increasing in hardness	571
		Sand rock	696

BRIDGER.

A well drilled by the railroad company at Bridger, in sec. 2, T. 16 N., R. 117 W., some distance west of the Rock Springs dome, throws some light on the older beds involved in the dome. This well was drilled to supply the water tank at Bridger, but the water was so alkaline that it could not be used. Mr. D. V. Bell, assistant superintendent of water service in Wyoming, gives the following data:

Section of water well of Union Pacific Railroad at Bridger, Wyo.

	Feet.
Quaternary:	
Red clay	0–30
Sand and gravel, water bearing	30–38
Wasatch formation:	
Red shale	38–125
Sandstone	125–133
Red shale	133–148
Gray shale	148–228
Hard sandstone; small flow of water	228–236
Gray, green, and red shales	236–345
Sandstone	345–360
Gray shale	360–405
Sandstone	405–410
Gray shale	410–460
Sandstone; small flow of water	460–465
Gray shale	465–505
Sandstone	505–520
Gray shale	520–530
Sandstone	530–540
Red shale	540–565
Gray shale	565–620
Shale with thin layers of sand rock	620–640
Wasatch formation—Continued.	
Gray shale	640–665
Red shale	665–675
Sandstone; small flow of water	675–695
Gray shale	695–730
Black shale	730–740
Shale with thin layers of sandstone	740–750
Gray shale	750–800
Red shale	800–880
Bear River formation:	
Sandstone	880–895
Black shale	895–920
Gray shale	920–960
Hard gray and black shale	960–1, 300
Shale, with thin layers of sandstone	1, 300–1, 318
Gray shale	1, 318–1, 378
Beckwith formation:	
Red shale	1, 378–1, 386
Sandstone not passed through, yielding flow of water, 20 gallons a minute.	1, 386

SPRING VALLEY.

The railroad company drilled a well at Spring Valley, southwest of Bridger, in the SE. ¼ SE ¼ sec. 27, T. 15 N., R. 118 W., in which at a depth between 491 and 493 feet a sand containing oil of very high grade was encountered. Oil of similar grade was struck again between 573 and 581 feet and between 1,148 and 1,170 feet. This well was drilled by L. E. Nebergall between September 3, 1900, and May 11, 1901. It was intended to supply water for a water tank at this station and for the mine of the Union Pacific Coal Co. The log of this well as entered in the driller's log book is given below.

Log of Union Pacific Railroad well at Spring Valley, Wyo.

	Feet.
Clay	0–58
White sand with some water	58–92
Black shale	92–230
Light shale	230–338
Dark shale	338–424
White sand with oil	424–463
Dark shale	463–535
Black sand	535–567
White sand with oil	567–575
Gray shale	575–685
Black shale	685–875
Black shale and streaks of harder material	875–920
Gray shale	920–924

	Feet.
Black shale and streaks of harder material	924–980
Gray shale	980–983
Black shale and streaks of harder material	983–1,008
Black shale	1,008–1,035
Gray sand rock	1,035–1,037
Black shale and streaks of harder material	1,037–1,050
Black shale	1,050–1,095
Hard black limestone	1,095–1,100
Black shale and streaks of harder material	1,100–1,115
Black shale	1,115–1,147
Sand rock, oil bearing	1,147–1,159
Hard blue sand rock	1,159–1,173
Gray shale	1,173–1,177
Black shale	1,177–1,181.5
Shale with gas	1,181.5–1,183.5

Other wells have been drilled for oil in the Spring Valley region, and the reader who is interested in the logs of these wells or additional information regarding the oil development in southwestern Wyoming is referred to the Survey reports already cited.[49]

WELLS DRILLED BY OIL PROSPECTORS, 1900–1903.

Oil men who had been directed to the favorable structure of the Rock Springs dome by King's reports of the Fortieth Parallel Survey and Powell's report on the eastern part of the Uinta Mountains, which also covered the southern part of the Rock Springs dome, first began testing this uplift about 1900. The Belgo-American Petroleum Co. drilled several wells in Baxter Basin in the vicinity of Baxter station, and according to report a number of smaller companies began drilling at about this time on Baxter Flat, south of the railroad station. Eight to ten wells were drilled in this part of the field, but none of them were located on or near the crest of the uplift, and they did not prove the presence or absence of a commercial oil pool. Most of the holes drilled were considerably less than 1,000 feet in depth. A few were more than 1,000 feet deep, and one was reported to have reached a depth of 2,300 feet and to have encountered a bed of coal 6 feet thick near the bottom. No detailed log of this well is available to the writer, but he saw a blue-print map showing the location and depth of the several wells, and on this map there was no indication that coal had been encountered at any horizon in the deep well. From what is known regarding the coal-bearing Frontier formation and underlying beds in this part of the State it is not believed that coal was struck in any of these wells or that coal is present in any of the rocks below the Rock Springs coal group of the Mesaverde formation.

At the time of the field examinations in 1907 and 1908 no record of these wells other than the blue print referred to above could be obtained, and in the field all traces of the location of the shallow wells, such as derricks, abandoned casing, and bailing, were obliter-

[49] U. S. Geol. Survey Prof. Paper 56, pp. 139–162, 1907; Bull. 340, pp. 164–373, 1908; Bull. 543, pp. 118–121, 1914.

ated. At only two localities where the deeper wells had been drilled was evidence of this type to be seen. Both of these localities are indicated on the map (Nos. 44 and 45). The writer learned from some of the citizens of Rock Springs that the deeper wells struck some gas and a small trace of oil but no water. The gas and oil were reported as being so small that the company did not feel justified in continuing drilling with the hope of finding a commercial supply of oil, and the work was therefore discontinued.

Another deep well was drilled on the west limb of the Rock Springs uplift in sec. 17, T. 18 N., R., 104 W. (No. 46 on Pl. I). This well was started in the lower part of the Blair formation and was drilled to a depth of 2,400 feet and struck a little oil at a depth of 625 feet; at depths of 30 and 90 feet flows of water were obtained. As this well, like those on the flat east and southeast of Baxter station, is outside of the possible petroleum-bearing area of the Rock Springs dome, the absence of commercial quantities of oil in the well has no positive value in determining the presence or absence of a commercial oil pool in the favorable area on this dome.

During 1902 and 1903 the Pittsburgh-Salt Lake Oil Co. drilled a well in the NW. ¼ NE. ¼ sec. 10, T. 14 N., R. 118 W., approximately 2 miles south of the Union Pacific Railroad Co.'s well at Spring Valley. The well was drilled to a depth of about 1,283 feet. At a depth of 775 feet a light showing of oil was found, and at 805 feet the drill struck a large quantity of water. Oil was found in sand beds in gray shale at 862 to 1,005 feet. The oil at the upper horizon and at 862 feet is heavy and black and altogether different from the oil found in the Aspen shale, of Benton age, in the Spring Valley field. The lowest oil, at 1,005 feet, is of much lighter gravity than that found above and probably comes from a different geologic horizon. As this well gives some information regarding the character of the rocks found below the surface in the Rock Springs field, the original driller's record, furnished by Mr. A. V. Taylor, of the Pittsburgh-Salt Lake Oil Co., is given below:

Red and gray shale alternating to 340 feet, where a little sand with a little water was encountered, not enough to drill with. Put 11⅝ casing in at 500 feet and shut off water by landing casing in red rock. A continuation of red and yellow rock, with an occasional streak of light blue, to 775 feet, where a light showing of oil was found; bluish black then to 805 feet, where a sand was found with lots of water; shut water off in a hard blue shale at 823 feet, 8-inch drive pipe; blue shale on to 862 feet, where a sand was found with a heavy oil. Through this sand at 897 feet light shale and shells to 935 feet, where a heavy shell, very hard, of about 3 feet in thickness. Under this, directly, a little soft sand; light-blue shale then to 1,005 feet, where a little more sand was found, with a nice showing of oil of a much lighter gravity than that above. Well continued on to 1,283 feet, but nothing more found. Six and a quarter drive pipe all pulled and five joints of the 8-inch pulled; the remaining amount left in.

The upper 500 to 750 feet of strata are regarded as belonging to the Wasatch. The dark-colored oil-bearing shale may belong to the Bear River formation or may in part represent both the Bear River and the Beckwith formations. The oil in the upper beds is heavy, its gravity being reported as 23°, and quite different from the light oil found in the Aspen shale at Spring Valley. The lower oil is of much lighter gravity and more nearly resembles that from the Aspen shale. The heavy oil may come from the Bear River and the lighter oil from the Beckwith. In 1906 A. C. Veatch [50] suggested that these dark-colored beds might be Jurassic (Twin Creek), but the data at hand at the time Professional Paper 56 was published in 1907 indicated to him that they are clearly higher. The location of the Meridian anticline and the thickness of the Beckwith beds entirely preclude a reference of these beds to a formation older than the Bear River. Positive information regarding the age of the beds in which the oil is found is lacking at the present time, but such data as are at hand indicate that the oil comes from either or both the Bear River and Beckwith formations. The Bear River is believed to be absent in the Rock Springs field, as it has not been identified in the Uinta Mountains as far east as Green River nor in the Rawlins uplift, east of the Rock Springs area.

WELLS DRILLED BY OIL PROSPECTORS, 1915-16.

In 1915 renewed interest in the search for oil was shown in the Rock Springs field, and five wells were drilled with the hope of striking oil in commercial quantities. All five of these wells were drilled in the southwestern part of T. 18 N., R. 103 W., in the vicinity of Dry Lake, shown on the topographic map of the Rock Springs quadrangle as lying in secs. 18 and 19. The locality of these wells and their relative positions with regard to Dry Lake is indicated in figure 7.

Two of these wells, in sec. 18, were drilled by the American Oil Co. The one in sec. 30 was drilled by the Midwest Oil Co. and the other two, one in sec. 16 and the other in sec. 20, were drilled by the Dry Lake Oil & Gas Co. So far as known to the writer all these companies have discontinued drilling in the vicinity of Dry Lake and for the present have abandoned the field. A brief discussion of these wells, together with the logs, furnished through the courtesy of Mr. John W. Hay, president of the Rock Springs National Bank, will be given in order to set forth the conditions found in this part of the Rock Springs dome. The wells were drilled in this particular part of the field on the advice of the consulting geologists, who stated that as the Dry Lake dome is a small dome within the larger Rock Springs uplift it is the most favorable location for the accumulation of oil.

[50] U. S. Geol. Survey Bull. 285, pp. 334, 353, 1906.

The first well (No. 47, Pl. I) was drilled in the southwest corner of sec. 16 by the Dry Lake Oil & Gas Co. This well reached the upper sands but did not find commercial oil. Gas was encountered at depths of 200 and 657 feet. Oil sands were penetrated at 2,060, 2,160, and 2,235 feet. A show of water was encountered in some of the sands, and at a depth of 2,098 to 2,118 feet a good supply of water was obtained. Another water sand was encountered at 2,590 feet. The sand encountered at the bottom of the well, 2,654 feet, yielded flowing water at the mouth of the well.

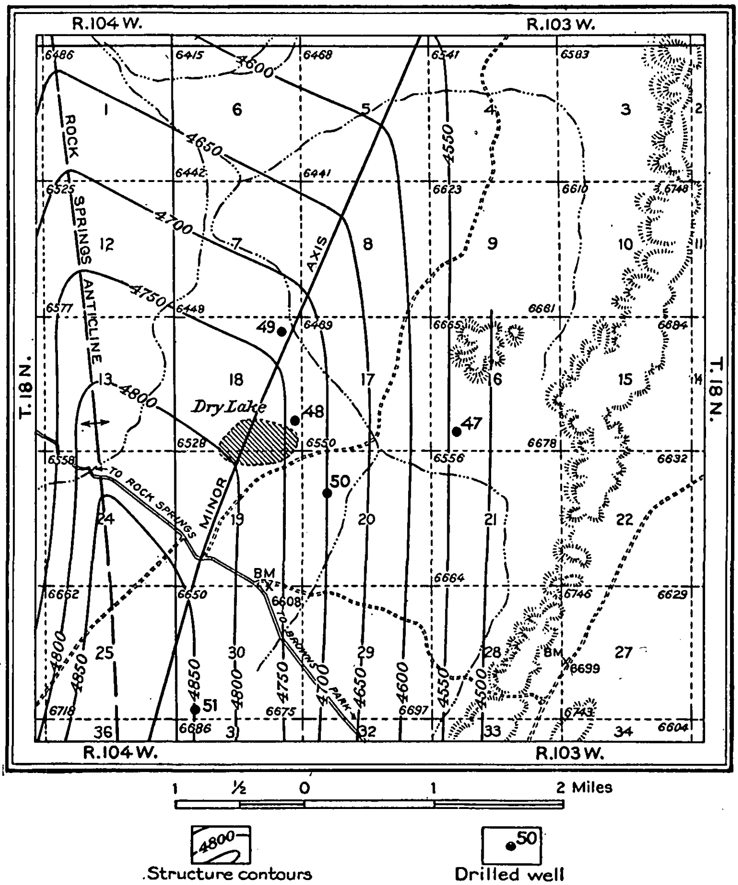

FIGURE 7.—Map of a part of the Rock Springs quadrangle, showing the location of the five wells drilled in the vicinity of Dry Lake, T. 18 N., R. 103 W., Sweetwater County, Wyo.

The log of this well, furnished to the writer by Mr. Hay, is given in figure 8.

The second well (No. 48, Pl. I) was drilled by the American Oil Co. to a depth of 1,770 feet in the southeast corner of sec. 18, and got gas in the first sand at 1,760 to 1,770 feet. The well was believed by the drillers to be located on the crest of the Dry Lake dome.

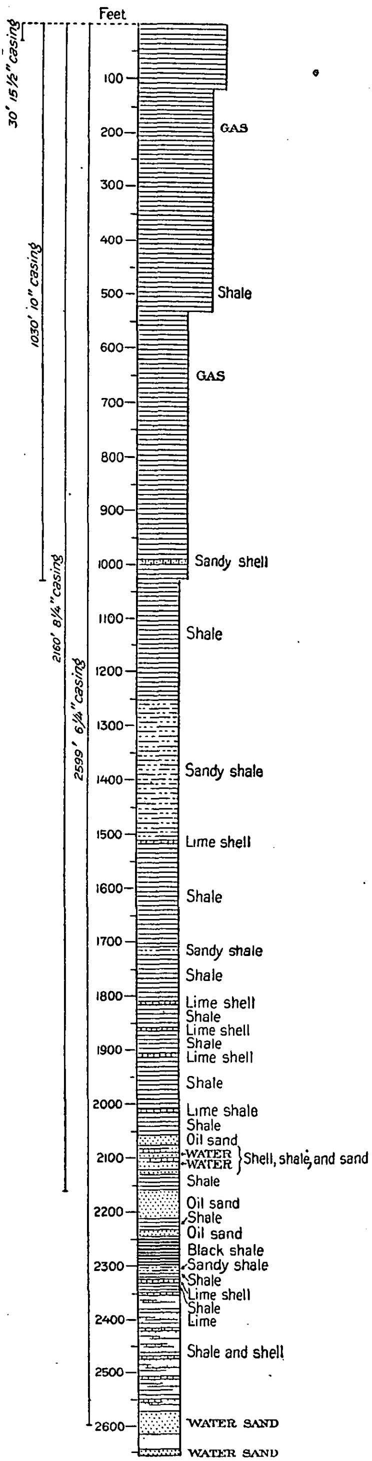

FIGURE 8.—Record of Hines well of Dry Lake Oil & Gas Co., in the SW. ¼ sec. 16, T. 18 N., R. 103 W.

The following log of this well was furnished to the writer by Mr. J. R. Greenless, Lawrence, Kans., at the request of Mr. Hay:

Log of well No. 48, in the SE. ¼ sec. 18, T. 18 N., R. 103 W.

	Feet.
Clay	0–12
Blue shale	12–25
Shale	25–190
Brown shale	190–290
Black shale	290–990
Coarse sand	990–1,050
Black shale	1,050–1,500
Light sandy shale	1,500–1,590
Black shale	1,590–1,760
Gas sand	1,760–1,770

The third well (No. 49, Pl. I) was drilled by the American Oil Co. in the northeast corner of the same section and struck the first sand between 1,340 and 1,350 feet and the second sand at a depth of 1,750 feet, and passed through 53 feet of sand and 10 feet of black shale into another sand that carried gas. Several other sands below this showed some gas. The lowest one yielded water also. The well was drilled to a depth of 2,345 feet and ended in sand from which an abundant supply of water was obtained. The log of this well given below was furnished to the writer by Mr. Greenless.

Log of well No. 49, in the NE. ¼ sec. 18, T. 18 N., R. 103 W.

	Feet.
Clay	0–30
Black shale	30–1,340
Sand	1,340–1,350
Black shale	1,350–1,540
White shale	1,540–1,570
Black shale	1,570–1,750
Water sand	1,750–1,803
Shale	1,803–1,813
Sand	1,813–1,817

	Feet.		Feet.
Black shale	1,817–1,845	Light shale	2,222–2,252
Shale	1,845–1,870	Dark shale	2,252–2,270
Sand	1,870–1,895	Sand containing gas	2,270–2,272
Shale	1,895–2,030	Lime shell	2,272–2,273
Sandy shale	2,030–2,035	Sand (gas increased a little)	2,273–2,290
Hard shale	2,035–2,190	Sand	2,290–2,340
Hard dark shale	2,190–2,222	Water sand	2,340–2,345

The fourth well (No. 50, Pl. I) was drilled by the Dry Lake Oil & Gas Co. in the southern part of the NW. ¼ sec. 20 and is the deepest well in the field. At a depth of 1,857 feet the first gas sand—the same sand as that in the well in sec. 16—was struck. On drilling into the sand to a depth of 1,877 feet salt water was encountered that rose in the well 300 feet. The sand was very soft and coarse grained and extended to a depth of 1,885 feet, thus having a total thickness of 28 feet. Several other gas sands were encountered to a depth of 2,550 feet. The second sand encountered was dry, and the third sand contained wet gas. At a depth of 2,615 feet the drill struck sulphur water that was perfectly black and rose in the well about 400 feet, indicating considerable head. The well was drilled to a depth of about 2,676 feet and then continued by means of a diamond drill to a depth of 2,744 feet. Nine samples of rock from the lower part of the well, between 2,615 and 2,744 feet, were furnished to the writer by Mr. Hay.

The first sample of rock from this well, collected at a depth of 2,615 feet, was a hard blue shale broken in small, fine angular fragments by the drill. The material resembled very closely rock of the Aspen formation. The second sample, collected at a depth of 2,641 feet, was very similar in composition but contained some larger fragments of drab shale. It is believed that these two samples represent a part of the Aspen shale in the Rock Springs field and that the second sample came from the base of the formation.

The next sample came from a depth of 2,665 feet and was composed of purple-green shale broken by the drill into fragments half an inch to 1 inch in size. This shale is poorly cemented and fragile and breaks with irregular fracture. The rock resembled the shale in the upper part of the Beckwith formation in southwestern Wyoming, at about the horizon of its upper sandstone member.

The fourth sample, from a depth of 2,678 feet, was a 5-inch piece from the 2-inch diamond-drill core. The rock consisted of fine-grained, firmly indurated greenish-drab shaly sandstone containing irregular fragments of rock and very fine isolated pebbles.

Another piece of rock representing the same length of the diamond-drill core was obtained at a depth of 2,702 feet. The rock was a firmly indurated fine-grained dark-gray sandstone with blotches of green claylike material distributed through it.

A 4-inch piece of the drill core from a depth of 2,706 feet was very similar to the one last mentioned, being composed of a hard fine-grained gray sandstone firmly cemented and almost quartzitic in texture. On a freshly broken surface it has a greenish hue. In places there appears to be greenish clay and sand.

At the base of this sandstone at a depth of 2,716 feet a broken sample of the drill core supplied fragments of greenish sandy shale containing numerous very small flakes of mica and very fine fragments of foreign rock and pebbles. The fragments were broken with irregular fracture and glistening surfaces resembling somewhat a slickenside surface. This sample was typical of some of the beds in the Beckwith formation in southwestern Wyoming.

Immediately below this rock, between 2,716 and 2,723 feet, is a 7-foot bed of very fine brownish-red sandy shale that contains irregular blotches of green shale distributed through the red sandstone.

The last sample was obtained from the bottom of the well, at a depth of 2,744 feet. The piece represents 1 inch of the diamond-drill core cut diagonally by a small fissure completely filled with vein material. The rock is a fairly coarse indurated sandstone containing small veins of calcite and a greenish claylike substance. The sandstone contains a number of small well-rounded pebbles and fragments of garnet and quartz. Some of the pebbles are nearly half an inch in diameter, and the rock might readily pass for a fine conglomerate. No small pebbles of black quartz like those in some of the Beckwith beds were noted, but the general aspect of the sample indicates that this rock came from the upper part of the Beckwith formation as mapped in southwestern Wyoming. Whether it represents a part of the upper sandstone member or the underlying conglomerate near the middle of the Beckwith could not be determined from the fragment of rock, but the log of the well indicates almost certainly that it represents one of the beds in the upper sandstone member.

The log of this well, compiled from data furnished to the writer by Mr. Hay, is given in figure 9.

The fifth well (No. 51, Pl. I), was drilled by the Midwest Oil Co. in the southwest corner of sec. 30. The well was put down to a depth of 1,000 feet and then discontinued, as the company was operating with a small boiler and rig which were not adapted to deep drilling. The company abandoned the field late in the fall of 1916.

Of these five wells four were drilled deep enough to encounter the Frontier formation. Only one of the wells (No. 50, in the NW. ¼ sec. 20) passed through the Frontier and Aspen beds into the older underlying rocks. All the samples from this well submitted to the writer were obtained from beds below the Frontier sands, and therefore very few data are at hand by which to compare the beds passed

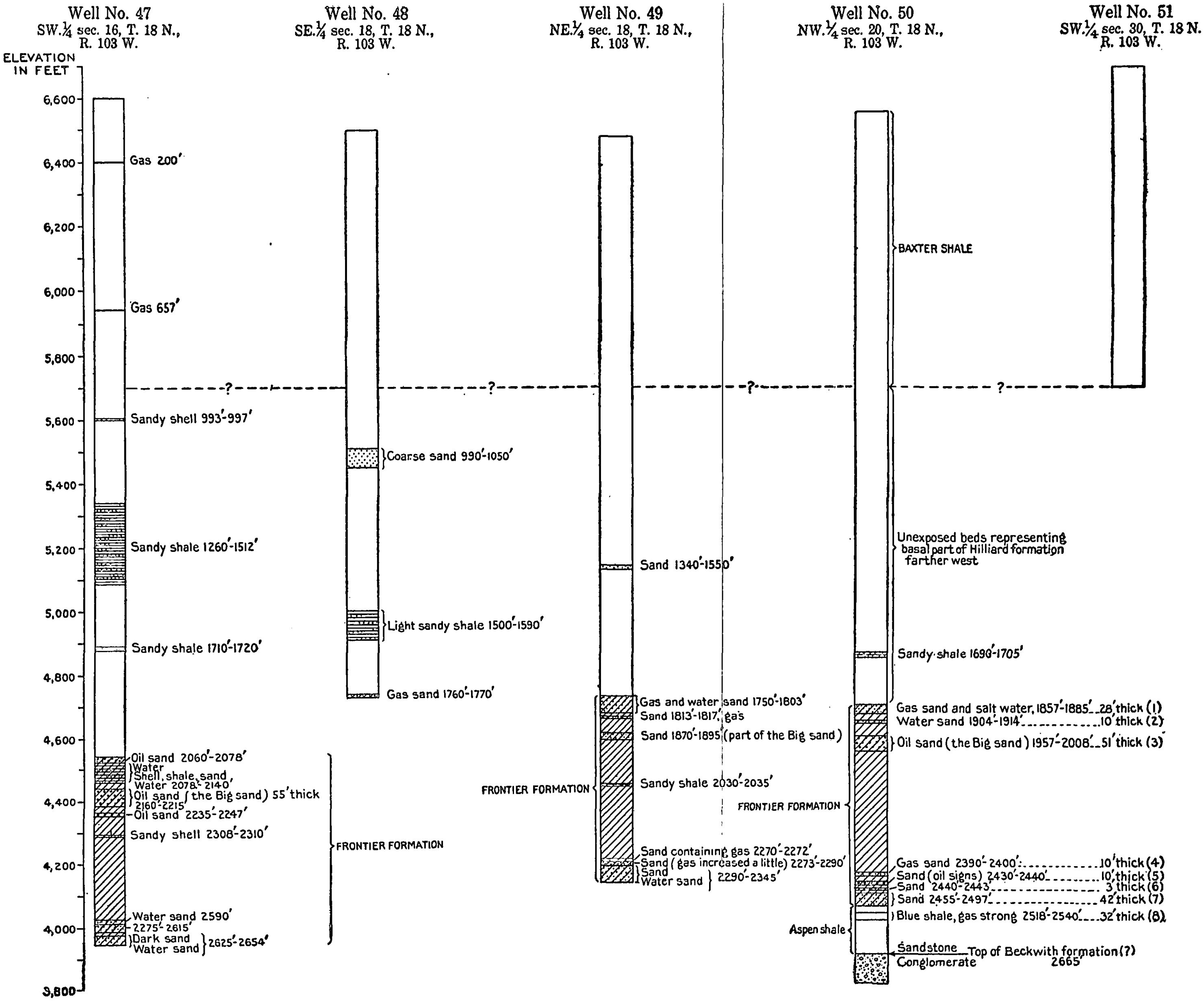

DIAGRAM SHOWING THE POSITION OF THE OIL, GAS, AND WATER SANDS IN THE UPPER PART OF THE BECKWITH FORMATION IN THE VICINITY OF DRY LAKE IN BAXTER BASIN.

through in the several wells. The surface in this vicinity is fairly level, and the difference of altitude at the collars of the wells, as indicated by the photographic map, is less than 220 feet and for the four deepest wells less than 120 feet. In order that the sands encountered in the wells, as indicated by the logs given above, may be better compared, they have been plotted to scale in Plate XVII.

There is considerable variation in the records of these wells, and the same sands or sandy shales are not reported in all the wells. There is, however, a remarkable uniformity in the records of the lower parts of the three deepest wells, so that the correlation may readily be carried from one well to another. From a careful study of these parts of the records the writer is of the opinion that the upper portion of the Frontier formation is represented approximately by the first oil sand encountered in the four deepest wells at depths ranging from 1,750 to 2,060 feet below the surface, or between 4,540 and 4,740 feet above sea level. The base of the Frontier formation is probably not far below the lowest water sand recorded in three of the deepest wells at depths ranging from 2,345 to 2,654 feet below the surface, or between 3,950 and 4,130 feet above sea level, making the total thickness of the Frontier formation approximately 640 feet. Gas was reported at 200 and 657 feet

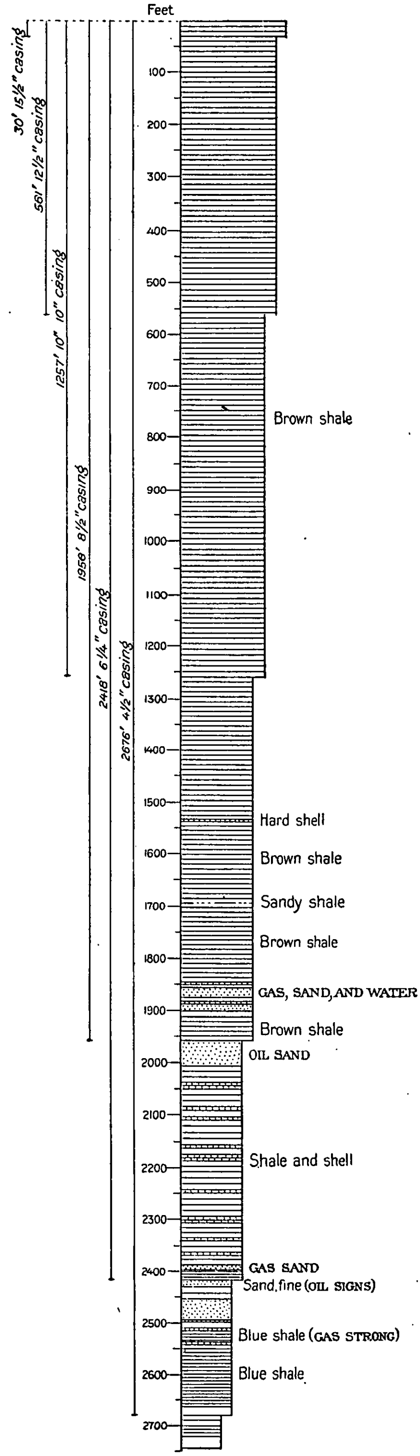

FIGURE 9.—Record of well in the NW. ¼ sec. 20, T. 18 N., R. 103 W.

below the surface in well No. 47, but no gas is recorded in the other wells at either of these horizons. On the other hand, all four of the deeper wells record the first oil, gas, and water sand at the top of the supposed Frontier formation. Assuming, therefore, that this sand is the same in all the wells, as is further indicated by its relation to the underlying big sand and the four gas and oil sands within the Frontier, we have a horizon from which we can check and partly determine the attitude of the oil sands in this part of the Rock Springs dome. The elevation of the upper or first sand at the two wells in sec. 18, according to the record, is approximately the same, being only 10 feet higher at the southern well. These two wells therefore lie somewhere near the strike of the beds. At the well in sec. 20 the same sand lies approximately 30 and 40 feet lower, respectively, than at the north and south wells in sec. 18; at the well in sec. 16 it is approximately 200 feet lower than at the well in the SW. ¼ sec. 18. The sand therefore dips toward the east and is carried down 200 feet in the distance from well No. 48 to well No. 47, or approximately 1¼ miles, which makes the dip less than 2°, or 160 feet to the mile. On the basis of these meager data, together with the information collected on the general structure of the Rock Springs dome, the writer has indicated on Plate I a few structure contours to illustrate the probable attitude of the oil sands in this part of the field. It is realized that the information at hand is not sufficient to determine the exact structure of the dome in this part of the field and that additional information may materially change the position and direction of the structure lines, but if the interpretation of the structure is essentially correct it is not surprising that the drillers failed to encounter oil at any of the wells. The place to drill for oil or gas is on the crown of the dome which lies somewhere along the crest southwest of Dry Lake. A sufficient showing of oil, gas, and water has been made in these wells to indicate that in all probability both oil and gas are present in commercial quantities, and it is merely a matter of locating the reservoir in which they are stored.

RELATION OF OIL TO THE DOME.

In many respects the Rock Springs dome is very similar to the Salt Creek anticline, on which is the most productive and valuable oil field thus far discovered in Wyoming. It is true that the Rock Springs dome is somewhat larger when the entire area of the uplift is taken into consideration, but the difference in size of the two domes is not great when the central parts of the two folds, or the portions lying below the Mesaverde outcrop, are considered. In the Rock Springs dome this central area is approximately 40 miles long by 15 miles wide; in the Salt Creek anticline the central area is 20 miles long by 6 miles wide. From this it will be seen that the central part of the Rock Springs dome is only about twice as long as that of the Salt Creek anticline. This difference between the two folds is still further reduced when the crests or highest parts of the two folds are taken into consideration. The Salt Creek anticline consists of two distinct domes—the northern or Salt Creek dome, which is 10 miles long and 6 miles wide, and the southern or Teapot dome, which is 8 miles long and 4 miles wide—and the two domes are separated by a shallow syncline. The highest part of the anticline lies along the Salt Creek dome. The crown of this dome, or that part which lies higher than the crest of the Teapot dome, is 7 miles long by 3½ miles wide. The corresponding highest part of the Rock Springs dome lies in the vicinity of Aspen Mountain and is approximately 9 miles long and 3 miles wide. In other words, the area covered by the crown of the fold, in which the oil would accumulate, is approximately the same as that in the Salt Creek dome. The structure in the Rock Springs field is ideal for the accumulation of oil, as none of the known faults cut the supposed oil pool, and if the other factors involved are as good as they are in the Salt Creek field a more productive oil pool should be discovered in this fold than has been developed in the Salt Creek field.

In the Rock Springs field there is essentially one primary oil pool, whereas in the Salt Creek field there are in fact three distinct pools in which oil has accumulated—the Shannon pool, the pool in the Salt Creek dome, and the pool in the Teapot dome. The Shannon pool appears to have been fairly well outlined. It contains approximately 160 acres and lies on the north end or "nose" of the pitching Salt Creek anticline, at a place where the fold narrows rather abruptly. The oil extends farther down the end of this fold than it does on the western flank.

The distribution of the oil in the Salt Creek dome, as in the Grass Creek and other domes in central Wyoming and the Big Horn Basin, is very regular. The same or similar conditions may be found to prevail in the Rock Springs dome, provided an oil pool is present there. In the Salt Creek field the line marking the contact of the oil pool with the water that occupies the sand on the flanks of the fold below the oil varies only about 150 feet in elevation in the entire circuit of the dome and lies at the very crest. The variation on three sides of the dome is not over 50 feet, and only at the north end does the pool extend farther down the slope of the fold than at other places. Somewhat similar conditions prevail on the east side of the Grass Creek dome. The distribution of the oil on the crown of the Teapot dome has not been determined by the drill.

The Frontier sands are very conspicuous in western Wyoming, in Uinta and Lincoln counties. Three prominent coarse sandstones are present in the Coalville district. To the east and northeast of the Rock Springs uplift, in the Rawlins, Lost Soldier, Big Muddy, and Salt Creek fields, two or three sands are everywhere present in the Frontier, which is underlain by the Mowry and Thermopolis shales in the same way as in western Wyoming it is underlain by the Aspen shale. It is reasonable, therefore, to expect that these same conditions prevail in the Rock Springs dome and that this field contains the sands for reservoirs and the source of the oil. In nearly all the Wyoming fields oil occurs at or near the crests of the anticlines or domes and is probably held in this position by water under pressure, because in nearly every Wyoming field the oil pool occupies the highest part of the uplift and the oil is surrounded by water that is under considerable head. If oil is present in the anticline it is forced up in the reservoir and held in position by the water and the overlying impervious rock. A well that enters the sandstone below the oil horizon gets water, and one that enters it above the oil horizon encounters oil, which may or may not contain gas under pressure. Both the water and the gas exert a pressure upon the oil and determine its distribution along the highest part of the dome or at some place where the oil is pocketed on account of irregularities in the structure.

In selecting the location of wells in order to test the oil possibilities of this structurally favorable area adequately, it becomes very necessary to determine where the oil, if present in this uplift, has accumulated and in what part of the porous sands it has been pocketed. Moreover, it is not enough to ascertain the highest part of the dome, but it is also necessary to consider the gathering ground from which the oil was obtained in order to determine whether or not the oil could have migrated to the place where the supposed oil pool lies.

From the studies thus far made it appears that the Rock Springs dome has in the Frontier sandstone and Aspen formation, respectively, reservoirs for oil and a source of supply with which to fill them. In this respect the field again compares favorably with Salt Creek. It should be noted, however, that no oil seeps like those in the Salt Creek field occur in the Rock Springs field, which resembles in this respect more nearly the Teapot dome, southeast of the Salt Creek field. Neither has mineral wax, or ozokerite, been found associated with calcite in vein fillings in the Rock Springs field, as it has in the Salt Creek and Teapot domes. Another point of similarity between the Salt Creek and Rock Springs domes is the large area of gathering ground for the oil. The gathering ground is in fact much better in the Rock Springs field than at Salt Creek. Both the east and west flanks of the Rock Springs uplift are more nearly comparable to the east limb of the Salt Creek field, where the eastern slope extends for many miles. On the west side of the Salt Creek fold the dips are comparatively steep, the slope is abrupt and short, and the axis of the syncline is only a mile or so west of the crest of the dome.

In the Rock Springs field both the east and west slopes extend for many miles. The westward dips are somewhat steeper than those toward the east, but both are ample to cause the oil to rise if it is backed by artesian water, which is known to be present. The gently dipping rock strata in which the oil originates or in which it is accumulating probably extend both east and west for long distances, possibly 50 to 60 miles or more in each direction, before beginning to rise toward the Rawlins uplift on the east and the Meridian anticline on the west. If the assumption is correct that the oil which is to be obtained from the porous sandstone by drilling at a certain point was originally distributed in small quantities through that sandstone or the adjacent sands or shales and has been working its way upward through the pores of the sandstone to the present reservoir, the quantity of oil collected in any favorable locality or parts of the sandstone capable of retaining it will depend largely upon the area which has supplied the oil. The feeding area of the Rock Springs dome is much larger than that of the Salt Creek field, and, if the source of oil is actually present, wells located on or along the crest or on either side near the top of the dome may tap oil reservoirs that have been supplied from broad areas. If the oil is distributed regularly along the crest of the dome, according to its altitude above sea level, all the oil in paying quantities may be segregated into one big pool at the highest part of the dome or into several isolated pools, if there are several saddles or minor crests along the axis. On the other hand, if minor folds occur in this area, which do not reach the surface or which can not be observed at the surface, they may retain part of the oil along their axes in sufficient quantity to warrant development.

The four important geologic factors that are always looked for in the search for new oil fields are (1) favorable structure, (2) oil sand, (3) water, and (4) original oil. There can be no question about the presence of all of these factors in the Rock Springs field as interpreted from known facts in the adjacent and near-by fields. It is known that the structure is favorable, that there are under the fold several open "sands" or other porous media to serve as retainers for oil and gas, that salt water or other water is present in the sands to serve as a concentrating factor in gathering oil and gas from a disseminated state to a commercial body, as demonstrated by the numerous flowing wells, and that the field contains petroliferous shale or other fossil-bearing rocks that produce oil in a disseminated form. The Aspen and Mowry shales and the Park City formation are particularly good carriers of original oil.

The structure of the Rock Springs dome has long been regarded by oil men as favorable to the accumulation of oil and gas. Several wells were drilled on this dome prior to 1907, but none of them were favorably located or drilled deep enough to reach the more promising sands, so that no positive statement can be made regarding the presence of oil in commercial quantities beneath the dome. Nevertheless many geologic features indicate that oil may be found, and the work of thoroughly prospecting the dome should go on until oil is discovered or until it is demonstrated beyond a doubt that the oil-bearing sands that are so productive in other fields in Wyoming are not present in Baxter Basin or, if they are present, that they do not contain oil. The final test of the presence or absence of oil in this field, as in every other, is the drill. Drill holes put down to moderate depths, say 1,000 to 2,000 feet, will not adequately test the field. Neither should one or two failures, even of properly located wells of sufficient depth, condemn the entire field. Until the Aspen formation, which yields oil in the Spring Valley field, and the Wall Creek sand of the Frontier formation, which yields the oil in Salt Creek and Big Muddy and other parts of the Big Horn Basin, have been explored by the drill at several of the most favorable points along this great uplift, its productivity or its barrenness can not be considered as satisfactorily demonstrated.

The oil sands to be sought in the Rock Springs dome are in the Frontier and Aspen formations. The Frontier lies at a depth of about 4,500 to 5,000 feet below the base of the Rock Springs coal group. In parts of Baxter Basin erosion has removed some of the intervening shale, and at places in the central part of the dome, particularly near Baxter, some of the oil sands may be reached at a depth of 2,000 to 2,500 feet. The data at hand indicate that the dome is most deeply eroded along Bitter Creek near Baxter, southward to the north base of Aspen Mountain. A point in this vicinity would therefore be one of the most favorable places to drill along the main crest, if it were the highest part of the dome, but it is definitely known that this is not the highest part. The most favorable locality lies along the main axis at the place where the oil sands form the crest of the dome. There may also be other desirable localities in different parts of this great fold if there are secondary and minor folds of sufficient magnitude to form pockets in which the oil has been captured.

The prospective oil sands lie at a greater depth below the surface at Aspen Mountain and at the south end of the dome than at other points in Baxter Basin north of Aspen Mountain. The oil sands in the vicinity of Aspen Mountain, however, lie nearer the highest part of the dome and therefore are more promising. The drilling already done has been confined to the northern part of the basin north of Aspen Mountain, and most of the wells drilled have not passed through the Montana and Colorado shale series.

The Aspen formation probably is the source of the oil and contains part of the oil, if any exists, in the sands of the Rock Springs dome. This oil, as well as that from lower sources, should collect in the sandstones of the Aspen itself or of the overlying Frontier. To test adequately all the sands of both these formations it may be necessary to drill 2,000 to 4,000 feet, the depth depending in part on the location of the well and in part on the variation in thickness of the beds from measured sections in near-by areas. The most favorable area to be tested lies along the major axis of the dome in the vicinity of Aspen Mountain. In selecting a location along this axis to test the presence or absence of oil in the Rock Springs dome the very highest part of the fold should be selected for the preliminary test. In making this selection the contour map (Pl. I, in pocket) will be of service.

In addition to the favorable structure and the practical certainty that there are rocks beneath the dome which elsewhere in Wyoming serve both as sources of oil and as reservoirs for oil, a favorable prognostication is strengthened by the fact that traces of oil and a little gas have actually been struck in some of the shallow and deeper wells drilled on unfavorable parts of the dome. The principal unfavorable feature of this field, from the point of view of the oil prospector, is the depth to the supposed oil sands and the uncertainty of the exact location of the highest part of the Rock Springs dome or of the "terraces" or crests of minor folds that furnish good locations as storage reservoirs for the accumulation of oil. The minor folds and terraces may in fact not be detectable on the surface and can be located or determined only by means of the drill.

PROBABLE SOURCE OF THE OIL.

In regard to the origin of the oil in this general region very little positive information can be given. As already indicated, oil occurs at six widely separated geologic horizons—in the Tertiary, Cretaceous, Jurassic, Triassic, Permian, and earlier Carboniferous rocks—for the most part in sandstones and shales. Whether it originated there or in some adjacent rocks and later migrated into the sandstone beds where it is now found is still an open question. It is the opinion of the writer that some of the oils may be of vegetable and others of mineral origin. It is highly probable that not all of the oil has the same origin or comes from the same source.

Although oil has been found in several different formations in this region, it does not follow that there are necessarily as many separate sources for the oil. Irrespective of its source or the number of geologic horizons at which oil is originally obtained, its occurrence is believed to be controlled in Wyoming primarily by the structure, because so far as known it occurs generally near the crest of an anticline or in some pocket along a secondary fold intimately connected with the major uplift.

The evidence collected in a study of the rocks in this general region indicates that two of the geologic formations from which oil has been obtained are particularly well adapted to supply oil to the different reservoirs and have no doubt furnished a large part of the oil that is being produced, irrespective of whether it comes from beds near the original source of from beds some distance removed. The two favorable formations are the Mowry shale and the Park City (Phosphoria) formation, in which both oil and phosphate are found.

The Mowry shale everywhere contains a great number of fish scales, bones, and teeth, proving conclusively that fishes were plentiful in the ocean in which the shale was deposited and suggesting that their bodies may have contributed to the oil supply. The presence of sulphur has usually been taken to denote animal origin. Sulphur springs and sulphur water are associated with the oil in most of the oil fields in Wyoming.

Part of the Phosphoria formation[51] in Wyoming, Utah, Idaho, and Montana, where it has been studied, consists of shale and shaly sandstone containing a percentage of lime, some bituminous matter, and petroleum which comes to the surface in oil seeps. Pieces of this rock contain small cavities filled with oil or lime and some of them filled with bitumen and other hydrocarbon compounds. Some of the shales have a glistening oily or waxy looking surface, which shows in places a slight iridescence. When rubbed or freshly broken or struck with a hammer the rock specimens emit an unmistakable odor of petroleum, and when placed in a fire the shale will burn. These beds are in most places highly fossiliferous and like the Mowry shale indicate that animal life was plentiful in the ocean in which they were laid down.

From the tests thus far made by the Survey as to the oil content of some of the samples from the Phosphoria formation it is found that the beds are true oil shales, as they contain very little free oil. The oil obtained appears to be the result of destructive distillation of the vegetable or animal matter in the shale. This is shown by the fact that almost no oil is obtained by extraction tests. Chase Palmer, a chemist of the Survey who examined most of the samples collected by the writer and other Survey members, found that the ethereal extract seems to be of mineral rather than vegetable composition. It probably exists as some form of mineral wax or other hydrocarbon produced by distillation of a part of the original organic matter in the shale. If this is true it may mean that a considerable part of the organic matter originally present in the shale has already suffered distillation. This in turn may account for the relatively small amount of oil obtained from the Phosphoria

[51] Equivalent to upper part of Park City formation.

beds. If the shales have already undergone partial distillation the question arises, What has become of the distillate? Obviously one of two things has happened. Either the oil and gas have escaped into the atmosphere or they are still retained in the rocks. Where the shales are exposed at the surface the oil has undoubtedly escaped, and this may account for the slight yield on extraction of rocks that give so strong an odor of petroleum. Where the shales are not exposed they may have been a source of petroleum in areas where the structural conditions are favorable for oil accumulation. It may therefore be that commercial accumulations of oil have been formed in the Phosphoria rocks and migrated upward into overlying sands wherever good reservoirs were found. If this should prove to be true it would open a new field for exploration in the West, and many of the localities not now tested might prove to be of commercial value as a supply of oil as soon as the structurally favorable areas are tested by the drill.

ANALYSES OF OIL FROM NEAR-BY FIELDS.

No oil seeps occur in the Rock Springs field, and so far as known to the writer none of the oil encountered in the wells already drilled has been analyzed. It seems advisable, however, to publish a few of the analyses made by the United States Geological Survey of oils collected from different fields in southwestern Wyoming, in order to determine as far as possible the kind of oil that may reasonably be expected to be present in the Rock Springs field. Analyses of only those samples collected in near-by areas from beds stratigraphically as low or lower than the beds from which the oil in the Rock Springs field may be obtained are given for comparison.

Analyses of oils from southwestern Wyoming and Colorado.

Name and location of well from which oil was obtained.	Depth of oil well (feet).	Temperature at which gas was given off on distillation (°C.).	Nature of product.	Percentage.	Gravity.		Analyst.
					Specific.	Baumé (°).	
1. Pittsburg-Salt Lake Oil Co., 1 mile north of Spring Valley, in sec. 22, T. 15 N., R. 118 W., Wyo.	....	50-150	Gasoline....	21.3	....	65	C. F. Mabery, Cleveland, Ohio, 1906.
		150-305	Burning oil.	39.7	0.81	44	
		305-350	Gas oil......	16.4	....	36	
		350-380	Oil partly cracked.	15.4	....	37	
2. Shallow surface, pit east of Labarge Ridge, in Green River Basin, sec. 34, T. 27 N., R. 113 W., Wyo.	....	Below 150	Suitable for burning.	Trace	....	....	D. T. Day, U. S. Geological Survey, 1908.
		150-300		34	.891	....	
3. Requina No. 1, Rangely oil field, sec. 21, T. 2 N., R. 102 W., Colo.	480	Below 150	Gasoline....	25	.68	....	D. T. Day, U. S. Geological Survey, 1907.
		150-300	Naphtha....	45	.751	....	
		Above 300	Illuminating oil.	27	....	....	
		Loss.	Residue.....	3	....	....	
4. Dutch No. 1, Salt Creek field, in sec. 23, T. 40 N., R. 79 W., Wyo.	1,000	Below 150	Gasoline....	8.4	.72	....	D. T. Day, U. S. Geological Survey.
		150-300	Naphtha....	40.6	.78	....	
		Above 300	Water-white oil.	51	.89	....	
			Residuum..	....	....	....	
			Lubricating oil.	....	....	....	

1. 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.

2. 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.

3. Initial boiling point 48° C. The oil contains no water. The residue contains much paraffin wax and there is no asphalt in the sample. Oil collected fresh from the pump that was running on August 19, 1907.

4. Specific gravity at 60° F., 0.8221 (40.3° Baumé). Color green. Begins to boil at 76° C. Oil collected from producing well. The oil is suitable for lubricating purposes; the others are suitable for profitable refining for the gasoline and kerosene which they will yield, together with lubricating oils, paraffin, etc. The specific gravity of the distillate, the absence of asphalt, and the comparatively low proportion of unsaturated hydrocarbons unite to show that these oils have a paraffin base, and the quantity of paraffin obtained from most of them is as great as is usually expected. No determination of water or sulphur was made, the distillate showing practically the absence of both of these substances.

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