

DEPARTMENT OF THE INTERIOR

FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY

GEORGE OTIS SMITH, Director

BULLETIN 621—L

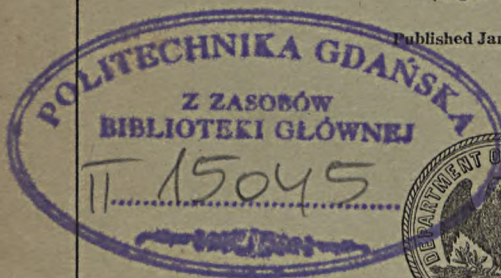
OIL AND GAS NEAR
BASIN, BIG HORN COUNTY, WYOMING

BY

CHARLES T. LUPTON

Contributions to economic geology, 1915, Part II
(Pages 157-190)

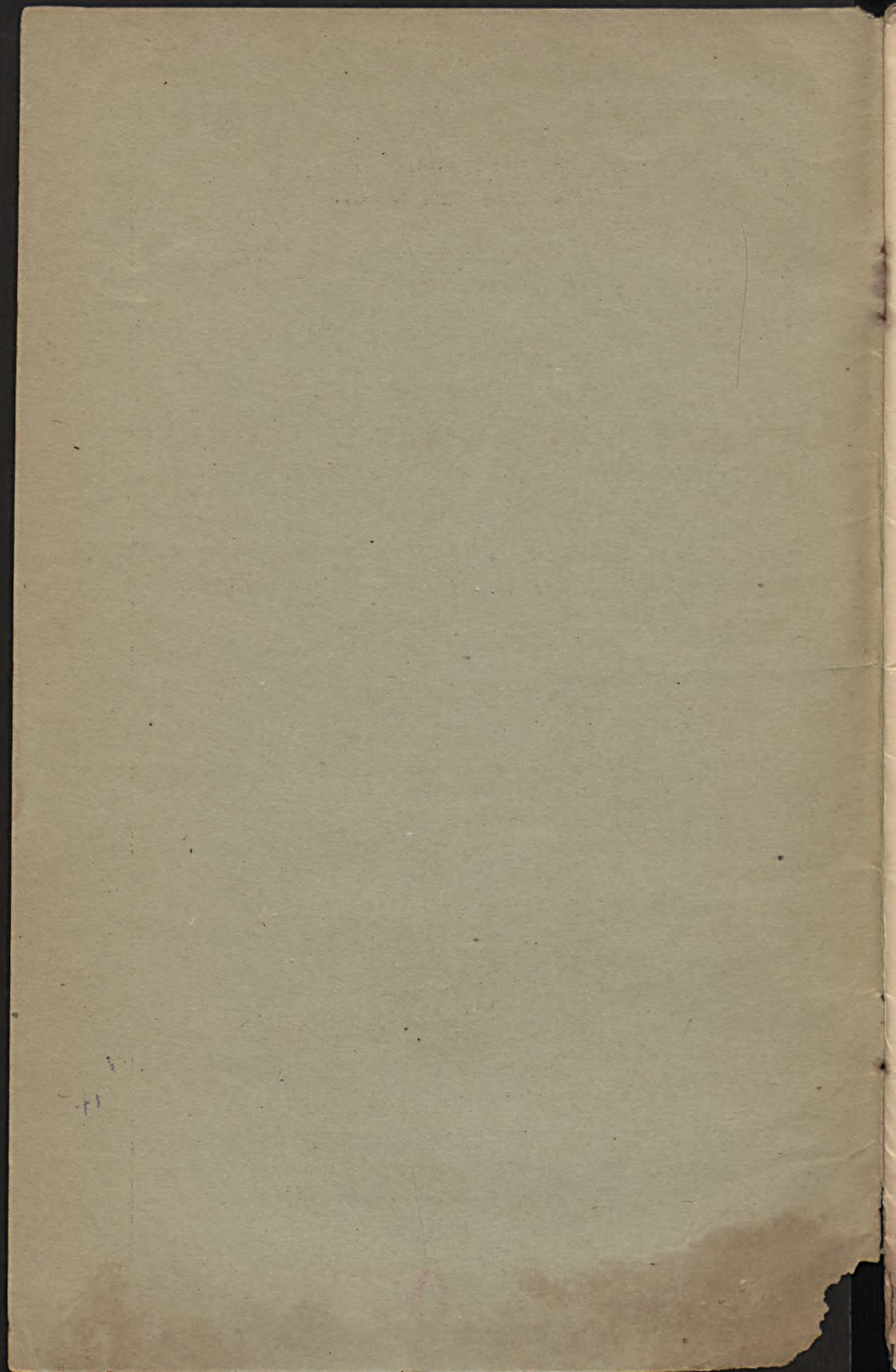
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OIL AND GAS NEAR BASIN, BIG HORN COUNTY, WYOMING.

By CHARLES T. LUPTON.

INTRODUCTION.

The discovery of a high-grade translucent oil and an opaque lubricating oil in what was originally believed to be only a mediocre gas field near Basin, Big Horn County, Wyo., has attracted the attention of engineers and oil operators, and since 1913 considerable drilling has been done in that part of the field where the attitude of the rocks is favorable for the accumulation of oil or gas and the land is not

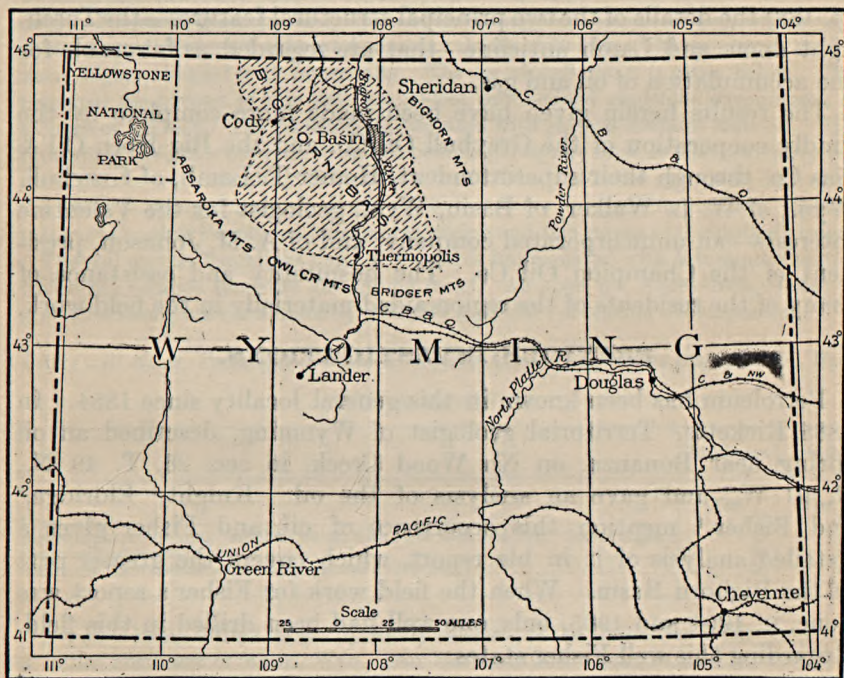


FIGURE 11.—Index map of Wyoming showing position of the Basin oil field.

included in the Government reserves. In addition to the oil wells larger gas wells than those previously known have been discovered, the yield of three of which is sufficient to supply Basin and Greybull, towns of about 900 inhabitants each, situated on the Chicago, Burlington & Quincy Railroad about 3 miles west and 8 miles northwest of the field, respectively.

The object of this report is to assemble all the data available on the field regarding the discovery of oil and gas and to present a map of the geologic structure from which it will be possible to determine the parts of the dome and anticlines that carry oil and gas and thus to separate the productive from the nonproductive areas. This field is only a small part of an extensive belt of similar territory along the foothills of the mountains bordering the Bighorn Basin, in which numerous domes and anticlines, more or less well adapted to the accumulation of oil, may be found. A report soon to be published contains a description of such structural features in the southern part of the Bighorn Basin.

The field herein described includes parts of Tps. 50, 51, and 52 N., Rs. 92 and 93 W. of the sixth principal meridian, and has an area of about 65 square miles. It is situated mainly east of Bighorn River and northeast, east, and southeast of the town of Basin. Plate XVII (p. 178) shows the general geology of the field and Plate XVIII (p. 188) the details of the two principal structural features—the Torchlight dome and Lamb anticline—that are regarded as favorable for the accumulation of oil and gas.

The results herein given have been made more complete by the kindly cooperation of the Greybull Oil Co. and the Big Horn Oil & Gas Co. through their superintendent, Homer T. Lamb, of Greybull, Wyo.; of W. L. Walker, of Basin, Wyo., geologist for the Valentine interests—an unincorporated company; and of A. M. Johnson, president of the Champion Oil Co. The hospitality and assistance of many of the residents of the region aided materially in the field work.

PREVIOUS INVESTIGATIONS.

Petroleum has been known in this general locality since 1884. In 1888 Ricketts,¹ Territorial geologist of Wyoming, described an oil spring near Bonanza, on No Wood Creek, in sec. 26, T. 49 N., R. 91 W., and gave an analysis of the oil. Knight,² Eldridge,³ and Fisher⁴ mention this occurrence of oil, and Fisher gives a detailed analysis of it in his report, which covers the greater part of the Bighorn Basin. When the field work for Fisher's report was done, in 1904 and 1905, only one well had been drilled in this field. Regarding this well Fisher states:

About 3 miles east of Basin, Wyo., a small well is being dug in the Pierre shale for the purpose of finding gas. The present depth of the well is about 100 feet, and an appreciable amount of gas has already been obtained. A small company has been organized and the work will be continued.

¹ Ricketts, L. D., Report of the Territorial geologist of Wyoming, 1888, pp. 39-40.

² Knight, W. C., Wyoming Exper. Sta. Bull. 14, p. 167, 1893.

³ Eldridge, G. H., A geologic reconnaissance in northwest Wyoming: U. S. Geol. Survey Bull. 119, pp. 64, 65, 1894.

⁴ Fisher, C. A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, p. 59, 1906.

Washburne,¹ while making an examination of the coal in the northeastern part of the Bighorn Basin in 1907, collected information of value regarding the principal folds in this region that may serve as reservoirs for oil and gas. Regarding the two anticlines described in the present report, Washburne says:

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

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

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

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

[No. 2 on Plate XVIII.]

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

A well is being drilled for gas by Henry Sherard, of the Union Gas & Oil Co., about 3 miles northeast of Basin, Wyo., near the northwest corner of sec. 11, T. 51 N., R. 93 W. The structure at this locality is that of a very gentle anticlinal flexure on the flanks of a larger anticline that extends from the Peay Hill dome near Greybull to the Torchlight dome, 3 miles east of Basin. The structure can not be thoroughly worked out because of the lack of exposures, but from the tracing of a thin sandstone along the hillside it would seem probable that the well is located on the side of a small minor anticline of domical form. The rocks at the well are not exposed, but from the depth of sandstone B in the well it is probable either that there is a fault

¹ Washburne, C. W., Gas fields of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 340, pp. 348-363, 1908.

between the hillside and the well or that the concealed rocks dip westward at an angle of over 10° .

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

Log of the Union Gas & Oil Co.'s well No. 1, 3 miles northeast of Basin, Wyo.

[No. 29 on Plate XVIII.]

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

This well (No. 29 on Pl. XVIII), according to report, was later drilled to a depth of 1,100 feet, but no oil or gas of economic importance was obtained.¹

FIELD WORK.

The field work on which this report is based was done in October, 1914. Some additional information regarding development, obtained during the field season of 1915, has been inserted in the proof. Wendell P. Woodring assisted in the mapping, and Henry C. Evans and Millard Massey contributed by assisting in rodding and doing camp work.

A base line 8,200 feet in length, represented on Plates XVII and XVIII by the line A-B, was measured along the track of the Chicago, Burlington & Quincy Railroad a short distance south of Basin, in secs. 27, 28, and 34, T. 51 N., R. 93 W. The altitudes of the stations at the ends of this base line were determined from a United States Geological Survey bench mark situated near the public square in Basin. The ends of the base line were then occupied and flags and prominent topographic and cultural features were located by inter-

¹ Since this paper was submitted for publication Bulletin 10 of the Wyoming Geological Survey, entitled "The Basin and Greybull oil and gas fields, Big Horn County, Wyo.," prepared by F. F. Hintze, jr., has been published. Several references to his report, explaining differences in terminology and structure, are made in footnotes in this paper.

section. The altitude of each located point was determined by means of vertical angles and distances between points. Where such careful triangulation work is done the results are more nearly correct than chained distances, especially if the chaining is done over broken country. The system of triangulation begun as above described was developed over the entire area mapped. Other United States Geological Survey bench marks in sec. 26, T. 51 N., R. 93 W., and sec. 6, T. 50 N., R. 92 W., were located in order to check the altitudes determined by the vertical-angle method. Particular attention was given to determining the locations and altitudes of the mouths of the wells in the Torchlight dome and Lamb anticline, except those drilled by the Union Oil & Gas Co. near the northwest corner of sec. 11, T. 51 N., R. 93 W. (No. 29) and by the Valentine interests in the SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 10 of the same township (No. 28), the locations and altitudes of which were furnished by F. F. Hintze, jr., of the Wyoming Geological Survey. Although the Peay Hill dome is shown on the map, it was not examined and its position is given merely to show its relation to the Torchlight dome and Lamb anticline.

In addition to locating the mouths of wells and topographic and cultural features, such as hills and roads, the outcrops of certain lithologic units, such as the Torchlight sandstone member of the Frontier formation¹ (sandstone B of Washburne's classification²) and other sandstone beds situated stratigraphically above and below the Torchlight sandstone, were mapped in and about the Torchlight dome. A very dark shale about 350 feet stratigraphically above the top of the Torchlight sandstone was mapped about both the Torchlight dome and the Lamb anticline. (See Pl. XVIII, p. 188.) The sandstone beds referred to are not exposed in the Lamb anticline, so the dark shale was used as a key to the stratigraphy. Altitudes on the outcrops of the several beds, as well as the dips of the strata, were determined in order that structure contours could be drawn. As noted on Plate XVIII and elsewhere in this report the structure contours are drawn on the top of the Greybull sand, or the top sandstone of the Cloverly formation.

LAND SURVEYS.

The earliest land surveys in this area were made along the east boundary of T. 50 N., R. 92 W., in 1882 by W. J. Boland. In the following year the remaining exterior lines and subdivisions of the same township were surveyed by E. La Peire. A few well-marked corners on the west range line were found, but no monument bearing

¹ The names Torchlight sandstone and Peay sandstone were proposed by Hintze for the sandstones previously called by Washburne sandstone B and sandstone A. As names are much preferred to letters for the designation of oil sands, Hintze's names will be used in this paper.

² Washburne, C. W., op. cit., pp. 350, 351.

marks was found in the interior of the township. Two corner monuments, probably set by private individuals and intended for the southeast and northwest corners of sec. 16, were found, but they were not exactly in the proper positions as shown by the General Land Office plat.

In 1903 Edward F. Stahle resurveyed the exteriors of T. 52 N., R. 93 W., and in the following year he resubdivided the township. Mr. Stahle also surveyed Tps. 50 and 51 N., R. 93 W., in 1903. A few well-marked corners, indicated on the accompanying maps, were found. That part of the eleventh auxiliary meridian which forms the western boundary of T. 51 N., R. 92 W., was surveyed by Mr. Stahle in 1903. The remaining exterior lines and the subdivisions of this township were surveyed by Wilford W. Utterback in 1912. All the land surveys noted above, except that by Mr. Utterback, who was in the direct employ of the General Land Office, were made under the contract system. The recent work by Mr. Utterback shows that the east-west dimension of the west tier of sections of T. 51 N., R. 92 W., is about one-fourth mile greater than the original survey of that township indicated. This condition suggests that the original survey of the interior of this township was never tied to the west range line. The interior corners and some on the southern township line are marked by iron posts with brass caps, on which are indicated the positions of the corners. All monuments found in other parts of the area are of stone.

HISTORY OF DEVELOPMENT OF THE FIELD.

The first discovery of oil in the eastern part of the Bighorn Basin is believed to have been made in sec. 26, T. 49 N., R. 91 W., near Bonanza post office, on a tributary of No Wood Creek, by Edward Lloyd in 1884. Knight¹ makes the following statement regarding the popularity of this spring:

One very hard winter in the eighties the supply of kerosene oil gave out in the Bighorn Basin and the crude oil from the Bonanza spring was burned in the lamps by many settlers. It was a very good substitute and has always been highly praised by those who actually used it for illuminating purposes.

A well was begun near the spring in 1888 and drilled to a depth of 1,200 feet. Artesian water was encountered, but no oil or gas. In 1902 a well was drilled in sec. 27, T. 49 N., R. 91 W. As this well was plugged it was believed by the settlers that oil was encountered, but no definite information could be obtained regarding the results.

The existence of the Bonanza oil spring has been an incentive to oil and gas prospectors to make further search for favorable places to drill in this part of the Bighorn Basin, and as a result the first wells

¹ Knight, W. C., and Slosson, E. E., Bonanza, Cottonwood, and Douglas oil fields; Univ. Wyoming Bull., Petroleum series, No. 6, p. 7, 1903.

were drilled in the Torchlight dome in 1904. In 1907 a well (No. 29, Pl. XVIII) was drilled in the NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 11, T. 51 N., R. 93 W., to a depth of about 1,100 feet, but without encountering oil or gas in commercial quantities. The results obtained at this well gave little encouragement, and no further drilling was done in the Basin field till 1912, when well No. 26, yielding water only, in the SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 35, T. 51 N., R. 92 W., was drilled to a depth of 1,800 feet. In 1913, 1914, and 1915 there was a revival of drilling operations in the Torchlight dome and Lamb anticline, and up to October 10, 1915, 48 wells were drilled, the greater number of which yielded oil or gas in commercial quantities. The outlines of the "pools" underlying the Torchlight dome and Lamb anticline have been determined in part, but further drilling will be necessary to locate them completely. All the wells drilled in 1915 are within proved territory except one, the Cleveland-Wyoming well, which is about $1\frac{1}{2}$ miles west of the Torchlight dome. The table under the heading "Wells drilled" (p. 187) summarizes the general information regarding the development of the field.

SURFACE FEATURES.

The Bighorn Basin, of which the area described in this report forms a part, is a broad depression lying between the Bighorn Mountains on the northeast and east, the Owl Creek and Bridger mountains (the latter being that part of the Owl Creek Mountains east of Bighorn River) on the south, and the Absaroka Mountains on the southwest.

The Basin oil field lies in the eastern part of this great depression and has a hilly surface. In elevation it ranges from about 3,800 feet above sea level at the river near Greybull, to about 4,600 feet on the northeast rim of the Lamb anticline, in the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 1, T. 51 N., R. 93 W. Its principal surface features are the broad valley of Bighorn River in the western part and a rough hilly country lying to the east, which includes the Torchlight dome, the Lamb anticline, and the northwest end of a southeastward-trending anticline of doubtful importance as a reservoir of oil or gas. The immediate valley of Bighorn River is marked by a flood plain, in places 2 or 3 miles wide. A number of remnants of gravel-capped terraces are conspicuous, especially on the west side of the river. They are present at but few places on the east side of the stream, for they have been removed by erosion as the river has gradually changed its course toward the east. No Wood Creek, which joins Bighorn River in sec. 30, T. 50 N., R. 92 W., has gradually changed its course to the south, as is shown by the prominent terrace remnants a mile or more in width lying just north of the present flood plain of that stream.

The hilly portion of the field consists of two parts which have very different topography. The part lying south of the Basin-Hyattville

road contains numerous hogback ridges trending northwest, with badland valleys intervening; the part lying north of the road contains smooth, gently rolling hills, with badland topography in places adjacent to stream courses where erosion has been most active. Just east of the river flood plain a prominent escarpment of shale forms the river bluffs, the edge of which is of badland character in many places, and extends through secs. 2, 11, 14, 23, and 26, T. 51 N., R. 93 W. In secs. 24 and 25 of the same township and sec. 19, T. 51 N., R. 92 W., which include the Torchlight dome, cliffs of sandstone 20 to 40 feet in height are conspicuous and in many places form nearly impassable barriers.

The surface of the central part of the Torchlight dome and that of the axis of the Lamb anticline contain irregular basin-like depressions. The central depression in the Torchlight dome is surrounded by two concentric inward-facing walls of sandstone, the outer of which is composed of the Torchlight sandstone, described in this report under "Stratigraphy," and the inner is a bed of sandstone about 100 feet lower. The depression along the axis of the Lamb anticline contains no exposures of the sandstone beds that are so prominent around the Torchlight basin. These topographic basins, being near each other, are both surrounded by an irregular inward-facing wall of shale, the approximate position of which is shown in Plates XVII and XVIII by the line marked "Band of dark shale." Plate XVII shows the relation of the surface features of the Torchlight dome to the geologic formations that crop out in it. The shale walls surrounding the depression representing the Lamb anticline are even more prominent than those that form the rim of the Torchlight basin, but no sandstones occur in that part of the section exposed.

In these areas the lowest part of the surface coincides with the highest part of the dome and the crest of the anticline. This is due to the erosion of the two uplifts by streams, which follow their trend in a general way. These valleys have made it possible to construct good roads with low gradients into both areas at a reasonable expense. The principal minor valleys contain well-traveled roads over which drilling machinery and supplies can be transported with ease.

CLIMATE AND WATER SUPPLY.

The climate of the Bighorn Basin is semiarid. Records of temperature have been kept at Hyattville, 25 miles southeast of Basin, for 11 years or more. During this time the lowest temperature recorded was 32° below zero in January, the maximum 105° above zero in August, and the mean or average 46.3° above zero for the entire year. The temperature variations at Basin have about the same range.

The question of water supply in this locality is one of importance to the oil driller. At no other place in the Bighorn Basin or in the entire State of Wyoming where records of precipitation have been kept for a number of years is the average annual rainfall so low as at Basin. Records kept from 1898 to 1909, inclusive, a period of 12 years, show that the mean annual rainfall is 5.8 inches, which is less than half that recorded at Thermopolis, Dubois, and Lander, and less than one-third of that at Newcastle and Gillette.

The main surface water supply in this area is that furnished by Bighorn River and No Wood Creek, its largest eastern tributary. Each of these streams carries throughout the year an almost inexhaustible supply of excellent water for domestic use. Many of the ranchers and some of the oil companies haul water several miles from the river to their ranches and drilling outfits. All the towns and villages along Bighorn River in northwestern Wyoming derive their water supply from this stream or the lower courses of its principal tributaries.

In the early drilling in the Torchlight dome and Lamb anticline water was pumped from Bighorn River in the vicinity of Basin. The Valentine interests, the Champion Oil Co., and the Cleveland-Wyoming Oil Co., which drilled a few wells in the Torchlight dome, hauled water from the river not only for domestic use but also for use in drilling.

The underground water supply in an oil or gas region is also of great importance, and anyone contemplating drilling in a semi-arid region like the Bighorn Basin should carefully consider the probability of obtaining water for domestic use or drilling in the rocks he expects to penetrate. In this field two sands—the Peay and Greybull—yield water in most of the wells drilled, and three others—the Torchlight, Kimball, and Muddy—carry water in some of the wells, as shown by the following table:

Percentage of wells obtaining water in sands in the Basin oil field.

Sand.	Wells penetrat- ing the sand.	Water bearing.	Dry.	Percent- age of wells ob- taining water.
Torchlight.....	19	2	17	11
Peay.....	48	41	7	85
Kimball.....	41	4	37	10
Muddy.....	7	2	5	29
Greybull.....	6	5	1	83

Some of the records are incomplete on this point, so that the percentage of wells encountering water in the Peay sand may be even greater than is indicated above. The best water obtained

from all the wells is that from the Peay sand in the Columbia No. 1 well (No. 18 on Pl. XVIII), in the SE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 12, T. 51 N., R. 93 W. From this well water for domestic use is pumped to the main camp of the Greybull Oil Co., in the SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 24 of the same township. The fact that the Peay and Greybull sands yield water in most of the wells should be of considerable value to those prospecting for oil and gas.

STRATIGRAPHY.

PUBLISHED CLASSIFICATIONS.

The stratigraphy of the Cretaceous and Tertiary rocks on the east side of the Bighorn Basin have been discussed in a general way by Eldridge, Fisher, and Washburne. Eldridge¹ recognized the Dakota, Colorado, Montana, Laramie, and Wasatch formations; Fisher² divided the Cretaceous system into Morrison, Cloverly, Colorado, Pierre, and Laramie and associated formations and described the Tertiary system as represented by the Wasatch and possibly other Eocene formations; Washburne³ considered the Cloverly formation to represent the Lower Cretaceous (?), and the Upper Cretaceous to include the Colorado shale, Eagle sandstone, Claggett formation, Judith River formation, Bearpaw shale, and Laramie (?) formation. The Tertiary system he regarded as represented by the Fort Union and Wasatch formations. Hewett,⁴ while making an examination of a part of the west side of the basin, measured in detail a thick section (14,500+ feet) on Shoshone River. These rocks, except the lower 1,110 feet, which is included in the Sundance (Jurassic) and the Morrison (Jurassic or Cretaceous), comprise the Cretaceous and Tertiary systems. Hewett divides the Cretaceous into "Cloverly," Colorado, Gebo, Meeteetse, and (possibly) Ilo formations, and the Tertiary into the Fort Union and Wasatch formations.⁵

The accompanying table shows the subdivisions of the Cretaceous and Tertiary systems in the vicinity of Basin, Wyo., as recognized in this report, correlated with the subdivisions adopted by Fisher, Washburne, and Hewett.

¹ Eldridge, G. H., *op. cit.*, pp. 22-27.

² Fisher, C. A., *op. cit.*, p. 8.

³ Washburne, C. W., Coal fields of the northeast side of the Bighorn Basin, Wyo., and of Bridger, Mont.: U. S. Geol. Survey Bull. 341, p. 167, 1909.

⁴ Hewett, D. F., The Shoshone River section, Wyoming: U. S. Geol. Survey Bull. 541, pp. 91, 95-107, 1912.

⁵ In a recent report (The Basin and Greybull oil and gas fields, Big Horn County, Wyo.: Wyoming Geol. Survey Bull. 10, p. 17, 1915) F. F. Hintze, jr., recognizes the Cloverly, Lower Benton, Upper Benton, Niobrara, Pierre, Eagle, undifferentiated Montana, and Ilo formations.

Various classifications of the rocks in reports on the Bighorn Basin, Wyo.....	166

Fisher (Prof. Paper 53, p. 8).		Washburne (Bull. 341, p. 167).			Hewett (Bull. 541, p. 91).			Lupton (present paper).				
System.	Formation.	System or series.	Group.	Formation.	System or series.	Group.	Formation.	System or series.	Group.	Formation. ^a	Thick- ness in feet.	Characteristics.
Quaternary.	Alluvium. Later terrace gravels. Early terrace gravels.							Quaternary.			0-50±	Alluvium along stream courses and soil covering a large part of the area.
											0-25±	Terrace gravel along No Wood Creek and Bighorn River consisting of fairly well rounded pebbles of sandstone, chert, limestone, and granite.
Tertiary.	Wasatch formation.	Tertiary (Eocene).		Wasatch formation. Unconformity. Fort Union formation. Unconformity.	Tertiary (Eocene).		Wasatch formation. Unconformity. Fort Union formation. Unconformity.	Tertiary and Tertiary (?).		Undifferentiated Fort Union and Lance formations.	1,275±	Yellowish-gray soft sandstone and drab shale, with valuable coal beds.
Cretaceous.	Laramie and associated formations.			Laramie (?) formation.	Cretaceous or Tertiary.		No formation.					
			Montana.	Bearpaw. Judith River. Claggett. Eagle.			Meeteetse formation. Gebo formation.		Montana.	Mesaverde formation.	1,200+	Marine sandstones, thick beds of shale, and coal beds of no importance in this field.
	Pierre shale.	Upper Cretaceous.			Upper Cretaceous.			Upper Cretaceous.		Cody shale.	3,360±	Gray and dark shale, sandy at top and base; contains the equivalent of the Niobrara.
									Colorado.	Frontier formation.	565±	Sandstone and shale alternating. Two sands (Peay and Torchlight) are oil, gas, and water bearing.
	Colorado formation.			Colorado shale. (Mowry shale.)			Colorado shale.			Mowry shale.	160±	Hard, platy grayish shale containing fish scales. Two sands (Kimball and Oeth Louie) carry oil and gas.
				Unconformity.						Thermopolis shale.	710±	Soft gray and dark shale, with a sand (Muddy) near middle.
	Cloverly formation.	Lower Cretaceous.		Cloverly formation.	Lower Cretaceous.		"Cloverly" formation.	Lower Cretaceous.		Cloverly formation.	113	Consists of two sands 10 to 30 feet thick separated by 80 feet or more of variegated sandy shale. The upper sand, the Greybull, contains water.

^a The correlations of these formations with those described by Hintze (Wyoming Geol. Survey Bull. 10) are given in footnotes under the detailed descriptions of the formations.

CRETACEOUS SYSTEM.

GENERAL SECTION.

The positions of the oil, gas, and water bearing sands in the Cretaceous strata below the Mesaverde formation are shown in the section given below:

- 1) *Generalized section of strata from the base of the Mesaverde formation to and including the base of the Cloverly formation in the Basin oil field.*

Mesaverde formation.

Cody shale:

	Feet.
Shale, gray, drab, and dark, sandy at top and base.....	3,360±

Frontier formation:

Conglomerate.....	7
Sandstone, Torchlight member, part poorly consolidated; carries a little oil, gas, and water	83
Shale, drab.....	100
Sandstone, shaly; contains a hard layer 12 feet thick that carries a little oil and gas.....	87
Shale ¹	105±
Sandstone, Peay member; oil and gas bearing.....	45
Shale, sandy, dark; contains bed of bentonite at base.	138
	565±

Mowry shale:

Shale, hard, platy.....	40
Sandstone, Kimball sand of drillers; oil, water, and gas bearing.....	50
Shale.....	45
Sandstone, Oath Louie sand of drillers; yields a little oil.....	25±
	160±

Thermopolis shale:

Shale, hard; contains lenses of sandstone.....	230
Shale, soft, dark.....	170±
Sandstone, Muddy sand of drillers; contains a little gas.....	35±
Shale, soft, dark.....	275±
	710±

Cloverly formation:²

Light-buff or tan-colored sandstone [Greybull sand of drillers].....	20
Maroon clay.....	4
Reddish and tan-colored sandy clay.....	10
Drab sandy clay.....	10
Deep-maroon sandy clay.....	20
Hard tan-colored sandstone.....	3
Deep-maroon to purple variegated clay.....	12
Lenses of maroon sandstone.....	3
Deep-maroon sandy clay.....	20
Olive-green soft cross-bedded sandstone, with hard layers lying on maroon and drab-gray Morrison shale..	11
	113

4,908±

¹ Thickness of strata below the lower part of this shale to the top of the Cloverly was determined by averaging a number of well logs.

² The section of the Cloverly is taken from U. S. Geol. Survey Prof. Paper 51, p. 52, 1906.

CLOVERLY FORMATION.

The Cloverly formation is not exposed at any place in this area. It has been penetrated in some of the oil and gas wells, however, and therefore will be briefly considered. At the type locality of the Cloverly formation, near Cloverly, Wyo., about 15 miles northeast of the northern part of this area, the formation, according to N. H. Darton, consists of 113 feet of strata, a detailed section of which is given above. The upper 20 feet of this formation constitutes the Greybull sand, which carries oil and gas in the Greybull field and water in the Lamb anticline and Torchlight dome. According to Darton—

The Cloverly formation is believed to represent the Lakota sandstone, Fuson formation, and Dakota sandstone of the Black Hills region. * * * On the basis of the above correlation it represents the later deposits of the Lower Cretaceous and the earliest deposits of the Upper Cretaceous.

It is not certain, however, that the Dakota sandstone is represented in the Cloverly formation at its type locality. The only determinable fossils from the Cloverly are a few plants belonging to the Kootenai flora as determined by Knowlton. They were collected on No Wood Creek, 30 miles above its mouth.

Near the southern edge of the Bighorn Basin the lower part of the Cloverly formation is a particularly gritty sandstone, and in places it is finely conglomeratic.

THERMOPOLIS SHALE.

The name Thermopolis shale¹ is here applied to a mass of generally shaly rocks, limited below by the top of the upper sandstone bed of the Cloverly (Greybull sand) and above, also conformably, by the base of the Mowry shale. It is named from the town of Thermopolis in Hot Springs County, near which it is well exposed. It is not exposed in the vicinity of Basin, but sections obtained in drill holes indicate that it is a predominantly dark shale about 700 feet thick and that it contains one or more lenticular beds of sandstone. The Muddy sand, which is well known to oil operators and in places contains a little gas and water, is the most persistent sandstone bed. It ranges from 15 to 55 feet in thickness and lies from 210 to 330 feet above the top of the Greybull sand, or the top of the Cloverly formation. In some of the wells a sandstone bed about 30 feet thick is present about 60 feet above the base of the Thermopolis shale but is of no economic importance. The generalized section given on page 167 shows the position of the Muddy sand in this shale.

¹ This formation corresponds to that part of the Lower Benton of Hintze's section lying below the Mowry shale.

MOWRY SHALE.

The Mowry shale, named for Mowry Basin, on the east side of the Bighorn Mountains, has been recognized over a broad area from the west side of the Bighorn Basin to the Black Hills and from northern Montana to the Uinta Basin, Utah. Wherever it has been recognized it is characterized by great numbers of fish scales and a remarkable absence of fish bones and vertebræ. It varies in thickness from place to place, being about 160 feet thick in the Basin oil field. Heretofore the Mowry has been considered as a shale member of the Benton or Colorado, but on account of its wide distribution and distinctive character, it is here treated as an independent formation.

The Mowry, like the Thermopolis shale, is not exposed in the Torchlight dome or the Lamb anticline. Records of wells drilled in and near the Torchlight dome and in the vicinity of Greybull indicate that the beds included in this formation are similar in character to the typical Mowry and that they have a thickness of about 160 feet as shown in the general section.

Two sandstones in this shale—the Kimball and Oeth Louie sands of the drillers—carry oil and gas. As indicated in the generalized section, the Kimball sand is about 40 feet below the top of the shale and the Oeth Louie about 45 feet below the base of the Kimball. The Kimball is the principal oil-bearing sand in the Torchlight dome, and in places it also contains gas and water. In the Lamb anticline, however, it is generally dry, yielding oil in only one well. The Oeth Louie sand is known to contain oil in many of the wells in this field. In fact, according to Homer T. Lamb, oil occurs throughout the Mowry shale in the Torchlight dome.

FRONTIER FORMATION.

The Frontier formation consists of about 565 feet of sandstone and shale with beds of bentonite (a hydrous silicate of alumina) ranging from a few inches to 3 or 4 feet in thickness. The upper 325 feet of the formation is exposed in the Torchlight dome, and the character of the lower part, about 240 feet thick, is known from well logs. As may be noted in the subjoined section, the formation is predominantly sandstone. The 12-foot yellowish-gray sandstone bed, which is about 90 feet above the base of the lowest beds exposed in the Torchlight dome, contains in places pieces of fossilized wood. The characteristics and relations of the beds of this formation are given in the following section:

Section of Frontier formation.

[The upper part was measured in the Torchlight dome, and the lower part (generalized) determined from well records in the vicinity. Measurements made in sec. 24, T. 51 N., R. 93 W. and sec. 19, T. 51 N., R. 92 W.]

Cody shale.

Frontier formation.

Conglomerate, consisting principally of dark chert pebbles ranging in size from sand grains up to 4 inches in diameter.	Feet. 7
Sandstone, Torchlight; contains some oil, gas, and water:	
Sandstone, very poorly consolidated.....	11
Sandstone, massive, gray, somewhat cross-bedded.....	32
Sandstone, gray, yellow, and drab, very poorly consolidated.....	40
Shale, drab, very sandy at base; contains a few layers of brown iron-stained concretions in the lower part.....	100
Sandstone; gray; weathers yellow; interbedded with shale.	9
Shale, drab, yellow, and pink, sandy at top.....	10
Sandstone, gray, soft, massive.....	4
Sandstone, yellowish gray; contains two or three layers of dark brownish-yellow concretions; vertical veinlets of calcite as much as 6 inches thick bearing north cut the bed; carries a little oil and gas.....	12
Sandstone, argillaceous, medium bedded, alternating with softer beds of sandstone.....	15
Sandstone and sandy shale, interbedded, gray and drab; contains a few disklike and spherical concretions.....	35
Sandstone, yellowish gray, very thin bedded; ledge maker..	2
Shale, dark drab, sandy; contains a few thin beds of sandstone (to bottom of arroyo in Torchlight dome).....	48
(Section below generalized from well logs in the region.)	
Shale, dark blue, hard.....	30±
Shale, white, hard.....	25±
Sandstone, Peay, white, poorly consolidated; bears oil, gas, and water.....	45±
Shale, blue and gray, hard.....	20±
Sandstone, poorly consolidated.....	20±
Shale, blue.....	18±
Shale, very sandy.....	25±
Shale, dark, sandy.....	55±
Mowry shale.	563±

The name Frontier was first applied by Knight¹ to a well-defined coal-bearing formation of Benton age in Lincoln and Uinta counties, Wyo. As described by Veatch,² it has at the type locality a thickness of 2,200 to 2,600 feet. In the mapping of several coal and oil

¹ Knight, W. C., Eng. and Min. Jour., vol. 73, pp. 720-723, 1902; Geol. Soc. America Bull., vol. 13, pp. 542-544, 1903.

² 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. 65, 1907.

fields in the State it has been found that there is generally a group of sandstone and shale beds in the middle of the Colorado, which is the representative of the Frontier formation of Lincoln County. The individual beds, as well as the group of beds, thin eastward and disappear at about the meridian of Douglas. These beds of sandstone, which contain the most prolific oil-bearing sands of the State, have previously been treated as individual members of the Colorado shale, but now it is proposed to consider them collectively as the Frontier formation and to name individual beds as members of this formation.

In the vicinity of the Torchlight dome the Frontier formation includes three sandstones that bear oil, gas, and water. Only one of these, the Peay sand, carries oil in commercial quantities. The value of the Peay and Torchlight sandstones and a sandstone stratigraphically between them as reservoirs for oil and gas is fully discussed under "Occurrence" (pp. 178-181). The Peay and Torchlight sandstones were first named and described by Washburne¹ as sandstones A and B, respectively, in 1908, and his designations have since that time been adopted by drillers in this region, but it is hoped that these names will be replaced by the terms Peay and Torchlight as proposed by Hintze.

CODY SHALE.²

The strata lying above the top of the Frontier formation and below the base of the Mesaverde formation consist in the vicinity of Basin of about 3,360 feet of shale with a single sandstone bed near the base and several thin beds of sandstone carrying fossils near the top. This shale is believed to contain not only the upper part of the Colorado group, but at least 1,000 feet of the Montana group, as is indicated by the fossils listed below. Cody, a town in the western part of Bighorn Basin, from which this shale takes its name, is situated on the outcrop of these beds near Shoshone River, where they are well exposed and where Hewett³ determined the thickness of the formation to be 2,150 feet. This shale, a detailed section of which follows, crops out directly south of the Torchlight dome. The thickness of the predominantly shaly part was calculated from dip readings and the width of the belt of outcrop, whereas the lower 200 feet and the upper 870 feet were measured with the hand level.

¹ Washburne, C. W., Gas fields of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 340, p. 350, 1908.

² This formation includes the Basin (Niobrara) shale and Pierre shale of Hintze's classification.

³ Hewett, D. F., op. cit., pp. 91, 98, 99.

Section of Cody shale in the southeastern part of T. 51 N., R. 93 W.

Mesaverde formation.

Cody shale:	Feet.
Shale, sandy, yellowish gray, soft.....	200
Sandstone, yellowish gray, medium bedded, interbedded with very sandy shale.....	60
Shale, grayish yellow, very sandy.....	11
Sandstone, gray, thin bedded, ripple marked.....	1
Shale, dark drab, sandy. (Fossil collection 8918 from the base of this shale)	63
Shale, dark drab; contains concretions of yellowish impure sandy limestone 4 to 7 feet in diameter.....	20
Shale, dark drab, with a few concretions (4 to 5 feet in diameter) of brown sandstone and yellowish impure limestone in lower part. (Fossil collection 8917 from the base of this shale).....	325
Shale, yellowish gray, in lower part very sandy.....	108
Shale, yellowish gray, thin bedded, soft; fragments slightly warped.....	8
Shale, yellowish gray, very sandy.....	20
Sandstone, gray, soft, thin bedded; fragments have curved surfaces when weathered.....	2
Shale, sandy, yellowish gray; contains lenticular beds 4 to 12 inches thick, of yellowish gray and brown sandstone.....	30
Sandstone, grayish brown, thin bedded; fragments warped...	1
Shale, dark gray and drab, sandy.....	23
Sandstone, brown, thin bedded, lenticular.....	1
Shale, bluish drab, with a few thin beds of fossiliferous sandstone and concretions about 200 feet below top. (Fossil collections 8921 and 8922 from this sandstone. Fossil collection 8920 from a stratum of shale about 350 feet above the base).....	2, 285
Sandstone, yellowish gray (highest sandstone encircling Torchlight dome).....	2
Shale, grayish drab, sandy.....	110
Poorly exposed, probably soft sandstone and shale, yellowish gray.....	90±
Frontier formation.	3, 360±

Collections of fossils, No. 8922, from the NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 5, T. 50 N., R. 92 W.; No. 8921, from the NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 1, T. 50 N., R. 93 W.; No. 8917, from the SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 35; and No. 8918, from the NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 35, T. 51 N., R. 93 W., from beds near the top of the Cody shale, indicate that the upper 1,000 feet or more of this shale is of Montana age. Lot 8922 was collected from a bed more than 1,000 feet below the base of the Mesaverde and contains the following species, which belong to the Montana fauna: *Inoceramus* sp. fragment, *Lucina* sp., *Nautilus dekayi* Morton, *Baculites ovatus* Say, and *Scaphites* sp. related to *S. hippocrepis* Dekay. Lot 8921, from a bed at the same horizon, contains only one species, *Baculites ovatus* Say?, regarding which T. W. Stanton states: "This species seems to

belong to the Montana fauna." Lots 8918 and 8917, from beds at a horizon a short distance below the base of the Mesaverde formation, contain but few species and according to Stanton may belong to either the Montana or Colorado fauna.

Fossil collection 8920, from a stratum about 350 feet above the base of the Cody shale, in the SW. $\frac{1}{4}$ sec. 7, T. 51 N., R. 92 W., is definitely from the Colorado fauna and is characteristic of the Niobrara formation, which is believed to be represented in the lower part of the beds included in the Cody shale. The species included in this collection are *Ostrea congesta* Conrad, *Inoceramus* sp., thick shelled, and *Scaphites*? sp.

MESAVERDE FORMATION.

The Mesaverde formation, which overlies the Cody shale in apparent conformity, is about 1,200 feet thick and consists principally of sandstone with a minor amount of shale and a little coal. Not enough field work was done in the vicinity of Basin to enable the writer to determine the upper limit of the formation with certainty. Washburne,¹ who extended his work into this region from the north, correlated the sandstone immediately overlying the Cody shale with the Eagle sandstone, which occupies a similar position with regard to the thick mass of shale along Yellowstone River in the vicinity of Billings, Mont., but it is evident that the Eagle sandstone dies out toward the south and that the sandstone overlying the shale in the vicinity of Basin is not the same as the Eagle, for fossils of Montana age have been found in the Basin field more than 1,000 feet below the sandstone called Eagle. In the type locality in northern Montana the Eagle sandstone is the lowermost formation of the Montana group, hence it can not be the same as a sandstone having 1,000 feet of shale of Montana age below it. Washburne's determination of this sandstone as Eagle is therefore in error.

Hewett,² working in the vicinity of Cody on the west side of the Bighorn Basin, recognized two prevailingly sandy formations in the general stratigraphic position of the Mesaverde and named them Gebo (lower) and Meeteetse (upper). The thickness of these formations at Cody is greater than that of the beds believed to be Mesaverde in the Basin field.

A few fossils were found in this sandstone in the Basin field. Collection 8919, obtained 65 feet above the base of the sandstone, contains *Anomia* sp., *Cardium speciosum* M. and H., *Telina* sp.,

¹ Washburne, C. W., Coal fields of the northeast side of the Bighorn Basin, Wyo., and of Bridger, Mont.: U. S. Geol. Survey Bull. 341, pp. 167-169, 1909. F. F. Hintze, jr., of the Wyoming Geological Survey, has evidently combined the classification of Fisher and Washburne, placing the Eagle sandstone above the Pierre shale. This is an impossible relation, for the true Eagle constitutes the base of the Montana group.

² Hewett, D. F., op. cit., pp. 91, etc.

Liopistha undata M. and H., and *Maetra formosa* M. and H. T. W. Stanton states that these species are of Montana age, occurring in the Eagle and Claggett and some of them in still higher formations. This evidence might be used in support of Washburne's classification, but it is completely offset by the finding of good Montana fossils in the shale underlying the sandstone.

In the Basin field the Mesaverde formation is not known to contain oil or gas, and for this reason only a general description of it is given.

TERTIARY SYSTEM.

UNDIFFERENTIATED LANCE AND FORT UNION FORMATIONS.

The Mesaverde formation is overlain by a mass of rocks several hundred feet thick that are believed to represent the Lance and Fort Union formations. During the field work no fossils were found in these rocks, and little evidence is at hand regarding the position of the formation boundaries and the thickness of each formation. At least 1,275 feet of beds were measured, and all are considered to be included in the Lance and the lower part of the Fort Union. The Lance formation is classified by the United States Geological Survey as Tertiary (?); the Fort Union formation is of Eocene age.

QUATERNARY SYSTEM.

TERRACE GRAVEL.

Gravel-capped terraces of Quaternary age are conspicuous surface features on the west side of Bighorn River, in the valley of Greybull River, and on the south side of No Wood Creek near its mouth. At the last-named locality terrace remnants at three different levels are present and slope not only toward Bighorn River but also toward No Wood Creek. Along the west side of Bighorn River and along the lower course of Greybull River, in the area represented by Plate XVII (p. 178), terrace remnants of the same age are present. The gravel consists principally of fairly well rounded pebbles of chert, jasper, chalcedony, limestone, and hard sandstone. The fact that the terraces are limited almost entirely to the west side of Bighorn River is due to the gradual eastward migration of this stream, gentle terraced slopes being thus formed on the west side of the river and in general abrupt cliffs on the east side, where undercutting of the banks and cliffs is much more common. These gravel deposits, the lowest of which is about 40 feet above the streams, serve as protectors of the comparatively soft underlying sandstone and shale from the agents of erosion.

ALLUVIUM.

Alluvium of excellent fertility is present in belts of varying width along all perennial streams in this region. Along Bighorn River

alluvium constitutes the present flood plain, which varies from one-third of a mile to about 2 miles in width, the widest part being in the northern part of T. 51 N., R. 93 W. The maximum thickness of the alluvium is unknown but probably reaches 50 feet in the vicinity of Basin.

STRUCTURE.

GENERAL FEATURES.

Structurally the Bighorn Basin is a great downfold with its longer axis trending northwest. It is limited in general on the east, south, and west by the enormous upfolds of the Bighorn, Owl Creek, and Absaroka mountains, respectively. The flanks of the syncline or edges of the basin are corrugated by small folds trending very regularly northwest. Some of these minor anticlines contain oil and gas in commercial quantities.

The structural features of greatest importance to the oil operator in the field here described are the Torchlight dome and the Lamb anticline. Both of these are on the same upfold on which the Peay Hill anticline is situated. The Peay Hill anticline is also of importance near the mouth of Greybull River as a reservoir of oil and gas, but a complete description of it will be reserved until further field work is done. At the south side of the area shown on Plate XVII there is an anticline which extends several miles southeast of No Wood Creek. In the southeastern part of this area, crossing sec. 35, T. 51 N., R. 92 W., there is a small northwestward-trending anticline regarding which the writer has little definite information. The rocks west of Bighorn River have a general westward dip toward the middle of the basin, ranging from 21° on the lowest beds exposed near Basin to about 50° on some of the higher beds a short distance west of the town.

The structure contours shown on Plate XVIII (p. 188) are drawn on the upper surface of the Greybull sand (top of the Cloverly formation): They are lines connecting points of equal altitude on this surface, and thus they show the deformation that the sand as well as all the other rocks have suffered in the wrinkling that has taken place in the bottom and on the rim of the great synclinal fold.

The value of structure contours lies in the fact that they show clearly the shape of the deformed rocks and, as oil and gas tend to collect in the anticlines, they show the areas most favorable for the location of wells. By their use the prospector may also determine roughly the distance which the drill must go in order to reach any particular sand at any particular place. As the contours are drawn on the upper surface of the Greybull sand, it is easy to find the depth of that sand below the surface by subtracting the altitude of the sand at any point, as shown by the structure contours, from the surface

altitude. For example, the depth of the Greybull sand at well No. 12, on the eastern edge of the Torchlight dome, in the west-central part of sec. 19, T. 51 N., R. 92 W., may be found by subtracting 2,850 feet (the well is situated halfway between the 2,800-foot and 2,900-foot contours), the altitude of the sand, from 4,203 feet, the altitude of the well mouth. The remainder, 1,353 feet, is the approximate thickness of strata between the surface and the top of the Greybull sand, or, in other words, the depth to the sand. In this manner the depth to the Greybull sand at any point in the field may be determined.

To determine the depths of any other sand it is generally more convenient first to calculate the depth of the Greybull and then to subtract from the result the distance from the top of the Greybull to the top of the other sand. Thus having found the depth of the Greybull in well No. 12 as 1,353 feet, the depth of the Kimball sand would be $1,353 - 830$, or 523 feet, and that of the Muddy sand would be $1,353 - 275$, or 1,078 feet. The operation outlined is based on the assumption that the sands are parallel to one another. So far as can be judged from the data at hand this seems a reasonable assumption, but it may be found that the sands are not parallel and so the depth of a sand calculated by this method may not be correct. If it is found on further drilling that such calculations are not accurate, the variations should be noted to see if they are all in the same direction—that is, all too great or too small—and then allowance should be made in future work for the increased or lessened interval.¹

TORCHLIGHT DOME.

The Torchlight dome is an elongated dome with its axis trending northwest and is situated mainly in secs. 24 and 25, T. 51 N., R. 93 W., and secs. 19 and 30, T. 51 N., R. 92 W. At the north it is closely related structurally to the Lamb anticline, the axis of which at its nearest point is within $1\frac{1}{2}$ miles of the axis of the Torchlight dome. The length of the Torchlight dome is about 3 miles and the width about 2 miles. The maximum diameter of the outcrop of the Torchlight sandstone in this structure is about 1 mile. The strata dip more steeply on the southwest side of the dome than on the northeast side, as is shown

¹ Many readers will doubtless compare the structure contours shown on Plate XVIII with those given in Bulletin 10 of the Wyoming Geological Survey and will note that there is a distinct difference. Part of this difference can be explained by the fact that in Bulletin 10 the contours are drawn on the top of the Peay sand, which is about 1,050 feet above the Greybull sand, the datum surface used by the writer. The most striking difference, however, is in the shape of the structures portrayed on the two maps. This can be explained only by the fact that the present writer had much more complete data than were available to Mr. Hintze, and hence it is believed that the structure of the folds in this field is much more accurately represented on Plate XVIII than it is in Bulletin 10 of the Wyoming Survey.

In Bulletin 10 it is suggested that the southeast end of the Torchlight dome is not accurately represented, and this is borne out fully by data in the writer's possession. In several places on the map in Bulletin 10 the structure contours are as much as 300 feet too low, as shown by the data contained in that report. This error is extremely important, as it gives the impression that any given sand in those particular areas lies 300 feet deeper than it actually does.

by dips recorded at different places and shown on Plate XVIII. The southwestward dips vary from a fraction of 1° near the center of sec. 24 to about 22° in the SW. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 25, T. 51 N., R. 93 W. In passing from the center of the dome to the west, southwest, and south, the dip of the strata is gentle at first, then gradually increases to about 20° at a distance of about 1 mile from the center. Beyond this point the beds have a nearly constant dip of 20° to 25° to the edge of the area represented on Plate XVIII. To the east and southeast the maximum dip observed is 9° near the point where the strike of the beds swings abruptly from N. 87° E. to N. 17° W. Along the northeast flank of the dome the greatest dip is 8° , in the NE. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 24, T. 51 N., R. 93 W.

LAMB ANTICLINE.

The Lamb anticline is a larger structural feature than the Torchlight dome, being about 5 miles long and 4 miles wide. Generally the dips are light; a maximum of 10° was noted on the northeast flank, in the SE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 7, T. 51 N., R. 92 W. The beds on the southwest flank within 1 mile of the axis have their greatest inclination (5°) in the SW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 11, T. 51 N., R. 93 W. Over a large part of the area represented by this anticline good exposures are so scarce that it is difficult to determine the attitude of the beds.

The syncline separating the Torchlight dome and Lamb anticline is narrow and comparatively shallow, as shown by the structure contours drawn on the Greybull sand.

OTHER FOLDS.

The Peay Hill anticline (shown on Pl. XVII), near the mouth of Greybull River, has yielded considerable oil and gas, but it has not been examined by the United States Geological Survey and its approximate position only is given.

Four miles south of the Torchlight dome is the end of a northwestward-trending anticline, which, according to reports, attains considerable proportions south of No Wood Creek. The lowest rocks exposed in this fold north of the creek are not older than Montana, but it is believed that south of No Wood Creek beds of Colorado age are exposed at the surface, and it is reported that some drilling has been done there. A maximum dip of 14° was measured on the northeast flank of this anticline near the center of sec. 21, T. 50 N., R. 92 W. On the southwest flank the greatest observed dip (21° SW.) is in the southern part of sec. 13, T. 50 N., R. 93 W. The axis of the syncline, which lies parallel with and northeast of this anticline, is comparatively close to the axis of the anticline on the north side of No Wood Creek, varying from less than a quarter of a mile near the center of sec. 12, T. 51 N., R. 93 W., to slightly more than $1\frac{1}{4}$ miles where the axes cross No Wood Creek.

In the southeastern part of T. 51 N., R. 92 W., there is a gentle anticline which trends nearly north and south. Little detailed information regarding this fold was collected, so that its extent and magnitude are not known.

OIL AND GAS.

OCCURRENCE.

WELLS AND PRODUCING SANDS.

In all, fifty-two wells have been drilled in this field up to October 10, 1915. The records of all these wells except three (Nos. 12, 17, and 30¹) are at hand and have been studied with care, but only a few can be published in detail, as they have been furnished by the owners on the condition that they be treated as confidential information. However, certain deductions drawn from their study are given at different places in this paper.

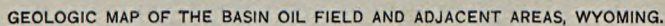
The Kimball sand, in the Mowry shale, is the largest producer of oil, and the Peay sand, in the Frontier formation, is the most important reservoir for gas in the Basin field. The other sands are of little or no importance as oil or gas reservoirs. The Torchlight sand yields oil in one well, oil and gas in one, and water in two, and in fifteen other wells it is dry. A lenticular sand between the Peay and Torchlight sands furnishes a little oil in one well, gas in five wells, and oil and gas in one and is dry in one hole. The Peay sand contains oil in one well, gas in six, oil and gas in four, and water (fresh or sulphurous) in forty-one, and in four holes it is dry. The Kimball sand yields oil in twenty-nine wells, oil and gas in two, and water in four, and in seven it is dry. The Oeth Louie sand carries a little oil in twenty-one wells, and in the remaining five it is barren of oil, gas, and water. The Muddy sand contains gas in three wells and water in two, and in two it is dry. The Greybull sand carries water in five holes and in one it is dry.

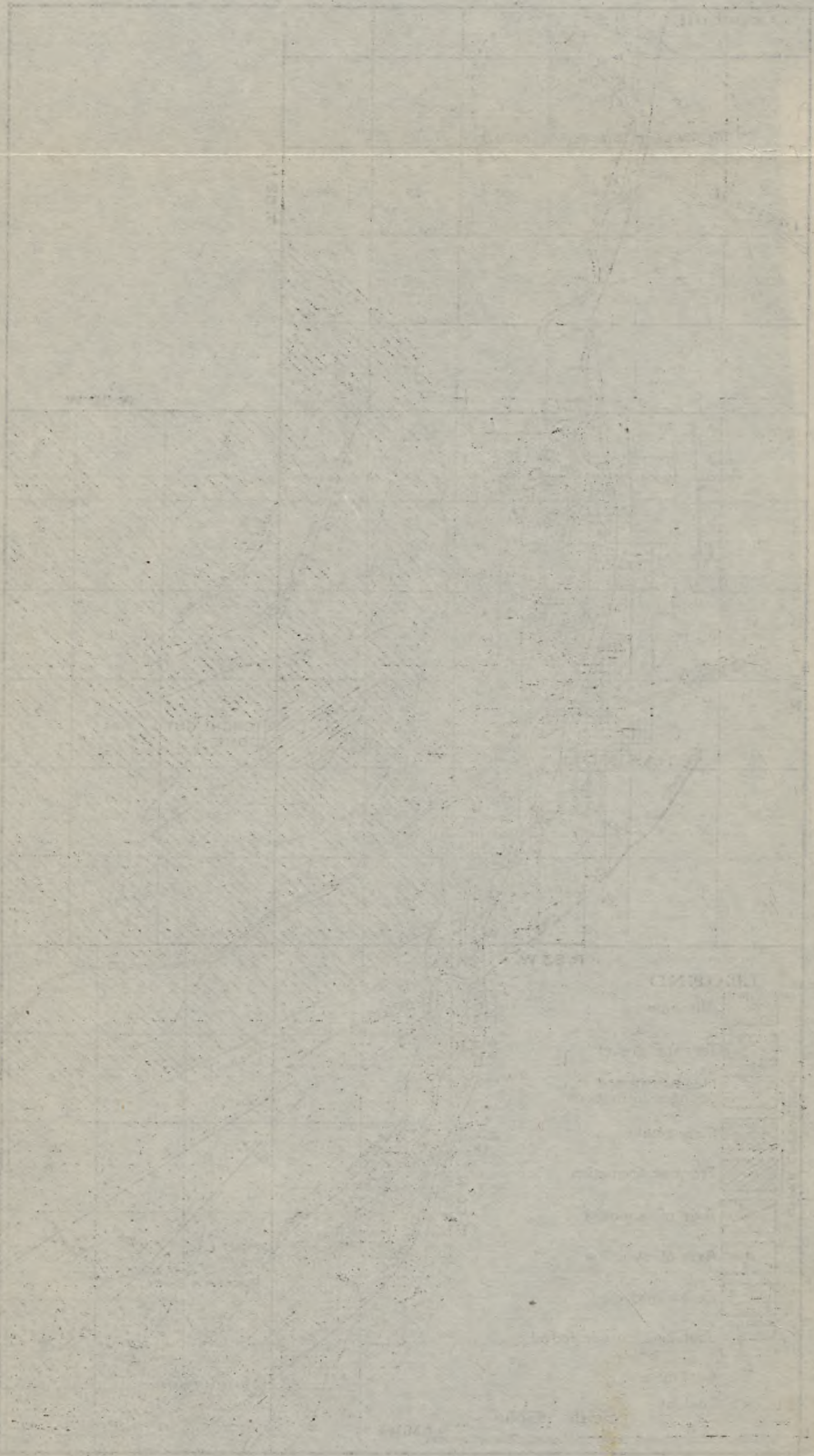
OIL IN THE TORCHLIGHT DOME.

In the Torchlight dome most of the oil is obtained from the Kimball sand, but oil is found also in commercial quantities throughout the Mowry shale and in the Peay sand and traces occur in some of the other sands. Seven holes penetrated the Torchlight sand, which is barren in five of them, oil bearing in one, and oil and gas bearing in one. The stray sand between the Peay and Torchlight sands was recognized in only one well, where it shows oil. The Peay sand was drilled through in thirty-four wells; one well showed gas alone, three oil and gas, thirty water, and four were absolutely dry.² The Kim-

¹ Numbers of wells refer to corresponding numbers on Plate XVIII (p. 188).

² In many wells water occurs in a different part of the same sand that carries oil or gas; hence in these summaries the total of wells showing oil, gas, and water may not be the same as the number of wells drilled.





ball sand was encountered in thirty-two wells. In twenty-eight it produced oil, in two oil and gas, and in three water. In twenty-three wells the Oeth Louie sand (or stray sand below the Kimball) was recognized. It contains some oil in all the wells, but not as much as the Kimball sand. The Muddy sand was encountered in three wells, in two of which it furnished a little gas and in one it was dry. Three wells in the Torchlight dome penetrate the Greybull sand, which in all three carries fresh water.

The productive area of the Torchlight dome, so far as development has gone, is limited by one dry hole (No. 7) on the north, another (No. 13) on the south, and one (the Cleveland-Wyoming well) in the NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 22, T. 51 N., R. 93 W., about $1\frac{1}{2}$ miles west of the westernmost producing wells in this dome. Well 14, which is about as far from the center of the dome as well 13, is reported to have encountered oil in the highest or Torchlight sand. The productive area has not been outlined even in a general way on the east and not closely on the west. It is believed, however, that future drilling will prove that the productive area is limited on the north by a line midway between the 2,700 and 2,800 foot structure contours and on the east, south, and west by the 2,500 or 2,600 foot contour. This latter boundary is arbitrary and is drawn halfway between the contours of known productive and nonproductive territory on the east, south, and west. Oil will probably be found lower on the west slope of the dome than on the east slope, to judge from the distribution of oil in other structural features in the Bighorn Basin. The fact that oil is reported from the Torchlight sand in well 14 and a show of oil and gas in well 7 suggests that this sand carries a little oil in the Torchlight dome.

These assumptions are based on the following facts: On the north side of the dome well 7, which yields neither oil nor gas but carries water in the Kimball sand, is just north of the 2,600-foot contour, and well 5, which encountered oil in the Kimball sand and water below it, is just north of the 2,800-foot contour. The line separating oil-bearing from non oil-bearing territory must be between these two structure contours. Hence, it is assumed that the limit of the oil-bearing territory is approximately midway between the 2,600 and 2,800 foot structure contours or on the 2,700-foot contour. Drilling may prove, however, that the productive area of the Torchlight dome is continuous with the productive area of the Lamb anticline in secs. 13 and 14, T. 51 N., R. 93 W. The presence of water in the Kimball sand in wells 7, 13, and 25 suggests strongly that water occurs in the Kimball sand around these folds at the altitude of this sand in these wells and probably is in part the cause of the segregation of the oil in the Kimball sand at the crest of the Torchlight dome. The fact that the Kimball sand does not contain oil in wells 7 and 13 is presumptive evidence that the area in which oil will be

found in this sand in commercial quantities is much smaller than the area in which traces of oil are found in the overlying Torchlight sand. The Greybull sand is believed to be barren of oil and gas in the Torchlight dome. W. L. Walker, consulting geologist for the Valentine interests in this field, makes the following statement regarding this sand in the Hiatus well (No. 10):

In the Hiatus well, which is located about 200 feet southeast of the southeast corner of sec. 24, T. 51 N., R. 93 W., the Greybull sand was found to contain water. The water is under a hydraulic head of several hundred feet and was present in such quantity that the hole could not be cleared by bailing. No trace of oil was noted. At this point in the Torchlight dome, but little more than a half mile from the summit of the fold, the Greybull sand is not oil bearing. I have had no personal connection with any operations which have tested this sand at any point nearer the center of the structure. While the Hiatus well does little more than indicate that the possible oil-bearing area of this sand is of less extent than the known productive area of the Kimball sand, certain other conditions in the district appear to give basis for doubting the productiveness of the Greybull sand generally in the Torchlight dome.

OIL IN THE LAMB ANTICLINE.

The Torchlight sand was penetrated in 10 wells in the Lamb anticline, and in all of these except No. 28, which yields water, the sand is dry. A stray sand between the Peay and Torchlight sands was encountered in seven wells. In five of these gas in varying amounts was struck in this sand; in one (No. 29), the partial log of which is given on page 160, a little oil and gas are present; and in one the sand is dry. Eleven wells cut the Peay sand. One of these (No. 20) yields oil; five gas; one (No. 28) a trace of oil and gas; and nine either fresh or salt water. The Kimball sand was encountered in eight wells. One of these yields oil and one water, and the others are dry. The Oeth Louie sand was cut by the drill in four wells and in each is dry. The Muddy sand is known to have been encountered in two wells. In one of these (No. 28) the sand is dry and in the other (No. 18) it carries fresh water. Only one well (No. 28) in the Lamb anticline penetrated the Greybull sand; it is reported to have found water only.

The productive area of the Lamb anticline is limited to a narrow belt one-fourth to one-half mile in width on the northeast side of the axis and another from one-fourth to 1 mile in width on the southwest side. At the southeast end it is limited by a line northwest of well 15, which reached the Oeth Louie sand. In secs. 2 and 11, T. 51 N., R. 93 W., the western limit of productive territory probably follows the 2,500-foot contour, except in the NE. $\frac{1}{4}$ sec. 2, where the line swings to the west around well 20, which produces oil. At the southwest side of the anticline the line is probably not more than one-third of a mile south of the south boundary of secs. 11 and 12, T. 51 N., R. 93 W. The position of the line separating the productive from the nonproductive territory in this

anticline is based on the position of the water table in the Peay sand, which is the principal oil-bearing sand in this anticline. It is significant that in well 21, which is the nearest well of economic importance to the Torchlight dome, the oil occurs in the Kimball sand, which is the most productive sand in the dome. This fact suggests that there is a connection between the two productive areas in the Kimball sand.

As indicated on the map of the Basin field (Pl. XVIII) there are two dry holes (Nos. 24 and 26) outside of the Torchlight dome and Lamb anticline. In each of these wells the Torchlight sand is dry, the Peay sand carries water, and the Kimball sand is dry. The Muddy sand yields a little gas in one well and in the other it carries water. In one well (No. 24) the Greybull sand is dry and in the other (No. 26) it contains water.

The oil and gas in this field occur on the highest parts of the upfolds, thus supporting the anticlinal theory. In different parts of both folds, as stated above, at distances varying from half a mile to $1\frac{3}{4}$ miles from the axes shown on the map, the wells do not encounter oil or gas.

The productive sands in the Basin field contain considerable water adjacent to the oil and gas bearing portions. Some wells show water in the same sand in which oil and gas occur, but in practically all the wells the water is not present at the same horizon as the gas and oil. This is true for the Peay sand in both the Lamb anticline and the Torchlight dome. In only one well (No. 5) in the Basin field does water occur with oil or gas in the Kimball sand. Water in the various oil and gas bearing sands doubtless has played an important part in causing the oil and gas to collect in the higher parts of the structure.

Gas in the Lamb anticline comes from the Peay sand only and at the present time is used by the towns of Basin and Greybull. These places have the distinction of being the only towns in Wyoming that use natural gas.

CHARACTER OF THE OIL.

The oil from the Torchlight dome is higher in grade and contains much more gasoline and kerosene than that from the Lamb anticline, as is indicated by the analyses given below. It has a dark-green color in reflected light and a deep wine color in transmitted light.

A sample of oil which is believed to be a fair representative of the oil of this dome was collected from Jackson No. 3 well (No. 27), in the NE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 24, T. 51 N., R. 93 W., from the Kimball sand. Some of the gasoline may have escaped before reaching the office, as the container came unsealed. The following analysis

made in the laboratory of the Bureau of Mines shows the character of this oil:

Analysis of crude petroleum from Jackson No. 3 well (No. 27), in the NE. $\frac{1}{4}$ SW. $\frac{1}{4}$, sec. 24, T. 51 N., R. 93 W.

Gasoline:		[Began to boil at 75° C.]	Per cent.
To 100° C.		10
100° to 125°		7
125° to 150°		9
			— 26
Kerosene:			
150° to 175°		7
175° to 200°		5½
200° to 225°		5
225° to 250°		7½
250° to 275°		4½
275° to 300°		5
			— 34½
Residuum		39½
			100

Specific gravities at 60° F.:

Crude oil	.....	0.8260 (39.5° Baumé).
Gasoline	.....	.7444 (58.0° Baumé).
Kerosene	.....	.8104 (42.7° Baumé).
Residuum	.....	.8935 (26.7° Baumé).

The oil from the Lamb anticline contains no gasoline and much less kerosene than the oil from the Torchlight dome. The residuum is excellently suited for lubricating oil. A sample of oil from this anticline was collected from Wilson No. 1 well (No. 20), in the NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 1, T. 51 N., R. 93 W., from the lower part of the Peay sand. The oil has a very dark green color in reflected light and does not transmit light. Thin films of the oil are yellowish brown in color. The oil from which the sample was taken came from the well in June, 1914, and was stored in an air-tight barrel until October of the same year, when it was sent to the laboratory for analysis. An analysis of this sample made in the laboratory of the Bureau of Mines is as follows:

Analysis of crude petroleum from Wilson No. 1 well (No. 20), in the NW. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 1, T. 51 N., R. 93 W.

Kerosene:		[Began to boil at 180° C.]	Per cent.
To 200° C.		½
200° to 225°		1½
225° to 250°		3
250° to 275°		8½
275° to 300°		9
			— 22½
Residuum		77½
			100

Specific gravities at 60° F.:

Crude oil	.....	0.8889 (27.5° Baumé).
Kerosene	.....	.8476 (35.2° Baumé).
Residuum	.....	.9038 (24.9° Baumé).

Another sample of oil for analysis was collected from Kimball No. 3 well (No. 9 on Pl. XVIII). This oil comes principally from the Kimball sand, near the top of the Mowry shale. The sample arrived at the laboratory in excellent condition, the bottle being well sealed, and hence at the time of analysis probably was little changed from its condition at the time it was collected. The analysis, which is given below, was made in the laboratory of the Bureau of Mines:

Analysis of crude petroleum from Kimball No. 3 well (No. 9 on Pl. XVIII), in lot 13, sec. 19, T. 51 N., R. 92 W.

Gasoline:	[Began to boil at 34° C.]	Per cent.
To 50° C.....		2½
50° to 75°.....		4½
75° to 100°.....		6
100° to 125°.....		10
125° to 150°.....		7½
		<hr/> 30½
Kerosene:		
150° to 175°.....		6
175° to 200°.....		5½
200° to 225°.....		5½
225° to 250°.....		6
250° to 275°.....		5½
275° to 300°.....		9½
		<hr/> 38
Residuum.....		31½
		<hr/> 100
Specific gravities at 60° F.:		
Crude oil.....	0.7955 (45.98° Baumé).	
Gasoline.....	.7216 (64.0° Baumé).	
Kerosene.....	.8102 (42.8° Baumé).	
Residuum.....	.8425 (36.2° Baumé).	

Oil from the Greybull field (Peay Hill anticline) is reported to be reddish green in color and to have a gravity of about 47° Baumé. It "freezes" on cooling into a stiff yellowish mass, which is said to be almost pure gasoline with a low flash point.

The subjoined commercial analysis was furnished by Homer T. Lamb, manager of the Greybull Oil Co. and the Bighorn Oil & Gas Co., of Greybull, Wyo. This analysis shows the various commercial products that are obtained in refining oil from the Torchlight and Greybull domes:

Commercial analysis of oil from Torchlight and Greybull domes, Wyoming.

	Per cent.
Crude naphtha.....	18.2
Superfine white stock.....	21.2
Water-white stock distillate.....	21.9
300 stock.....	5.0
Wax stock.....	19.1
Cylinder stock.....	8.0
Loss.....	6.6
	<hr/> 100.0

The "crude naphtha" (18.2 per cent) corresponds to the gasoline in the analysis made by the Bureau of Mines. The amount of gasoline determined by the Bureau of Mines analysis, however, is about 8 per cent higher than that shown for "crude naphtha" in the analysis given above. The total amount of kerosene in the bureau analysis is about 8 per cent less than the kerosene percentage in Mr. Lamb's analysis. The total of kerosene and gasoline in each analysis, however, is approximately the same, the bureau analysis showing 60.5 per cent and Mr. Lamb's analysis 61.3. It is possible that the "superfine white stock" contains some of the gasoline separated by the Bureau of Mines and that the "crude naphtha" does not include all the gasoline content.

Oil from the Bonanza Spring, referred to in this report, was analyzed by E. E. Slosson, of the University of Wyoming, and the essential part of the distillation of the product is given below:

Distillation of Bonanza petroleum.^a

[Specific gravity of crude petroleum, 0.850 or 34.6° Baumé.]

Boiling point.	Gravity of distillate.	
	Specific.	Baumé.
		<i>Degrees.</i>
60° to 157° C.	0.762	53.5
157° to 200° C. ....	.792	46.5
200° to 237° C. ....	.822	40.3
237° to 273° C. ....	.843	36.1
273° to 297° C. ....	.853	34.1

^aFisher, C. A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, p. 59, 1906.

This table shows that the oil begins to boil at 60° C. The part distilling between 60° C. and 157° C. was practically all gasoline, which has a specific gravity slightly lower than the gasoline from Jackson No. 3 well, in the Torchlight dome. All material distilling between 157° C. and 297° C. is kerosene, the specific gravity of which varies from 0.792 to 0.853, or from 46.5° to 34.1° Baumé. The specific gravity of the kerosene from Jackson No. 3 well is 0.8104 (42.7° Baumé). These comparisons show that the oil from the Bonanza Spring is probably similar to that from the Torchlight dome.

CHARACTER OF THE GAS.

All wells that yield oil in the Torchlight dome produce also a little gas. In fact some of the wells furnish enough gas to cause the oil to flow. The principal gas wells in the area shown on Plate XVIII are located on or near the axis of the Lamb anticline, in the E. $\frac{1}{2}$ sec. 12, T. 51 N., R. 93 W., and the extreme western part of sec. 7, T. 51 N., R. 92 W. Gas from these wells is from the Peay

sand and is without color but has a strong odor. Lane No. 1 well, the original large gas well (No. 23), produces more gas than any of the other wells drilled in the Torchlight dome and Lamb anticline. A sample of gas from this well was collected for analysis by displacement of air. The results of this analysis are given below:

Analysis of natural gas from Lane No. 1 well (No. 23), in the SE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 12, T. 51 N., R. 93 W.¹

[Laboratory No. 5722; G. A. Burrell, analyst.]

Specific gravity (air free), 0.59.	
Carbon dioxide (CO ₂).....	0.4
Oxygen (O ₂).....	.0
Methane (CH ₄).....	93.5
Ethane (C ₂ H ₆).....	3.5
Nitrogen (N ₂).....	2.6
	100.0

The heating value of this gas at 0° C. and 760 millimeters pressure (calculated) is 1,061 British thermal units.

Two samples of gas from the Greybull field were collected by W. R. Calvert² in 1912. Their analyses are given below, together with Calvert's comments.

Analysis of natural gas from Greybull, Wyo.

[G. A. Burrell, analyst.]

	3224	3222
Density (air=1).....	0.64	0.77
Carbon dioxide (CO ₂).....	0.20	0.00
Oxygen (O ₂).....	.00	.00
Methane (CH ₄).....	81.70	51.55
Ethane (C ₂ H ₆).....	17.35	47.20
Nitrogen (N ₂).....	.75	1.25
Claroline absorption..... per cent..	100.00	100.00
Gross heating value, at 0° C. and 760 millimeters pressure..... British thermal units..	.26 1,192	22.60 1,427

Sample No. 3224 is from the Island No. 1 well, one of the eight wells that produce gas commercially. The initial production of this well was 750,000 cubic feet at a rock pressure of 120 pounds. The volume was not ascertained at the date of the writer's visit, but the pressure has decreased to 30 pounds.

Sample No. 3222 is of casing-head gas from a nonproducing well in which some oil was found, the object being to ascertain the difference, if any, between this "wet" gas and that from the "dry" gas wells. As shown by the analyses the gases have a different composition. The composition of the gas represented by sample No. 3224 is practically identical with that of the natural gas supplied to Pittsburgh, Pa., according to analyses made by Burrell.

¹ This analysis is slightly in error because possibly a small amount of whisky may have been taken up by it from the cork of the bottle in which the gas was contained.

² Calvert, W. R., A preliminary report on the utilization of petroleum and natural gas in Wyoming U. S. Bureau of Mines Tech. Paper 57, p. 13, 1913.

As the gas from Lane No. 1 well (laboratory No. 5722) is from a sand that yields an oil much lower in gasoline than the sand from which samples Nos. 3224 and 3222 were taken, it is reasonable to expect that the last two samples should be higher in ethane, a prominent constituent of gasoline, than the first.

PRODUCTION.

It is estimated that the total production of oil from the Torchlight dome is probably about 800 barrels daily, or nearly 300,000 barrels a year, on a basis of twenty-seven producing wells. Shooting the wells and additional drilling will probably increase this amount considerably.

The wells drilled in the Lamb anticline at the time the field was examined (October, 1914) were not producing, as pipe-line connections had not been made. Although the oil is of a lower grade than that from the Torchlight dome, there is no reason to believe that the yield per well will not be approximately as great.

Only three wells (Nos. 18, 22, and 23) in the Lamb anticline are producing gas in commercial quantities. These wells are reported to yield sufficient gas to supply the towns of Basin and Greybull. It is estimated that these three wells when first drilled each yielded approximately 5,000,000 cubic feet of gas daily, or 1,825,000,000 cubic feet a year. Each well had a rock pressure of 147 pounds to the square inch. The gas is furnished to customers in Basin and Greybull at 40 cents a thousand cubic feet for eight months of the year and 35 cents a thousand for the remaining four months.

WELLS DRILLED.

The greatest number of wells drilled in the Torchlight dome and Lamb anticline were begun and completed in 1913, 1914, and 1915. Information regarding the wells is given in the following table:

Wells drilled in the Basin oil field, Wyoming.

NOTE.—Between November, 1914, and October 10, 1915, 22 wells were drilled in the Torchlight dome. Their location is not shown on Plate XVIII, but some notes on them, with logs of two of the wells, are given in the text below.

No. on Pl. XVIII.	Name.	Company.	Results.	Depth in feet.
1.....	Original gas well.....	Torchlight Drilling & Mining Association.	A little gas.....	106
2.....	No. 2.....	do.....	Gas and a little oil.....	222
3.....	Torchlight No. 1.....	Valentine interests.....	Oil.....	(a)
4.....	Torchlight No. 2.....	do.....	do.....	(a)
5.....	Jackson No. 2.....	Greybull Oil Co.....	do.....	(b)
6.....	Jackson No. 1.....	do.....	do.....	(b)
7.....	Champion No. 1.....	Champion Oil Co.....	Show of oil and gas.....	? 816
8.....	Kimball No. 1.....	Greybull Oil Co.....	Oil.....	(b)
9.....	Kimball No. 3.....	do.....	do.....	(b)
10.....	Hiatus No. 1.....	Valentine interests.....	Oil and gas.....	(a)
11.....	Kimball No. 2.....	Greybull Oil Co.....	Oil.....	(b)
12.....	Cleveland-Wyoming No. 1.....	Cleveland-Wyoming Oil Co.....	do.....	(?)
13.....	Schaeffer.....	Greybull Oil Co.....	Water.....	1,090
14.....	Champion No. 2.....	Champion Oil Co.....	Oil reported.....	210
15.....	Durham No. 1.....	Greybull Oil Co.....	Water.....	1,088
16.....	Cushing No. 1.....	do.....	Gas.....	(c)
17.....	Harvey No. 1.....	do.....	Dry.....	(?)
18.....	Columbia No. 1.....	do.....	Gas and fresh water.....	(c)
19.....	Griggs No. 1.....	do.....	Dry.....	(c)
20.....	Wilson No. 1.....	do.....	Oil and gas.....	(c)
21.....	Lane No. 2.....	do.....	Oil.....	(c)
22.....	Jennings No. 1.....	do.....	Gas.....	(c)
23.....	Lane No. 1.....	do.....	do.....	(c)
24.....	Ruth.....	do.....	Water and a little gas.....	2,100
25.....	Armstrong No. 1.....	do.....	Fresh water.....	965
26.....	do.....	do.....	Water.....	1,800±
27.....	Jackson No. 3.....	do.....	Oil, gas, and fresh water.....	(b)
28.....	Padmore.....	Valentine interests.....	A little water.....	(a)
29.....	Union Gas & Oil Co.'s well.....	Union Gas & Oil Co.....	Trace of oil and gas.....	1,100±
30.....	Cleveland-Wyoming well No. 2.....	Cleveland-Wyoming Oil Co.....	Oil and gas.....	400+

a The exact depths of producing wells are confidential and are withheld at the request of the different oil companies.

b Most of these wells vary in depth from 450 to 700 feet, according to their position on the dome.

c Most of these wells vary in depth from 450 to 900 feet.

Complete information regarding all the wells listed above was not obtained. If "oil" or "gas" is not shown in the "Results" column, the well is considered a dry hole.

Development has been very active on the Torchlight dome since the field was examined in October, 1914. During the following 12 months 22 additional wells have been drilled, mainly in the interior of the dome. Twenty of these wells are on the Kimball and Jackson claims of the Greybull Oil Co. One well was drilled by the Valentine interests on the Philip Minor claims, in the NE. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 24, T. 51 N., R. 93 W., about 300 feet west of Kimball well No. 3 (No. 9 on Pl. XVIII), and one by the Cleveland-Wyoming Oil Co. on the Tillard claim, in the NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 22, about 1½ miles west of any other wells on this dome.

All these wells except the Cleveland-Wyoming well have encountered oil in commercial quantities in the Kimball and Oeth Louie sands of the Mowry shale, at depths ranging from 400 to 600 feet. The Cleveland-Wyoming well was not drilled deep enough to penetrate

the Mowry shale. A trace of oil is said to have been encountered in this well.

Ten of the wells drilled by the Greybull Oil Co. are on the Jackson claim, which includes the E. $\frac{1}{2}$ W. $\frac{1}{2}$ sec. 24, and are known as Jackson wells Nos. 4 to 13, inclusive. Jackson No. 4 is 350 feet north of Jackson No. 1 (No. 6 on Pl. XVIII); Jackson No. 5 is 350 feet south of Jackson No. 3 (No. 27, Pl. XVIII); Jackson No. 6 is 350 feet south of Jackson No. 5; Jackson No. 7 is 350 feet north of Jackson No. 4; Jackson No. 8 (No. 33, Pl. XVIII) is 350 feet north of Jackson No. 7; Jackson No. 9 is 350 feet north of Jackson No. 8. The log of well No. 8 follows:

Partial log of Jackson well No. 8, in the SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 24, T. 51 N., R. 93 W.

	Depth (feet).
Top of Peay sand (yields sulphur water).....	265
Top of Kimball sand (yields oil).....	475
Top of Oeth Louie sand (yields oil).....	548
Bottom of hole.....	606

Well No. 8 was begun June 26 and completed July 6, 1915. A Star rig was used in drilling this well, as in all wells drilled by the Greybull Oil Co. in this field. The altitude of the mouth of the well is approximately 4,170 feet above sea level. Homer T. Lamb, manager of this company, states that the strata between the top of the Kimball sand and the base of the Oeth Louie sand, or practically all of the Mowry shale, carry some oil.

Jackson well No. 10 is 350 feet south of Jackson No. 6; Jackson No. 11 is 350 feet south of Jackson No. 10; Jackson No. 12 is in the SE. $\frac{1}{4}$ NW. $\frac{1}{4}$ sec. 24, about 150 feet from the west line and 500 feet from the south line; Jackson No. 13 is 350 feet north of Jackson No. 12.

Ten wells have been drilled by the Greybull Oil Co. on the Kimball claim, which includes the west range of forties in sec. 19, T. 51 N., R. 92 W., and are known as Kimball wells Nos. 4 to 13, inclusive. These wells reach the oil-bearing rocks at depths similar to those on the Jackson claim, as is shown by the log of Kimball well No. 7 (No. 49, Pl. XVIII) given below:

Log of Kimball well No. 7, in lot 14, sec. 19, T. 51 N., R. 92 W.

	Depth (feet).
Top of Peay sand (yields sulphur water).....	287
Top of Kimball sand (yields oil).....	500
Top of Oeth Louie sand (yields oil).....	585
Bottom of hole.....	631

This well was commenced February 4 and completed February 15, 1915. The altitude of its mouth is about 4,148 feet.

The new wells on the Kimball claim are situated as follows: Kimball Nos. 4, 5, 6, and 7 are at 350-foot intervals in order south from



Kimball well No. 3 (No. 9, Pl. XVIII); Kimball Nos. 8, 9, 10, 11, and 12 are at 350-foot intervals in order north from Kimball No. 1 (No. 8, Pl. XVIII); Kimball No. 13 is 350 feet east of Kimball No. 7.

The Cleveland-Wyoming Oil Co.'s well in the NW. $\frac{1}{4}$ NE. $\frac{1}{4}$ sec. 22, T. 51 N., R. 93 W., was commenced March 15 and finished April 10, 1915. It is about 900 feet deep and at the bottom encountered a sand that carried a little water. This sand is probably a thin bed in the lower part of the Cody shale, about 100 feet above the top of the Torchlight sand. About six weeks after the drilling operations were completed the well had filled with water. A scum of oil was on the water and about the casing where the water had overflowed. Whether the oil came up with the water or was put there by someone interested in creating an oil excitement is an unsettled question.

Information collected in the summer of 1915, too late to be incorporated in Plate XVIII, indicates that the small dome at the end of the Lamb anticline is not so well defined nor so sharply separated from the main fold as is shown on the map. The 2,400-foot contour, instead of closing in secs. 35 and 36, T. 52 N., R. 93 W., swings to the north and east through sec. 36 of the same township and secs. 31 and 30, T. 52 N., R. 92 W., keeping about half a mile to the east and north of the Ruth well (No. 24). From this point it swings to the west and southwest, joining the 2,400-foot contour, as represented in Plate XVIII on the west side of the main anticline, near the southwest corner of sec. 2, T. 51 N., R. 93 W. The depression between the Lamb anticline and the next dome to the north is so slight that the 2,300 and 2,200 foot contours do not connect around the north end of the anticline, as is suggested by that part shown in Plate XVIII.

The Griggs well No. 1 (No. 19, Pl. XVIII), in the S. $\frac{1}{2}$ sec. 1, T. 51 N., R. 93 W., is shown on the map as an "oil and gas well." The yield of oil and gas in this well is so slight, according to Homer T. Lamb, that it should be considered a dry hole.

CONCLUSIONS.

As the Torchlight dome and Lamb anticline are comparatively small structural features, the amount of oil and gas that they can produce is necessarily limited. It is believed that the outlines of producing territory in these folds can not be determined by the wells now drilled, but will be pushed outward in both areas by further drilling, that the initial yield will be much enhanced by careful shooting of the wells, and that the life of the field will be prolonged by preventing the escape of gas. The production will be greatly increased by more thorough drilling inside of the limits of the productive area already approximately determined. As the areas in which gas has been found in commercial quantities are rather small, and the areas in which oil has been found are considerably larger, it

seems safe to predict that further drilling within limited areas will yield more oil than gas and that the field will be preeminently an oil field.

The lowest sand containing oil or gas in commercial quantities in these structures is the Kimball, or top sandstone of the Mowry shale. Deeper drilling in the Lamb anticline may possibly prove that the Greybull sand of the Cloverly formation contains oil or gas, but this is doubtful. It is also possible, but hardly probable, that the more prominent sandstone beds in the Morrison formation, which underlies the Cloverly, may prove to be of importance as producers of oil and gas in both the Torchlight dome and the Lamb anticline, as the oil known to be present in places in the late Carboniferous limestone may have ascended to and saturated these porous beds.

The operation of a refinery in this general region near the railroad undoubtedly would be of economic importance to the companies producing oil in this part of the Bighorn Basin. Such a plant is now being constructed at Greybull, about 5 miles northwest of the Lamb anticline, and probably will be in operation before this report is published.



