DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

Bulletin 656

ANTICLINES IN THE SOUTHERN PART OF THE BIG HORN BASIN, WYOMING

A PRELIMINARY REPORT ON THE OCCURRENCE OF OIL

BY

D. F. HEWETT AND C. T. LUPTON

WASHINGTON
GOVERNMENT PRINTING OFFICE
1917

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INTRODUCTION.

By DAVID WHITE.

The information regarding 50 domes and anticlines in the south half of the Big Horn Basin, Wyo., given in this report, was gathered during geologic examinations made for the purpose of classifying the lands in that region according to their content of oil or other minerals. The report presents briefly the economic results that pertain to oil and gas or to anticlines that may be favorable to their accumulation.

The work of the Geological Survey in formally classifying as mineral or nonmineral the public lands withdrawn from entry because they were supposed to contain coal, oil, or phosphate was begun in 1906 and has been prosecuted energetically since that time. A full account of the withdrawals and restorations of oil lands has been published by the Survey as Bulletin 623. Of 1,321,316 acres in the State of Wyoming that were withdrawn for classification, 339,158 acres have been restored to entry as nonmineral land; and about 668,000 acres, including parts of the area here described, have been classified as oil land and now await congressional action that will provide some method of developing the oil and gas.

The work of organizing and supervising the field investigations and the mapping necessary for classifying lands supposed to contain coal or oil was placed in the hands of M. R. Campbell, who had already established the high standards of structural and economic mapping that are now followed for the eastern coal and oil fields and that have been adopted by the foremost oil and gas geologists in the world, including those engaged in both public and private work. At first, in order to get immediate results, large areas were covered by reconnaissance surveys and were mapped by determining direction by hand compass and distance by pacing. Very soon, however, this crude and hasty method was replaced by triangulation and by plane-table mapping on a large scale with telescopic alidade, the work comprising stadia traverse and the determination of elevations by vertical angles. For a considerable part of the area examined the geologists have been obliged to prepare their own base maps. Mr. Campbell, with meager allotments of funds and a small geologic staff, laid out the regions in projects and so organized and employed

the annual field parties as not only to classify the lands effectively and economically but also to work out systematically the general stratigraphy, structure, and geologic history of the broad regions embracing the coal and oil bearing formations of the West. As Mr. Campbell has now been largely relieved of the supervision of the Survey's investigations of oil and gas in the West in order to lessen his administrative duties and to afford him more time for special geologic researches, it is appropriate to note the great advance in the knowledge of the upper Mesozoic and older Tertiary formations of the fuel-bearing lands in the Western States that has resulted directly from the work done under his guidance.

During a large part of the period, approximately 10 years, since the Survey began its classifications for the use of the Secretary of the Interior and the General Land Office, the pressure for field examinations and for the preparation of data for classification has been so great as to leave the geologists little opportunity to prepare for publication either economic or scientific reports on the areas thus classified. Yet for Wyoming alone a considerable number of detailed descriptions or preliminary economic reports on areas that might contain oil and gas have been issued, as is shown by the subjoined list, in which the reports are arranged in the order of publication.

Mineral resources of the Bighorn Mountain region [Wyo.], by N. H. Darton: Bull. 285, pp. 303–310, 1906.

Mineral resources of the Bighorn Basin [Wyo.], by C. A. Fisher: Bull. 285, pp. 311–315, 1906.

Coal and oil in southern Uinta County, Wyo., by A. C. Veatch: Bull. 285, pp. 331–353, pls. 10–12, 1906.

Geology and water resources of the Bighorn Basin, Wyo., by C. A. Fisher: Prof. Paper 53, 72 pp., 16 pls., 1906.

Geography and geology of a portion of southwestern Wyoming, with special reference to coal and oil, by A. C. Veatch: Prof. Paper 56, 178 pp., 26 pls., 1907.

Gas fields of the Bighorn Basin, Wyo., by C. W. Washburne: Bull. 340, pp. 348–363, pl. 3, 1908.

The Labarge oil field, central Uinta County, Wyo., by A. R. Schultz: Bull. 340, pp. 364–373, pl. 4, 1908.

The Lander and Salt Creek oil fields, Wyo.: The Lander oil field, Fremont County, by E. G. Woodruff; The Salt Creek oil field, Natrona County, by C. H. Wegemann: Bull. 452, 87 pp., 12 pls., 1911.

The Powder River oil field, Wyo., by C. H. Wegemann: Bull. 471, pp. 56–75, pl. 7, 1912.

The Douglas oil and gas field, Converse County, Wyo., by V. H. Barnett: Bull. 541, pp. 49–88, pl. 4, 1912.

The Shoshone River section, Wyo., by D. F. Hewett: Bull. 541, pp. 89–113, pl. 5, 1912.

Geology and geography of a portion of Lincoln County, Wyo., by A. R. Schultz: Bull. 543, 141 pp., 11 pls., 1914.

The Moorcroft oil field, Crook County, Wyo., by V. H. Barnett: Bull. 581, pp. 83–104, pl. 3, 1915.

Possibilities of oil in the Big Muddy dome, Converse and Natrona counties, Wyo., by V. H. Barnett: Bull. 581, pp. 105–117, pl. 4, 1915.

Oil and gas near Basin, Big Horn County, Wyo., by C. T. Lupton: Bull. 621, pp. 157–190, pls. 17–18, 1915.

Anticlines in central Wyoming, by C. J. Hares: Bull. 641, pp. 233–279, 1917.

The present report by Messrs. Lupton and Hewett gives the results of several seasons of field work done by them and by others and is, in effect, an installment of the economic and scientific results accumulated in the course of the classification of the lands. Others now nearly completed include a detailed report on the Grass Creek field, by D. F. Hewett, and a report on the Salt Creek field, by C. H. Wegemann. Field examinations in the north half of the Big Horn Basin are still in progress.

The area described in the following report embraces some productive oil territory in Wyoming that is undeveloped but very promising. Besides the Greybull, Torchlight, and Grass Creek anticlines, which are already sufficiently developed to contribute largely to the production of oil in Wyoming, there are seven or more domes and anticlines in which oil or gas has been struck, but which are not yet sufficiently drilled to indicate their value as oil reservoirs. Thus 11 of the anticlines here described have already proved to be productive. About as many more anticlines have been tested by one, two, three, or four holes, though some of the holes have not been theoretically well located. Most of these anticlines on which the first tests have been unfavorable are probably barren of oil, though other test wells drilled more nearly on their crests may find oil. It must be borne in mind that oil development in Wyoming is still in a very early stage and that drilling has not yet covered enough ground to indicate the probable productivity of all the anticlines.

The probability that the remaining anticlines and domes described in this report may contain oil or gas has been carefully considered by the authors, who have noted their form and prominence, their mutual relations, their positions in the basin, the formations exposed on their axes, and their similarity to like domes and anticlines that carry or do not carry oil or gas. So far as can now be determined from the surface indications, about half of these are considered promising, but the drill, which is the final test, may show that some of them are barren and that others which are now regarded as less promising may be productive. It is highly probable that half or more of the anticlines and domes here described constitute a large part of the most promising undeveloped oil territory in Wyoming. The Big Horn Basin seems to be destined to furnish a large contribution to the Nation's supply of high-grade oil.

ANTICLINES IN THE SOUTHERN PART OF THE BIG HORN BASIN, WYOMING: A PRELIMINARY REPORT ON THE OCCURRENCE OF OIL.

By D. F. HEWETT and C. T. LUPTON.

SCOPE OF REPORT.

This report has been prepared to meet demands by oil and gas operators and others for information regarding possible oil and gas fields in the Big Horn Basin, Wyo. (See fig. 1.) Some of the anti-

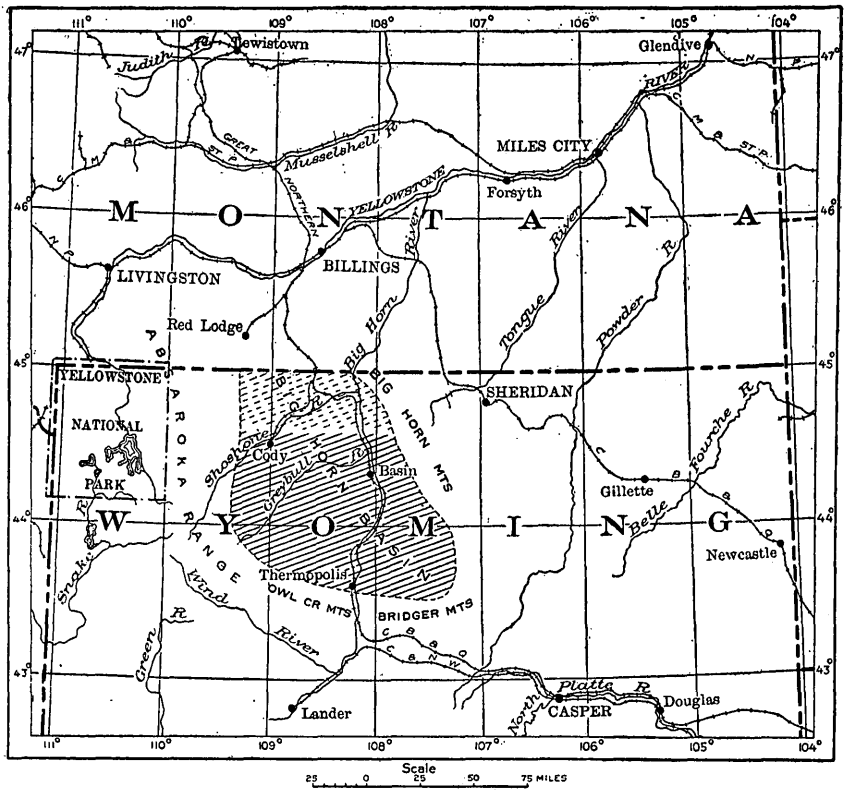


FIGURE 1.—Index map showing location of area examined.

clines considered now yield oil and gas in commercial quantities; others are believed to be fairly good reservoirs; and still others obviously do not contain oil or gas in commercial quantities. The

field work done in most of the area has been complete enough to warrant the publication of more detailed descriptions of the geologic features than those here given, and reports containing such descriptions are in preparation. Only reconnaissance work was done in some parts of the area, however, but all the information obtained by such work is given here.

The purpose of the authors has been to set forth briefly and clearly, by means of maps, cross sections, and descriptions, the essential information collected and the conclusions that may be drawn from them, so that not only engineers but persons who have had little or no technical training may learn the possibility of obtaining oil and gas in any part of the area considered.

With the exception of small upfolds in the Wasatch formation, all the known anticlines that are of possible economic value as oil or gas reservoirs in the Big Horn Basin south of a line drawn through Greybull and Cody are considered in this report. These anticlines are not only described separately but are shown by cross sections and are represented on the maps by structure contours.

The oil discovered in the Big Horn Basin, except that struck in two wells in the Lamb anticline, is of the "light" variety—that is, it contains large percentages of gasoline and kerosene. In general, its specific gravity ranges from 0.8485 to 0.7865, or from 35° to 48° Baumé. Most of the gas is "wet"—that is, it contains some gasoline—and ranges in content of methane from 39 to 94 per cent. Its content of nitrogen ranges from 0.75 to 15.5 per cent. The oil is piped to the railroad at Chatham and Greybull, where it is refined or shipped to refineries in other parts of the country. Some of the gas is used locally to generate power for drilling, but all that is produced in the Lamb and Greybull fields is appropriated for domestic use at the towns of Basin and Greybull, which have the distinction of being the only towns in Wyoming that use gas as a source of heat and light.

ACKNOWLEDGMENTS.

The authors desire to acknowledge the generous cooperation of the officials of the principal oil companies operating in the Big Horn Basin. They have furnished logs of wells and other valuable information. Special thanks are due to John McFayden and M. D. Woolery, of the Ohio Oil Co., Homer T. Lamb, of the Bighorn Oil & Gas Co. and the Greybull Oil Co., W. L. Walker, of the Valentine interests, T. L. Harrison and C. M. Edgett, of the Enalpac Oil & Gas Co., and J. C. Tanberg, of the Tanberg Oil Co. Valuable information was furnished by Good & Drayton, Nathan and Kendrick Levi, Martin McGrath, F. X. Whiting, R. H. George, J. A. Grant, of Thermopolis; Henry M. Sherard, Otto Ahrens, and L. E. Cherry, of Greybull; Sam Scoville and

W. E. Taylor, of Bonanza; and C. A. Fisher, consulting geologist, of Denver, Colo. The writers desire especially to express their warm appreciation for all favors granted by residents of the Big Horn Basin.

The field and office work was done under the supervision of M. R. Campbell, whose helpful counsel and advice is hereby acknowledged. J. D. Northrop, W. P. Woodring, M. W. Ball, R. H. Wood, E. M. Parks, W. B. Emery, and C. J. Hares, of the United States Geological Survey, assisted in geologic work in the field. To Millard Massey, H. C. Evans, and A. C. Sutherland much credit is due for the efficient manner in which they performed camp and other duties.

The report, except those parts whose authorship is specifically indicated under the individual headings, was prepared by the two authors jointly.

FIELD WORK.

The field work was of three classes—detailed work with topographic map, detailed work without topographic map, and reconnaissance examination. Practically all field work of Mr. Hewett was of the first class, and all done by and under the supervision of the junior author was of the second and third classes. Mr. Hewett devoted the field seasons of 1911, 1912, and 1913 to geologic work in the Oregon Basin, Meeteetse, and Grass Creek basin quadrangles. In this work geologic features were located by plane-table and by compass readings on numerous prominent objects, the positions of which were determined in making the topographic maps. Mr. Lupton continued the work during the field seasons of 1914 and 1915, though without topographic base maps, around the south and east sides of the basin as far north as Greybull. In this work the anticlines were mapped by plane-table methods. The first step in the process was the measurement of a base line a mile or more in length, from which a system of triangulation was developed. From these triangulation stations detailed mapping was done, and by means of vertical angles the elevations of a sufficient number of adjacent points were determined to enable the geologist to draw structure contours on a chosen bed. In addition the formations were measured and studied in detail to determine which of them might serve as reservoirs for oil and gas. In producing oil fields, samples were collected for analysis so that the oil and gas of these fields might be compared with one another and with those of other producing areas.

A reconnaissance examination of part of the west side of the basin was made in July, 1915, by Mr. Lupton, in company with M. W. Ball and Millard Massey. At this time the wells drilled and drilling in the Grass Creek and Little Buffalo Basin fields were located instrumentally and many of the records were obtained. In October, 1916, Mr.

Hewett visited all the fields west of Big Horn River and obtained information concerning the results of the drilling that had been done for a year.

GEOGRAPHY.

LOCATION.

The Big Horn Basin lies in northwestern Wyoming. (See fig. 1, p. 11.) It is bounded on the east and northeast by the Big Horn Mountains, on the south by the Bridger and Owl Creek mountains, and on the west by the Shoshone Mountains and other ranges that lie east of Yellowstone National Park. On the north the basin is open toward the plains of southern Montana.

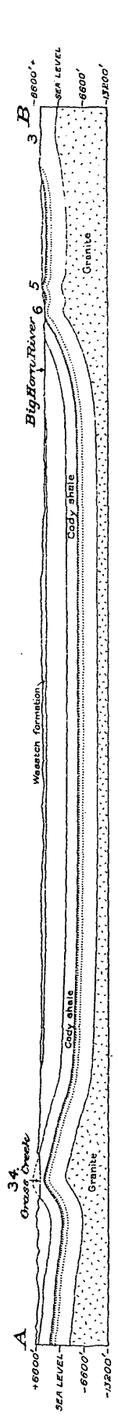
TOPOGRAPHY.

The Big Horn Basin, as the name suggests, is a depression nearly surrounded by mountains. It is drained by the tributaries of Big Horn River, which enters it through the Wind River canyon on the south and flows northward to the junction with Yellowstone River in Montana. The most important tributaries of Big Horn River rise in the Owl Creek, Shoshone, and Absaroka mountains on the west, and among them may be mentioned Owl Creek, Cottonwood Creek, Greybull River, and Shoshone River. A few important streams, such as No Wood and Shell creeks, rise in the Big Horn Mountains on the east. The surface of the basin is trenched by the numerous tributaries of Big Horn River and is rolling or hilly except in places where extensive terraces border the stream courses.

The anticlines and domes form a belt 15 to 25 miles wide around the border of Big Horn Basin. (See Pl. I.) On the east and south sides of the basin they lie mainly between the outcrop of Wasatch and later formations and the mountains that limit the basin. On the west side observations are limited by outcrops of Wasatch and younger formations, including volcanic tuffs, but there is reason for believing that the folds persist much farther westward under these rocks.

ACCESSIBILITY.

The Big Horn Basin is accessible from both the north and the south by the Denver-Casper-Billings branch of the Chicago, Burlington & Quincy Railroad, completed in 1914, which follows closely the course of Big Horn River. By this railroad the anticlines and domes in the southern and eastern parts of the basin may be reached with comparative ease, although some of them are 50 miles from the road. Many of the anticlines along the west side of the basin may be reached most easily from Cody, which is about 65 miles distant from the most remote anticline (Fourbear, No. 41, Pl. I).



T. 53 N.

Shoshone Cody
Shoshone Reservoir
Shoshone River
Sage Cr
Burlington
Otto
Greybull River
Greybull
Greybull oil and gas field
Shell
Shell Cr
Trapper Cr
Basin
Basin oil and gas field
Manderson
Rairden
Bonanza
Hyattville
Paintrock Creek
Nowood
PARK CO
BIG HORN CO
BIG HORN CO
WASHAKIE CO
Meeteetse
Meeteetse Cr
Rawhide Cr
Pitchfork
R. 102 W.
Sunshine
Sunshine River
Wood R
Dickie
Grass Creek
Grass Creek oil field
Grass Cr
Cottonwood Creek
Collins
Meeteetse Cr
Gooseberry Creek
PARK CO
HOT SPRINGS CO
BIG HORN RIVER
Worland
Colter
Neiber
Winchester
PO
Chatham Sta
WASHAKIE CO
HOT SPRINGS CO
Kirby
Kirby Cr
Gebo
Lucerne
Thermopolis
CHICAGO BURLINGTON & QUINCY RAILROAD
Tensleep
Tensleep Cr
Big Trails
No Water Cr
No Wood
R. 88 W.
T. 42 N.

EXPLANATION

Wasatch and younger formations including volcanic tuffs

Crest of anticline Arrow indicates broad limb

Axis of syncline

Scale 1/500,000

5 0 5 10 15 20 MILES

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

GENERAL MAP OF THE SOUTHERN PART OF BIGHORN BASIN

By D. F. Hewett and Charles T. Lupton

CLIMATE AND VEGETATION.

The climate of the Big Horn Basin is semiarid. Records of temperature and precipitation kept at a number of places in the basin for periods of several years show that in general the annual rainfall on the border of the basin is 11 to 12 inches and that in the interior of the basin is about 6 inches, and that the interior is colder in winter and warmer in summer than the border. The greatest variation in temperature between 1898 and 1903 was recorded at Basin, where the thermometer has registered a minimum of 51° below zero in February and a maximum of 114° above zero in July.

The low winter temperature, as well as the meager rainfall, tend to increase the cost of development in an oil or gas region. In Oklahoma, for example, work can be carried on throughout the year, but in the Big Horn Basin exceedingly cold weather hinders development work for two or three months during the winter, usually in January and February and possibly in parts of December and March.

The Big Horn Basin is mainly a grazing region but contains strips of irrigable and irrigated lands along the perennial streams. Vegetation is comparatively scanty. Cottonwood trees, which have little value except for fuel, border the streams that flow throughout the year. Scrub cedar and a sparse growth of small pines occur here and there in the more hilly sections, but timber valuable for lumber is scarce. Cactus, sagebrush, and greasewood are common in the dry parts of the basin.

WATER.

Water is all important to those who are exploring or planning to explore for oil or gas. Hence, in this report, especially in the detailed descriptions of the anticlines, particular attention is called to the water supply.

The surface-water supply of the Big Horn Basin includes Big Horn River, its tributaries, and springs, which occur throughout the basin but are most abundant in the border zone adjacent to the mountains. Big Horn River and its principal tributaries, Greybull and Shoshone rivers, and Owl, No Wood, and Shell creeks, afford an abundant supply of good water throughout the year. Many of the other tributaries, though perennial in their upper courses for most of the year, carry no surface water along their lower courses except in periods of flood. The springs that yield good water are most numerous along the edges of the basin; those of the interior yield small flows of alkaline water that can be used by stock but that is not good for domestic use.

In the absence of a surface supply, water in sufficient quantity for use in camp may be obtained by drilling to depths ranging from 100

to 300 feet in the sandstones of the formations that overlie the Cody shale, preferably the Mesaverde, the Meeteetse, and the Lance.

Both the surface and underground water supplies are described in the detailed descriptions of the anticlines and domes.

FUEL.

Fuel is essential to the development of an oil and gas field, and its accessibility materially affects the cost of each well and therefore the development of the field. Thus, in the Grass Creek field, Wyo., coal is plentiful and sells for about $4 a ton, whereas in Green River Desert, Utah, coal must be hauled 60 to 80 miles and has sold for as much as $20 a ton. This difference in the price of fuel naturally affects the number of wells drilled.

In the Big Horn Basin the principal oil fields are not far from the outcrops of coal beds, from which fuel can be obtained easily and cheaply. The coal beds that have been most extensively developed lie in the southern part of the basin in the vicinity of Gebo and Crosby. A few local mines have been opened at places around the edge of the basin, but some of these have not been operated recently. The extent and the characteristics of the coal have been described by Washburne [1] and Woodruff.[2]

Gas has been discovered in commercial quantities in the Greybull, Lamb, Grass Creek, Little Buffalo Basin, Oregon Basin, and Byron fields, and is being used for fuel and light in camps and towns and for drilling purposes. Crude oil is also used as a fuel in drilling in the Grass Creek and other fields. Cottonwood, scrub cedar, pine, and other trees constitute an additional fuel supply.

GEOLOGY.

STRATIGRAPHY.

SEQUENCE AND CORRELATION OF THE FORMATIONS.

The formations outcropping in the Big Horn Basin have been examined in part and at different times by several geologists. The following table shows the equivalence of the formations noted by the authors named and describes them briefly. Fisher,[3] as the table indicates, is the only author who has made a general examination of all of the formations.

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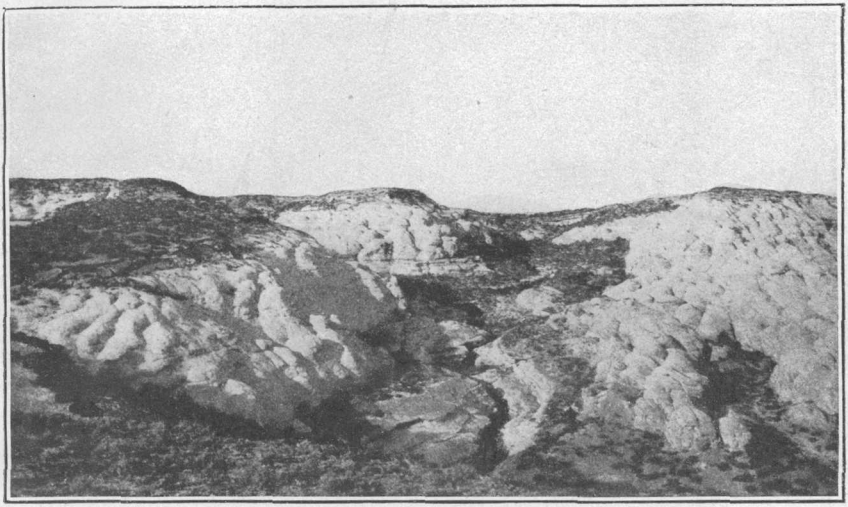
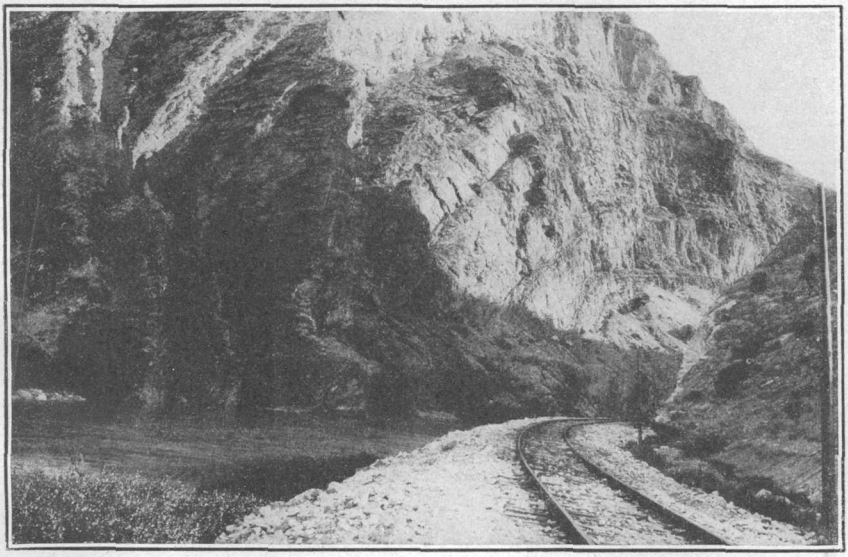
[1] Washburne, C. W., Coal fields of the northeast side of the Bighorn Basin, Wyo., and of Bridger, Mont.: U. S. Geol. Survey Bull. 341, pp. 165–199, 1909.

[2] Woodruff, E. G., Coal fields of the southwest side of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 341, pp. 200–219, 1909; The coal field in the southeastern part of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 381, pp. 170–185, 1910.

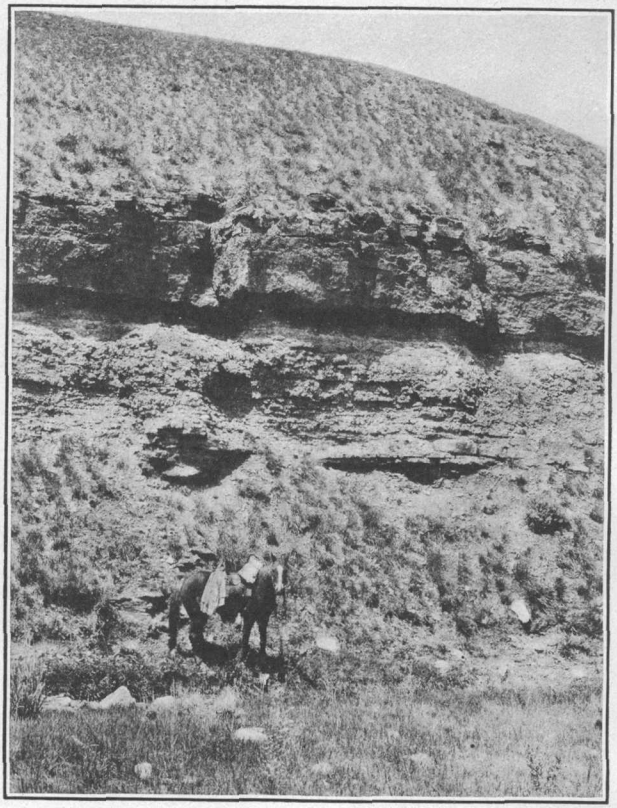
[3] Fisher, C. A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, 1906.



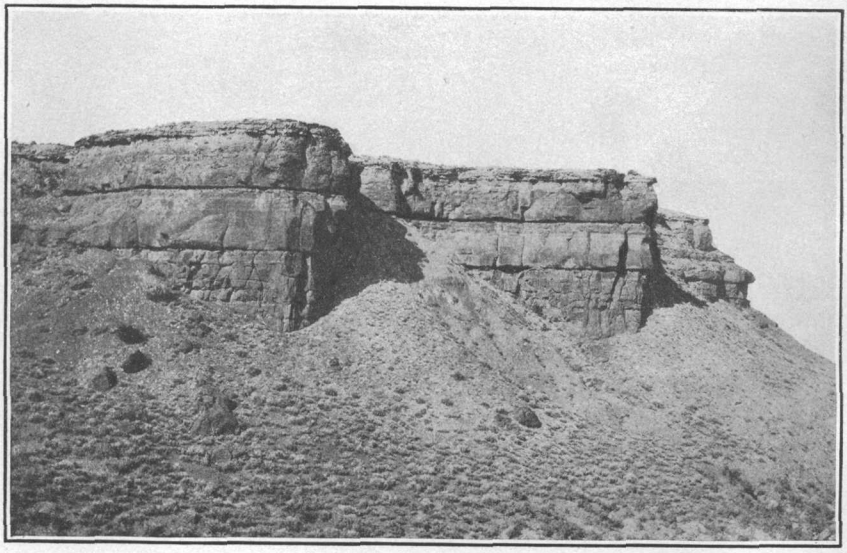
A. TENSLEEP SANDSTONE ON WEST SIDE OF BROKENBACK ANTICLINE.



B. MADISON LIMESTONE IN ANTICLINE IN SHEEP MOUNTAIN CANYON.



A. LIMESTONE PART OF THE EMBAR FORMATION NEAR HEAD OF NO WOOD CREEK.



B. RED SANDSTONE IN MIDDLE PART OF THE CHUGWATER FORMATION ON NO WOOD CREEK NEAR TENSLEEP.

Correlation of formations of the Big Horn Basin described in recent reports.

System.	Fisher, 1906: U. S. Geol. Survey Prof. Paper 53. Entire Big Horn Basin.	Washburne, 1909: U. S. Geol. Survey Bull. 341, p. 167. East side of basin.	Woodruff, 1909: U. S. Geol. Survey Bull. 341, p. 202. West side of basin.	Hewett, 1914: U. S. Geol. Survey Bull. 541, p. 91. Shoshone River.	Hintze, 1915: Wyoming Geol. Survey Bulls. 10 and 11. West side of basin.	Lupton, 1916: U. S. Geol. Survey Bull. 621. East side of basin.	Hewett and Lupton, 1917: present report. East and west sides of basin.		
							Formation.	Thickness in feet.	Character of rocks.
Quaternary.	Alluvium. Hot-spring deposits. Later terrace gravels. Early terrace gravels.					Alluvium. Terrace gravels.	Alluvium..... Hot-spring deposits... Terrace gravels	0–50 0–30	Valley and flood-plain deposits along streams. Local deposits of calcareous tufa. Gravels and boulders washed from adjacent mountains.
							Volcanic rock.	(?)	Andesitic tuffs and flows on west side of basin.
Tertiary.	Wasatch.	Wasatch. Unconformity	Wasatch. Unconformity	Wasatch. Unconformity	Fort Union.	Undifferentiated Fort Union and Lance.	Wasatch. Unconformity	1,300+	Red and drab clay; buff and white sandstone with gravel lenses. Many areas of badlands around border of basin.
	Laramie and associated formations.	Fort Union. Unconformity(?) Laramie(?).	Fort Union. Unconformity(?) Laramie(?).	Fort Union. Unconformity(?) Ilo.	Ilo.		Fort Union. Unconformity	2,000–5,600	Buff and white gritty sandstone, with drab, red, and green clay; lenses of gravel and lenticular beds of coal.
Tertiary?							Lance.	840–1,800	Buff and drab sandstone with drab and green shale. No red shale or coal beds.
		Montana group. Bearpaw. Judith River. Claggett. Eagle.	Montana group. Undifferentiated Montana. Eagle.	Meeteetse.	Montana. Meeteetse.	Montana. Mesaverde.	Montana. Meeteetse.	250–1,400	Soft gray and brown shale; gray and buff sandstone and lenticular beds of coal.
				Gebo.	Eagle.	—(a)—	Mesaverde.	1,120–1,410	Buff and white sandstone, gray and brown shale and lenticular beds of coal near base.
	Pierre.			Colorado. Upper member.	Pierre.	Cody.	Cody.	1,900–3,400	Gray, green, and black shale, with calcareous concretions near base, merging with buff sandstone at top. No persistent sharply marked beds.
Cretaceous.	Colorado.	Colorado.	Colorado shale.	Colorado. Middle member.	Basin. (Niobrara) Colorado.	Colorado. Frontier.	Colorado. Frontier.	494–648	West side: Seven or more beds of gray and buff sandstone with gray and brown shale and bentonite. East side: Two to six or more beds of sandstone.
				Colorado. Lower member.	Benton.	Mowry.	Mowry.	160–375	Hard gray shale containing fish scales with lenses of gravel-bearing sandstone.
		Unconformity				Thermopolis.	Thermopolis.	400–800	Gray to black shale with one persistent sandstone, the Muddy sand of the drillers.
	Cloverly.	Cloverly.	Cloverly.	"Cloverly."	Cloverly.	Cloverly.	Cloverly.	110–300	Two beds of massive buff sandstone separated by gray or variegated shale. Upper sand is the Greybull.
Cretaceous?	Morrison.			Morrison.			Morrison.	150–580	Purplish and pale greenish-gray shales with sandstones interbedded.
Jurassic.	Sundance.			Sundance.			Sundance.	250–530	Greenish-gray sandstones and shales with a little limestone interbedded.
Triassic.	Chugwater.			Chugwater.			Chugwater.	700–1,100	"Red Beds": Red sandstones and shales with a thick bed of gypsum near top.
	Embar.						Embar.	250–480	Gray limestone, with gray and red sandy shale and gypsum interbedded. Limestone very thin on east side of basin.
	Tensleep.						Tensleep.	30–230	Massive gray sandstone, containing thin layers of limestone.
Carboniferous.	Amsden.						Amsden.	150–200	Red sandy shales and sandstones, with layers of limestone and chert.
	Madison.						Madison.	600–1,000	Gray massive limestones.
Ordovician.	Bighorn.						Bighorn.	150–300	Siliceous gray limestone, very hard and massive.
Cambrian.	Deadwood.						Deadwood.	700–900	Sandstone, shale, conglomerate, and limestone.

a In U. S. Geol. Survey Bull. 621, through a typographic error, the Montana-Colorado boundary was erroneously drawn at this position.

CARBONIFEROUS SYSTEM.

MADISON LIMESTONE.

The massive gray Madison limestone ranges in thickness from 600 to 1,000 feet. Its upper part is more nearly pure than its lower, which is sandy. It contains a Mississippian (lower Carboniferous) fauna. In the area shown on Plate I this formation is exposed only in Sheep Mountain Canyon, on Big Horn River about 8 miles north of Greybull. Its character is shown on Plate II, *B*, where only the upper 800 feet of the limestone crops out in the walls of the canyon.

AMSDEN FORMATION.

The Amsden formation overlies the Madison and comprises 150 to 200 feet of limestone, shale, and chert. Its lower 60 to 80 feet is bright-red shale and contains layers of limestone and considerable chert. A few fossils collected from it indicate that it is of Pennsylvanian (upper Carboniferous) age.

TENSLEEP SANDSTONE.

The Tensleep sandstone, which conformably overlies the Amsden formation, is one of the most prominent formations on the east side of the basin. It consists of 30 to 230 feet of yellowish-gray to white massive cross-bedded sandstone alternating with beds of limestone. (See Pl. II, *A*.) The sandstone usually contains water and is believed to yield the lowest and strongest flow of water in Catherine No. 2 well (No. 11, Pl. XI, p. 98) near Bonanza.

EMBAR FORMATION.

The term Embar, as used by Darton [1] and Fisher,[2] includes a group of marine deposits consisting of gray to greenish limestone and chert beds lying between the top of the Tensleep sandstone and the base of the nonmarine red Chugwater formation ("Red Beds"). It ranges in thickness from about 250 feet near Embar post office to 480 feet at Sheep Mountain Canyon.

Recent investigations in the Wind River Mountains by Blackwelder led him to divide the Embar into two formations, the Dinwoody above and the Park City below. These units were recognized near Thermopolis and near Sheep Mountain (Black) Canyon, at the southern and eastern sides of the Big Horn Basin but were not separable over a large part of the area considered in this report. The limestone portion of the Embar is abundantly fossil bearing and is gray in color; it bears oil in the Lander field.

[1] Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, pp. 35 and 36, 1906.

[2] Fisher, C. A., Geology and water resources of the Bighorn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, pp. 17 and 18, 1906.

In the southern part of the basin the Embar is principally limestone, but farther east and north it grades laterally into the nonmarine red sandstone, shale, chert, and gypsum with minor limestone that constitute the lower part of the "Red Beds" or Chugwater formation. (See Pl. III, *A*.) This change in character naturally makes it difficult to determine the exact limits of the formation.

TRIASSIC SYSTEM.

CHUGWATER FORMATION.

The Chugwater formation consists of the rocks commonly designated "Red Beds." It is predominantly sandy but includes beds of sandstone, shale, gypsum, with a little limestone at the top. (See Pl. III, *B*.) It ranges in thickness from 700 to about 1,100 feet. Its lower part is apparently less resistant than its upper part and consequently forms valleys. The Chugwater is not known to contain any beds of sandstone which would serve as reservoirs for oil and gas nor, as the formation is generally sandy, to contain any beds of shale that would serve as impervious caps for the sandstones. At one place on Red Spring anticline, however, an oil seep was found in this formation. In places the sandstone beds carry water, as in the well (Catherine No. 2, Pl. XI, p. 98) drilled on Paintrock anticline near Bonanza. This well encountered water at not less than five horizons, some of which are in this formation.

JURASSIC SYSTEM.

SUNDANCE FORMATION.

The Sundance is a marine formation of Upper Jurassic age, 250 to 530 feet in thickness, that consists principally of greenish sandstone, shale, and limestone. The thin limestone beds are fossiliferous throughout the formation. In this region the Sundance is predominantly sandy, and some of the sandstones might serve as reservoirs for oil or gas. The formation has, however, been tested nowhere in the Big Horn Basin except in the vicinity of Bonanza, where the sandstones yield no trace of oil or gas but are believed to have yielded some of the water in Catherine No. 2 well.

CRETACEOUS (?) SYSTEM.

MORRISON FORMATION.

The Morrison formation has been recognized throughout the Big Horn Basin. It consists principally of variegated sandstone and shale, the latter predominating. It rests with apparent conformity on the underlying Sundance formation, and in places its lower part is so nearly like the upper part of the Sundance that it is difficult to separate the two. The Morrison is characterized by gastroliths or

"stomach stones" (very hard, highly polished pebbles of chert, quartz, and quartzite, 2 to 4 inches in diameter), which are most abundant near the top of the formation. They occur embedded in both shale and sandstone, in many places associated with the bones of dinosaurs, and serve to identify the formation. The Morrison ranges in thickness from about 150 to 580 feet.

Plants collected from the top of the Morrison near Tensleep indicate, according to F. H. Knowlton,[1] that it is of Cretaceous age. The fossils were obtained from the same general locality as the leaves mentioned by Fisher [2] in his paper on the Kootenai formation.

CRETACEOUS SYSTEM.

CLOVERLY FORMATION.

The Cloverly formation in places unconformably overlies the Morrison formation. It has an average thickness in the Big Horn Basin of about 125 feet. In most places its lower part is a fine white conglomerate or conglomeratic sandstone 15 to 25 feet thick, the pebbles of which are well rounded and are mainly chert. Its middle part is reddish sandy shale and thin-bedded sandstone about 75 feet thick. This in turn is overlain by 10 to 20 feet of yellowish gray sandstone, locally termed the Greybull sand, and here designated the Greybull sandstone member of the Cloverly formation,[3] from the town of Greybull, near which it is typically exposed. It is this sand that produces practically all the oil and gas in the Greybull field. Its relation to the underlying Morrison formation is shown in Plate IV, *A*.

Darton [4] believes that this formation corresponds to the Dakota, Fuson, and Lakota formations in the Black Hills region. Fisher [5] collected leaves of Kootenai age from these beds.

THERMOPOLIS SHALE.

The Thermopolis shale conformably overlies the Cloverly formation. It consists mainly of a dark shale 400 to 800 feet thick, sandy near its top and base and containing a persistent bed of sandstone near its middle. The sandy beds, 100 or more feet thick, near the base have been termed "rusty beds" by Washburne,[6] and the persistent bed of sandstone near the middle is termed by the drillers the "Muddy sand." It is unusually persistent, and being overlain by

[1] Knowlton, F. H., Note on a recent discovery of fossil plants in the Morrison formation: Washington Acad. Sci. Jour., vol. 6, No. 7, pp. 180, 181, 1916.

[2] Fisher, C. A., Southern extension of the Kootenai and Montana coal-bearing formations in northern Montana: Econ. Geology, vol. 3, pp. 84, 85, 1908.

[3] This should not be confused with the "Gray Bull beds," proposed by Granger (Am. Mus. Nat. Hist., vol. 33, p. 203, 1914) as the name of a faunal zone in the Eocene of this region.

[4] Darton, N. H., Geology of the Bighorn Mountains: U. S. Geol. Survey Prof. Paper 51, p. 53, 1906.

[5] Fisher, C. A., op. cit., p. 85.

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

shale constitutes a good reservoir for oil and gas. On the east side of the basin it contains only a trace of oil and a showing of gas, but on the west side it is believed to furnish the strong flow of gas in the Oregon Basin field. Near Cody a little oil is yielded by a sand lying at approximately the horizon of the Muddy sand. In Plate IV, *B*, the Thermopolis shale is represented by the floor of the valley on which the drilling rig stands.

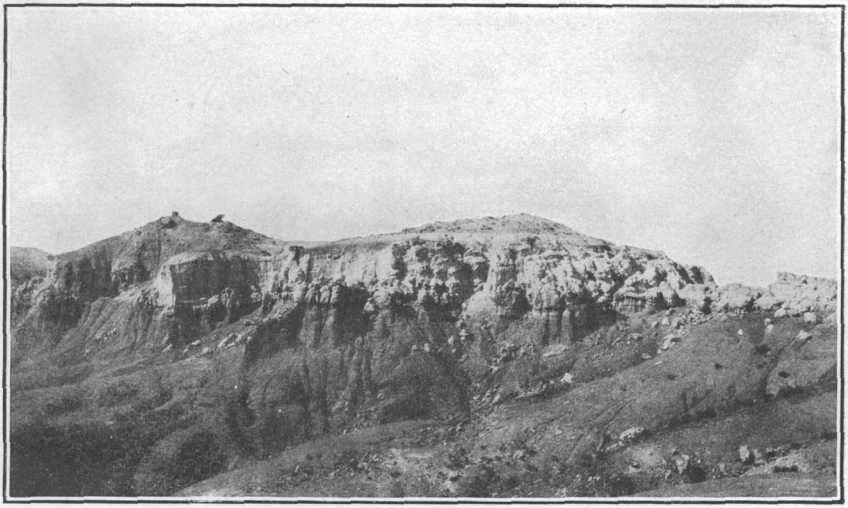
MOWRY SHALE.

The Mowry shale (Pl. IV, *B*), named from Mowry Creek, on the east side of the Big Horn Mountains, is a hard, platy bluish-gray shale which conformably overlies the Thermopolis shale. It weathers light gray to white and is characterized by large numbers of fish scales. Its thickness ranges from about 160 feet near Greybull to about 375 feet near Thermopolis. In places it contains thin beds of bentonite and also beds of sandstone which have been named by drillers the Kimball and Octh Louie sands, and which yield most of the oil produced in the Torchlight dome near Basin. The presence of the fish scales suggests that at least part of the oil contained in the formation originated there.

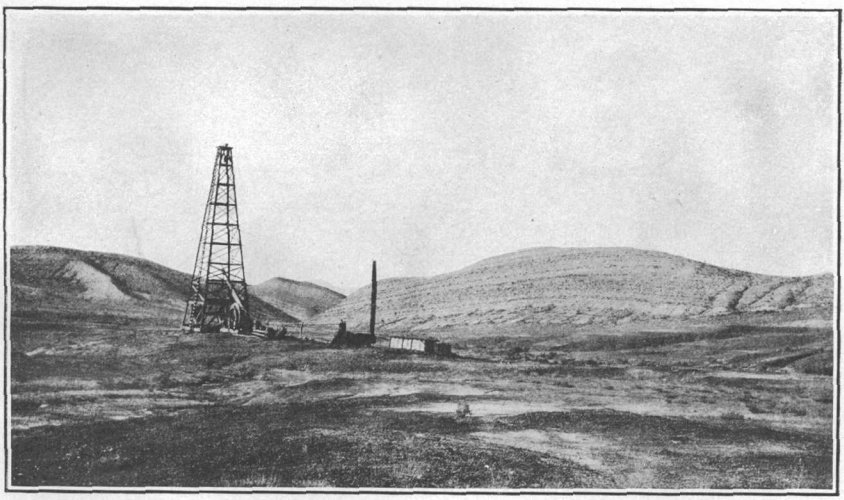
FRONTIER FORMATION.

The Frontier formation (Pl. V, *B*) conformably overlies the Mowry shale, and includes from about 500 to about 650 feet of sandstones and interbedded shale. Near Greybull only two beds of sandstone are present, but in the southern and western parts of the basin there are five or six beds. In the vicinity of the town of Basin the two principal sandstones have been named the Torchlight and Peay sandstone members. On the west and south sides of the basin the top sandstone of the Frontier is here called Torchlight (?) sandstone member, as it is believed to be the equivalent of the Torchlight on the east side of the basin. The outcrop of Peay sandstone near Greybull is shown in Plate V, *A*. The sands of the Frontier formation contain one or more thin beds of fine conglomerate, the most persistent being at the top of the Torchlight sand or base of the Cody shale. In places this conglomerate is unconsolidated and is 1 or 2 inches thick, but elsewhere it is consolidated and attains a maximum thickness of 7 feet. The lower of the two sands, the Peay, yields all the gas produced in the Lamb anticline. The sandstones of the formation also yield oil and gas in the Grass Creek and Little Buffalo fields.

The sandstone beds of the Frontier formation, so far as development work has progressed, appear to be the most important reservoirs of oil and gas in the Big Horn Basin, and it is believed that future development will confirm this conclusion.

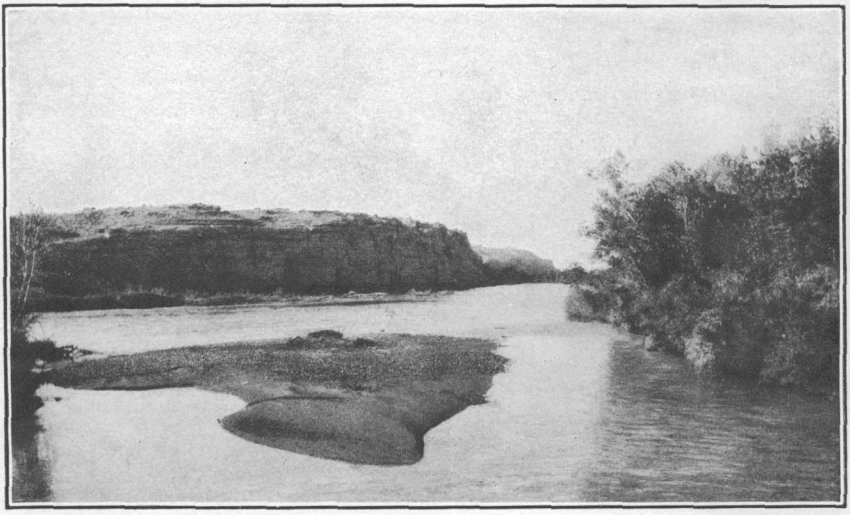


A. UNCONFORMABLE CONTACT BETWEEN WHITE SANDSTONE OF THE CLOVERLY FORMATION AND VARIEGATED SHALE OF THE MORRISON FORMATION NEAR TENSLEEP.

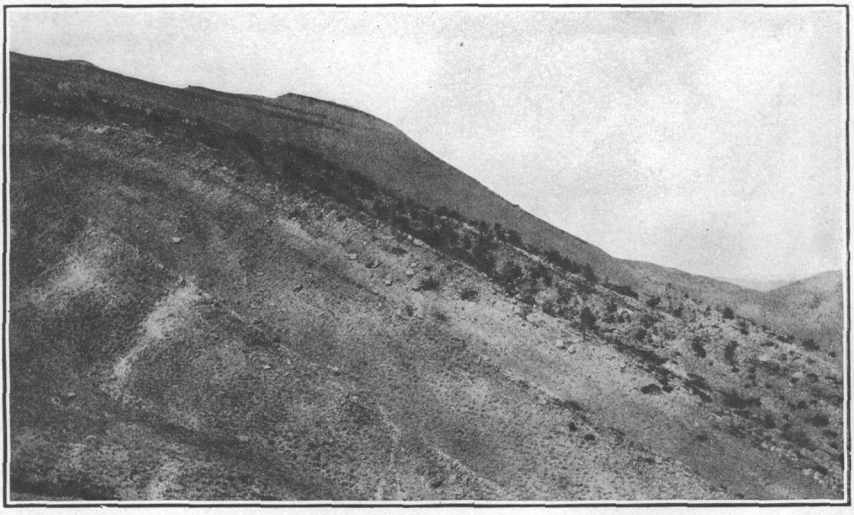


B. THERMOPOLIS AND MOWRY SHALES NEAR BONANZA.

Standard drilling rig in foreground.



A. PEAY SANDSTONE MEMBER OF THE FRONTIER FORMATION ON EAST SIDE OF BIG HORN RIVER NEAR GREYBULL.



B. FRONTIER FORMATION IN LYSITE MOUNTAIN ANTICLINE.

The name Frontier in its type locality in southwestern Wyoming[1] is applied to a group of sandstone, shale, and coal beds 2,200 to 2,600 feet thick. In Carbon County, Wyo., about 200 miles farther east, the formation ranges from 400 to 800 feet thick and has no coal beds. In the Big Horn Basin beds of sandstone and shale occur at the same stratigraphic position and hence have been given the same name.

As this formation probably contains most of the oil and gas in the Big Horn Basin, a number of detailed sections are given in order to show the changes its character undergoes from place to place.

Section of Frontier formation on west side of Sheep Mountain, in T. 53 N., R. 94 W., near Greybull, Wyo.

	Feet.
Sandstone (Torchlight), gray, soft, cross-bedded, conglomeratic at top; pebbles mainly chert	20+
Shales, gray, drab, and yellowish, contains a few thin sandstone beds	250
Sandstone (Peay):	
Sandstone, yellowish, soft at base; dark gray, weathering very rusty brown, harder, and more concretionary in middle; and white to gray, massive, cross-bedded in upper part	50
Shale, very sandy, with some beds of sandstone	40
Sandstone, gray, weathering brown, soft, shaly	10
Shale, gray, drab, and yellowish, sandy	25
Sandstone, yellowish, soft, shaly	6
	401+

Section of Frontier formation in southeastern part of T. 49 N., R. 91 W., near Bonanza, Wyo.

	Feet.
Sandstone (Torchlight), yellowish gray, soft, slightly conglomeratic at top	33
Sandstone, gray to white, contains yellowish-brown, concretionary, slightly conglomeratic lenses	10
Sandstone, dark gray and brown, carbonaceous, soft, grades into clay	20
Clay, sandy, gray	85
Shale, gray and drab, sandy	100
Sandstone and shale, most of sandstone in upper half; gray, weathers brown; contains a thin bed of shale intermixed with small chert pebbles; shale weathers to light clay	45
Sandstone (Peay):	
Sandstone, yellowish gray, slightly conglomeratic at top, medium bedded, contains a few thin beds of gray shale	50
Sandstone and sandy shale alternating	17
Sandstone, gray, weathers brown, medium bedded	100
Shale, contains thin beds of bentonite	30
Bentonite	4
Shale, grayish brown, soft	55
	549

[1] 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. 65–69, 1907.

Section of Frontier formation in northeastern part of T. 44 N., R. 88 W., near Bigtrails, Wyo.

	Ft.	in.
Sandstone (Torchlight?), brown, massive at top, thin bedded at bottom	15	0
Shale, dark, sandy, contains a few thin beds of sandstone	150	0
Sandstone	2	0
Shale	85	0
Sandstone, buff, fine grained, massive	22	0
Shale, upper half gray and buff; lower half dark, contains ferruginous masses	110	0
Sandstone, buff and brown, thin bedded at base, massive at top; upper 2 feet contains many black, red, and white chert pebbles ranging in size from sand grains to an inch in diameter	80	0
Shale, dark, sandy, contains a few lenses of sandstone	19	0
Sandstone, pepper and salt appearance, coarse		6
Shale, dark, sandy, contains ferruginous masses that weather blackish red	20	0
Shale, black, fissile	5	0
Sandstone, gray, upper part stained greenish yellow, thin bedded, huge ripple marks at top	13	6
Shale, dark, sandy	30	0
Shale, light gray to blue, resistant	13	0
Shale, dark, fissile, contains fish remains	23	0
Sandstone	1	6
Shale, dark, fissile	30	0
Bentonite		6
	620	0

Section of Frontier formation along Big Horn River, in T. 43 N., R. 94 W., near Thermopolis, Wyo.

	Feet.
Sandstone (Torchlight?), brown and gray, soft, shaly, some pebbles at top	48
Shale, light, bentonitic	64
Sandstone, gray	16
Shale	50
Sandstone	30
Sandstone, gray	20
Shale, concealed	75
Sandstone, gray	10
Concealed, probably shale	55
Sandstone, gray massive, resistant; forms ridge	15
Shale, partly concealed	25
Sandstone, brown, massive	10
Shale, brownish	5
Sandstone, brown, thin bedded and shaly	15
Shale, gray, contains thin beds of sandstone near top	110
Sandstone, gray, massive	20
Sandstone, dark, thin bedded	10
Shale, bluish, sandy	25
Bentonite	5
Shale, dark	40
	648

Section of Frontier formation on Shoshone River in T. 53 N., R. 101 W., near Cody, Wyo.

	Feet.
Sandstone (Torchlight?), buff, separated into three benches by thin brown shale bands; upper and lower benches contain chert pebbles, the largest half an inch in diameter	24
Sandstone, buff to gray, shaly	60
Shale, brown	1
Bentonite	8
Shale, brown	5
Sandstone, buff	6
Bentonite	6
Shale, brown, with 4 inches of coal	3
Sand, brown, shaly	8
Shale, brown, with two thin coal beds	2
Shale, dark	13
Sandstone, buff	3
Shale, sandy	30
Sandstone, buff	6
Shale, sandy	55
Sandstone, drab, separable into four massive benches by thin shale layers; second bench from the top contains black chert pebbles three-fourths of an inch in diameter	40
Shale, sandy	32
Sandstone, buff, thin bedded	18
Shale, sandy	22
Sandstone, buff, thin bedded	12
Shale	16
Sandstone, buff	8
Shale	16
Sandstone, buff	40
Shale	24
Sandstone, buff, thin bedded, containing nonpersistent zones of chert pebbles as much as 3 inches thick near the top and a highly persistent zone 6 inches thick near the middle; the pebbles measure from three-fourths of an inch to 2 inches; fragments of bone and bivalve shells are common	36
	494

Section of Frontier formation on the east side of Wood River in sec. 15, T. 47 N., R. 101 W., near Sunshine, Wyo.

	Feet.
Sandstone (Torchlight?), buff, with two thin persistent zones of chert pebbles	67
Shale, black and brown	7
Sandstone, buff, thin bedded	13
Shale, with some sandy zones	151
Shale, black	2
Sandstone, buff	24
Shale	36
Sandstone, buff	14
Shale	12
Sandstone, buff	48
Shale	106
Sandstone, buff	23
	503

Section of Frontier formation on the north limb of the Cottonwood anticline south of Cottonwood Creek in sec. 11, T. 44 N., R. 98 W.

	Feet.
Sandstone (Torchlight?), buff to white, persistent	45
Shale, sandy, with several nonpersistent thin beds of sandstone	40
Sandstone, buff	18
Shale, sandy, gray and black	40
Sandstone, thin bedded	10
Sandstone, shaly, buff to white	30
Sandstone, thin bedded	1
Bentonite	1
Sandstone, white	1
Bentonite	3
Shale, sandy	10
Sandstone, buff to gray, persistent; forms ridge	18
Shale, sandy	20
Sandstone, local lens	2
Shale, sandy, gray	18
Sandstone, local lens	2
Shale, sandy	6
Sandstone, buff, persistent	3
Shale, gray; weathers light	18
Sandstone, shaly	10
Shale, gray; weathers white; resembles Mowry shale	25
Shale, dark gray, easily disintegrated	10
Sandstone, gray to white, persistent; forms ridge	42
	373

CODY SHALE.

The name Cody shale was recently applied by Lupton [1] to the group of shale and shaly sandstone beds that overlie the Frontier formation near Basin, Wyo. The unit occupies the same position in the section as that mapped by Fisher [2] as the Pierre shale, as that described by Hewett [3] as the upper shale member of the Colorado formation on Shoshone River, and as the Basin and Pierre formations as described by Hintze.[4] In contrast with the underlying Frontier formation and the overlying Mesaverde formation the Cody shale weathers readily and therefore underlies broad rolling plains or valleys limited by escarpments of the higher formation. For this reason, the knowledge of the shale is derived from exposures of parts of the unit in small badlands areas or stream valleys.

The thickness ranges from a minimum of 1,900 feet on the south side of the Cottonwood anticline to a maximum of 3,400 feet on the west side of the North Sunshine anticline. In general, the differences in the measured thickness appear to result from folding, as well as from conditions of deposition. Measurements of thickness

[1] Lupton, C. T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621, p. 171, 1916.
[2] Fisher, C. A., op. cit., p. 30.
[3] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 98, 1914.
[4] Hintze, F. F., jr., The Basin and Greybull oil and gas fields, Wyo.: Wyoming Geol. Survey Bull. 10, pp. 24, 27, 1915.

on the limbs of folds are commonly greater on the steep than on the flat limbs. The available data indicate that on the west side of the basin the thickness of the shale increases from 2,150 feet in the latitude of Cody to nearly 3,000 feet on the Enos Creek anticline, then decreases to about 2,000 feet on Cottonwood Creek. On the east side of the basin the thickness is 300 to 600 feet greater than on the west side. It apparently increases to about 3,000 feet on Big Horn River near Lucerne, at the south end of the basin, and remains constant along the south and east sides as far as Bonanza. Northwest from Bonanza it thickens to about 3,350 feet at the south side of the Torchlight dome, and then thins to about 2,600 feet on Greybull River, west of Greybull.

The character of the Cody shale and higher formations will not be presented in detail. The lower two-thirds of the formation is largely shale, predominantly dark gray but locally light gray, brown, and black. This part includes poorly defined interbedded lenses of fine-grained gray and brownish sandstone and in some sections considerable green glauconite.

Many marine fossils have been found in the shale 200 to 500 feet above the base, but a larger number are obtained from rounded calcareous concretions which occur sporadically in the shale. These fossils are reported by T. W. Stanton to be characteristic of the Colorado group. There is no sharp limit between the lower shaly part of the formation and the upper, which is largely thin-bedded buff sandstones. Lenses of resistant sandstone 20 to 45 feet thick, which occur from 100 to 400 feet below the top of the formation, are more conspicuous in basins south of the Oregon Basin. On the south and east sides of the Big Horn Basin the Cody shale consists almost entirely of shale with lenses of sandstone near the base and more persistent concretionary beds near the top.

Several collections of marine fossils from a zone about 1,000 feet thick at the top of the formation are reported by T. W. Stanton to belong to the Montana group.[1] Other collections from the upper sandy part include shark teeth but are not diagnostic.

At no place in the Big Horn Basin is the Cody shale known to contain oil or gas in commercial quantity. It is possible that these substances may be found in the sandstone where conditions are favorable.

MESAVERDE FORMATION.

The Mesaverde formation is a group of massive resistant sandstones with thin layers of interbedded coal and shale that overlies the Cody shale and forms prominent escarpments in many parts of the Big Horn Basin. The name was first applied to a group of coal-bearing

[1] Lupton, C. T., op. cit., p. 172.

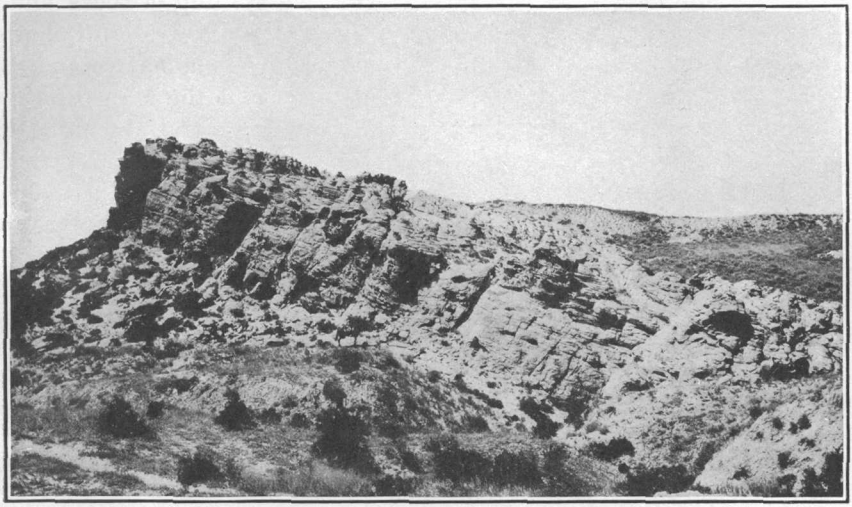
rocks about 1,000 feet thick that overlies the marine Mancos shale and is in turn overlain by the marine Lewis shale in southwestern Colorado.[1] Field work by members of the United States Geological Survey has shown that a similar coal-bearing group of rocks underlain and overlain by marine shale persists through western Colorado and southwestern and central Wyoming, and fossils have warranted the correlation of the successive formations with the Mancos, Mesaverde, and Lewis formations, except that in central Wyoming the lower marine shale is known as the Steele shale, as it there represents only the upper part of the Mancos, the rest of the Mancos being represented by several older formations. In describing the coal fields of the Wind River Basin in central Wyoming, Woodruff and Winchester[2] recognized a group of coal-bearing beds 1,000 to 3,000 feet thick, overlying a thick shale, the lower part of which contains marine fossils of Colorado age and the upper part marine fossils of Montana age. The shale was correlated with the Mancos shale and the coal-bearing beds with the Mesaverde formation, although the marine Lewis shale known to the east and south was not known to be present. The character of the Upper Cretaceous beds of the west side of the Big Horn Basin and the northwest corner of the Wind River Basin are strikingly similar, and, although the overlying marine Lewis shale is absent, the use of the term Mesaverde is warranted.

On the west side of the Big Horn Basin the lower part of the formation is characterized by two beds of massive buff sandstone 40 to 60 feet thick, between which there are one or more lenticular but locally important beds of coal. The lowermost of these two sandstones was first identified by Washburne[3] as the Eagle sandstone but has been shown by recent work to lie considerably higher in the section than the type Eagle of northern Montana. (See Pl. VI, *A*.) The coal beds of this part of the formation are not important east of Big Horn River; the higher beds are locally thick enough to warrant mining, but the separate beds are not persistent over large areas, and according to the evidence on the west side of the Big Horn Basin, the thickest beds become thinner and disappear toward the southwest and are succeeded by overlapping higher beds. The upper limit of the formation is the top of a group of gray to white beds of sandstone 200 to 400 feet thick. In contrast with the sandstone of the overlying Meeteetse and Lance formations, that of the Mesaverde is hard and resistant, so that the beds near the base form prominent escarpments over the softer Cody shale and the beds at

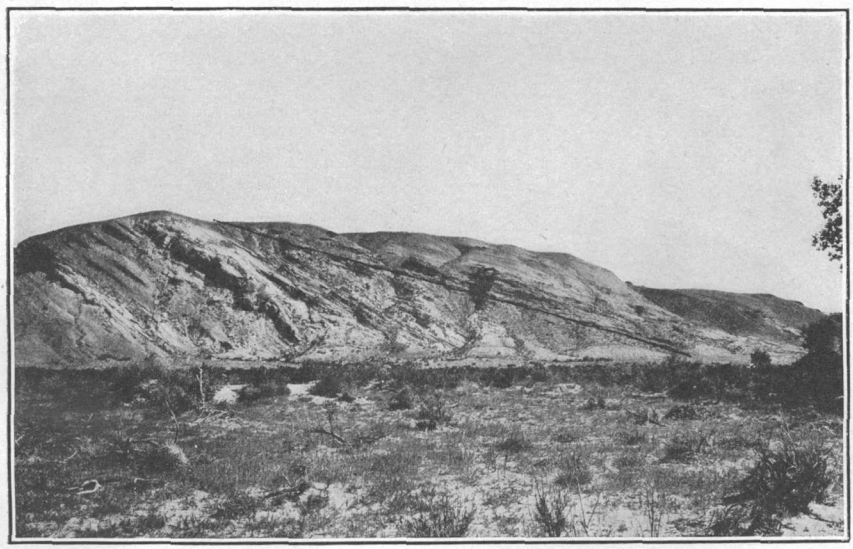
[1] Holmes, W. H., U. S. Geol. and Geog. Survey Terr. Ninth Ann. Rept., p. 244, 1875.

[2] Woodruff, E. G., and Winchester, D. E., Coal fields of the Wind River region: U. S. Geol. Survey Bull. 471, p. 522, 1912.

[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, pp. 167-168, 1909.



A. LOWER SANDSTONE (FORMERLY CALLED EAGLE) OF MESAVERDE FORMATION NEAR ZIMMERMAN BUTTE.



B. ANGULAR UNCONFORMITY (REPRESENTED BY HEAVY LINE) BETWEEN THE FORT UNION AND LANCE FORMATIONS ON DRY CREEK NEAR GREYBULL.

the top form persistent ridges that limit the valleys carved in the Meeteetse beds.

The thickness of the formation ranges from a maximum of 1,410 feet north of the Cottonwood anticline to 1,120 feet on Shoshone River, and the average thickness throughout the Big Horn Basin is about 1,200 feet. The age of the formation is fixed by the identification by F. H. Knowlton of fossil leaves from several horizons.

MEETEETSE FORMATION.

The Meeteetse formation includes the beds of soft gray shale, sandstone, and coal which overlie the Mesaverde formation. Where the beds dip more than 10° or 15° narrow valleys follow the outcrop of the formation, but where the dip is not so steep badlands are common. On the west side of the Big Horn Basin the thickness ranges from a maximum of 1,240 feet in T. 50 N., R. 101 W., to 750 feet in T. 46 N., R. 97 W., east of the Grass Creek basin and is separable into two nearly equal parts, a lower dominantly sandy part with shale but no coal and an upper part, which contains a number of beds of brown shale and of coal, some of which are locally mined. Throughout this part of the basin the upper limit of the formation is the base of the first massive sandstone that overlies the uppermost coal bed. Although the formation has yielded many leaves and plant remains which are regarded by F. H. Knowlton as Montana in age no vertebrate or invertebrate fossils have yet been found in it.

It is believed to include the equivalent of the Bearpaw shale although no marine fossils have been found in it in the area under consideration. Washburne [1] reports marine fossils from shale at the horizon of the Bearpaw formation near Elk Basin anticline, in the northwestern part of the Big Horn Basin.

TERTIARY (?) SYSTEM.

LANCE FORMATION.

The name Lance is applied to the beds included by Hewett in the "Ilo formation" along Shoshone River [2] and to a similar group of beds on the east side of the Big Horn Basin which have yielded enough vertebrate fossils to warrant correlation with the Lance formation of eastern Wyoming. The base is the first massive sandstone that overlies the coal-bearing part of the Meeteetse formation west of Big Horn River and the shale east of the river. The upper limit of the formation is the base of a conglomerate or gravel-bearing gritty sandstone of the Fort Union formation that has been traced

[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, p. 169, 1909.

[2] Hewett, D. F., op. cit., p. 103.

over a large part of the basin from two areas in which it is unconformable on the Lance beds. One of these areas lies in the eastern part of T. 50 N., R. 100 W., east of the Oregon Basin, and the other in the eastern part of Tps. 51 and 52 N., R. 94 W., near the mouth of Greybull River. This unconformity also is well exposed in Dry Creek. (See Pl. VI, *B*.)

The formation is largely soft drab and gray massive sandstone with shale. It contains no coal on the west side of the Big Horn Basin, but in the vicinity of Greybull and farther southeast it includes lenticular beds that are locally mined. Its correlation with the Lance formation is based on the identification of *Triceratops* bones by C. W. Gilmore. On the west side of the basin its thickness ranges from 1,790 feet on Shoshone River to 840 feet on Prospect Creek, 50 miles south, and on the east side of the basin it averages about 1,800 feet.

Although this formation is usually classed in the Tertiary(?) system the striking unconformity at its top in the Big Horn Basin inclines the writers to believe that it is more properly assignable to the Cretaceous.

TERTIARY SYSTEM.

FORT UNION FORMATION.

The recognition of the Fort Union formation is based on the identification by F. H. Knowlton of many species of fossil leaves. In comparison with most of the regions in which it is known the formation in the Big Horn Basin has yielded few invertebrate fossils. On the west side of the Big Horn Basin the lowest sandstone of the Fort Union may be traced from sec. 29, T. 50 N., R. 100 W., where it rests on the Lance formation 1,360 feet thick, to sec. 2, T. 50 N., R. 100 W., where it rests on the lower part of the Meeteetse formation, which contains no coal. The maximum discordance in dip occurs in the latter locality, where the Meeteetse beds dip 22° E. and the Fort Union sandstone 9° E. On the east side of the basin it may be traced southward from Sheep Mountain to the vicinity of Tensleep Butte, where the Fort Union and Lance are overlapped by the Wasatch. Southward from this locality the unconformity was traced for 10 miles or more. Along the south side of the basin east of Big Horn River no evidence of an unconformity was observed. The Fort Union is overlain unconformably by the Wasatch and younger formations. The best exposures are found where streams have cut valleys across the strike of the beds, as along Greybull River and in the "Hole in the Ground" in T. 48 N., R. 99 W. The maximum thickness of the Fort Union formation, 5,592 feet, was measured in the Shoshone Canyon and in the east half of T. 51 N., R. 101 W. East of the Oregon Basin it is completely overlapped by beds of the Wasatch formation.

On the east side of the Big Horn Basin the Fort Union formation ranges in thickness from about 1,200 feet near Kirby to about 2,000 feet on Greybull River, about 4 miles above its mouth.

The formation is largely composed of white, buff, and drab sandstones with gray, olive, and red shale. On the west side of the basin, the basal bed is generally conglomeratic and there are also several higher persistent beds of conglomerate. The pebbles of the conglomerate are largely white and red quartzite, but there are also cherts with Carboniferous and Permian fossils, silicified wood that resembles the variety found in the Meeteetse formation, and pale red andesite. Granite pebbles are rare and limestone and vein quartz have never been found. The formation contains important but lenticular beds of coal at 100 to 150 and at 480 feet above the base on the west side of the basin. On the east and south sides of the basin no coal of economic importance is known to be present. Thin beds of coal and carbonaceous shale are known near the top of the formation on Antelope Creek, about 3 miles southwest of the town of Basin.

Although the beds of the Fort Union formation are involved in the folds the relations to the underlying beds show that a slight amount of local folding took place when the basal beds were laid down. The persistent occurrence of water-worn fragments of silicified wood suggests that some of the sediment was derived from the Meeteetse formation.

WASATCH AND YOUNGER FORMATIONS.

In this report the name "Wasatch" is applied to a group of beds that are separated from the underlying Fort Union and older formations by an unconformity commonly recognizable by a discordance in dip and that are covered by the volcanic tuffs and flows adjacent to the Shoshone Mountains. As thus defined, the formation includes beds that attain a probable maximum thickness of 2,500 feet [1] in the vicinity of McCulloch Peak and contain the faunal zones recently given the names Greybull, Lysite, Lost Cabin, and Tatman by Sinclair and Granger.[2]

In areas of pronounced unconformity the basal beds contain lenses of conglomerate and gravel composed of the rock types represented in the Fort Union formation and of limestone and pale-red granite. In the matrix of the gravel angular feldspar is an important constituent. The higher beds contain gritty calcareous sandstone and numerous alternations of drab, olive, and red sandy clay. Many streams of the central part of the basin rise in badlands, the walls of which

[1] Fisher, C. A., op. cit., p. 33.

[2] Sinclair, W. J., and Granger, Walter, Notes on the Tertiary deposits of the Bighorn Basin: Am. Mus. Nat. Hist. Bull., vol. 31, p. 57, 1912.

Granger, Walter, On the names of lower Eocene faunal horizons of Wyoming and New Mexico: Am. Mus. Nat. Hist. Bull., vol. 33, p. 201, 1914.

show many such alternations of somber and highly colored beds. A very striking feature of the formation is the lenticular character of each of the beds, the succession in one badland area rarely being the same as that in an adjacent area. The clay beds of the badlands areas have yielded bones of a number of mammalian vertebrates, from which, on the basis of determinations by C. W. Gilmore, the age of the formation is established. Locally, thin beds of brown shale yield leaves and the variegated clays yield invertebrate fossils, but these are uncommon. The formation does not contain coal in the basin.

STRUCTURE.

DEFINITIONS OF STRUCTURAL TERMS.

In general, the term "anticline" is applied to an upfold in bedded rocks and the related term "syncline" to a downfold. Horizontal folds that are beveled by a surface which is approximately horizontal show nearly parallel outcrops of the beds of rock. In an anticline the oldest beds—those that were originally the most deeply buried—lie in the middle and are bordered on both sides by belts of younger rocks—the oldest nearest the middle—which dip outward from the central older rocks. In a syncline the youngest rocks form the middle belt and are bordered by belts of older rocks, which dip inward toward the central and younger rocks. Some anticlines and synclines show on the surface as exceptionally regular parallel belts of rock beds 50 to 100 miles long. Most folds, however, are shorter, and the outcrops of the beds that form them appear at the surface as roughly parallel elliptical belts. Where these belts are nearly circular, or slightly elliptical, and the rocks dip away from the center, the fold is called a dome.

As some of the terms that have been applied to parts of folds have been very loosely used and as some parts have never been named, it seems desirable to redefine some of these terms and to introduce new names for parts that have heretofore had no specific names. The term "axis" is in common use, but its usage is variable and not at all exact. It has been applied to three distinct parts of a fold—(1) the line on the surface of the ground which separates opposed dips, (2) the highest part of a chosen bed in an anticline and the lowest part of the bed in a syncline, and (3) the line of intersection of the axial plane or axial surface of a fold with a particular stratum. In some folds these lines will coincide if they are viewed from a point high above the surface of the ground; but in other folds, such as most of those in the Big Horn Basin, if thus viewed, they may appear to be several hundred feet apart. It is important, therefore, to the oil operator and prospector that the three lines be so clearly discrimi-

nated that they may be easily recognized in the field and that the terms used to designate them be clearly understood.

The word "axis" should be used in only one of the three meanings given above, and it is proposed to limit it to the third meaning. Other names will be suggested for meanings 1 and 2. The definition of "axis" then is, the line marking the intersection of the axial plane or axial surface of a fold with any particular stratum. The "axial plane" of a fold has been defined by Willis[1] as the plane that bisects the angle between its limbs. (See diagram 1, fig. 2, p. 35.) For the other two lines to which the term "axis" has been applied, new names are proposed. The term "crest trace" is proposed for that line on the surface of a folded stratum which passes through the highest points of all vertical sections that cut the surface at right angles to the trend of the fold. If the length of an anticline is almost equal to its breadth, the fold becomes a dome and its crest trace is short. The term "crest line" is proposed for that line on the surface of the ground from which the beds dip away in opposite directions. If a given bed has the same dip on both limbs of an anticline the horizontal position of the crest line will coincide with both the axis and the crest trace of the bed. It seems desirable that the term "crest" be left free for application generally to the high part of a folded bed and not restricted to any particular line.

Where the beds in a fold are strictly parallel (see fig. 2) the crest trace of a buried bed lies vertically beneath the crest line on the surface. On the other hand, where the beds are parts of "similar" folds, such as are probably formed by the oil-bearing sands of most of the anticlines of the Big Horn Basin, the crest trace of a buried bed does not lie vertically beneath the crest line but is offset in the direction of the flat limb of the fold.

In the simplest type of anticline, the dip of the beds increases from zero at the crest to the point of its maximum inclination, and beyond this point it decreases again to zero at the axis of the syncline or at the point where the anticline merges into flat-lying beds. In many anticlines, however, the dip from the crest first increases, then decreases for a short distance, and then increases again. That part of the fold in which the dip thus decreases is called a structural terrace. (See cross section of Cottonwood anticline, Pl. XXII, p. 150.) Many of the anticlines of the Big Horn Basin are unsymmetrical—that is, the maximum dip of one limb is much greater than the maximum dip of the other.

According to the definitions proposed the axis and the crest trace are lines on folded beds, and there can be as many axes and crest traces as there are beds. Therefore, if these definitions are accepted

[1] Willis, Bailey, The mechanics of Appalachian structure: U. S. Geol. Survey Thirteenth Ann. Rept., pt. 2, p. 220, 1892.

it will be appropriate to refer to the axis or to the crest trace of a folded bed but not to the axis of an anticline or fold. The axis of a folded bed can, of course, rarely be determined, as it can be discovered only by means of cross sections of the bed. The crest trace can be determined only by making a structure-contour map of the bed. The crest line, however, being a line on the surface of the ground, may be drawn by making a number of observations of dip.

In discussing many regions in which the folded rocks yield oil, definitions so precise as those here suggested are not necessary. Where the dip of the strata in the limbs of the folds is low and almost uniform the horizontal position of the axis, the crest trace, and the crest line coincide, or so nearly coincide that they need not be discriminated, but where the dip differs greatly from place to place the horizontal projection of the crest trace of one bed may be several hundred feet distant from that of a bed a thousand feet deeper, and neither may coincide with the projection of the crest line. As oil and gas tend to occur along the high part or crest of certain folded sandstones it is necessary, in regions where the difference in dip on the limbs is great, to place exploratory holes in positions where they may strike the crest traces of the productive sands. Folds of this type are common in the Big Horn Basin, and drill holes that may give conclusive results should be located, not necessarily along the crest lines but in positions where they may strike the crest traces of the most productive buried sand. In order to place them in proper positions careful studies of all available field data may be necessary in advance of drilling.

GENERAL STRUCTURE OF THE BIG HORN BASIN.

The important general features of the structure of the Big Horn Basin and the surrounding mountains have been described by Fisher.[1] Structurally the Big Horn Basin is a depression bounded on all sides except the north by prominent upfolds which form the mountains that surround it. The structure of the Cretaceous and older rocks along the mountains on the west and southwest sides of the basin is largely concealed by a thick cover of approximately horizontal volcanic tuffs and lava flows of Tertiary age. The difference in elevation of the pre-Cambrian surface restored over Cloud Peak, which has an elevation of 13,163 feet, and the same surface under the trough of the basin amounts to about 27,000 feet and gives a measure of the deformation that produced the basin.

On the basis of structure the Big Horn Basin may be separated into two parts (see Pl. I), an inner or central part in which the surface rocks belonging to the Wasatch and younger formations are almost

[1] Fisher, C. A., op. cit., p. 36.

horizontal, and an outer or border part adjacent to the mountains in which the beds older than the Wasatch are thrown into a number of pronounced but comparatively small folds. The Wasatch and younger beds of the central part are only locally horizontal, however, for they dip slightly toward a fairly defined middle trough trending roughly N. 40° W., and there are also several minor, approximately parallel, less extensive folds. One such minor syncline trends southeast in the southwest part of T. 51 N., R. 99 W. The Neiber anticline (No. 29, Pl. I; see also Pl. XX, p. 140) in the southern part of the basin is perhaps the most conspicuous fold developed in the Wasatch formation. The dips of the Wasatch beds are steepest on the basinward limb of the border belt of folds. Locally, on the east limb of the Oregon Basin domes, the dip is as great as 33°, but the usual range is 5° to 15°, and in the central part of the basin it rarely exceeds 3°.

The border belt of folds is not sharply separable from the upfolds that coincide with the mountains (Big Horn, Bridger, Owl Creek, and others) around the basin, because transitions in size may be found from the smallest folds, most of which lie nearest the middle of the basin, to the largest, most of which occur near the mountains. Along the border belt of folds the dip of the beds commonly ranges from 10° to 45° and in many places from 45° to 75°.

Local but important unconformities (see p. 28) are shown where, east of the Oregon Basin, the beds of the Fort Union formation rest upon the middle part of the Meeteetse formation, and west of Greybull along Dry Creek and Greybull River where the Fort Union formation shows a striking discordance in dip with older beds whose age has not been definitely determined. These unconformities show that some of the folding in the border belt took place before the deposition of the Fort Union formation. The border relations of the Wasatch and the younger formations show that further folding took place before the beginning of the Wasatch deposition but was not completed until after an undetermined but probably large part of this formation had been laid down. There have been minor folding and faulting since that time, but the folding has been along axes that only locally coincide with those of the earlier epochs.

STRUCTURE OF THE ANTICLINES AND DOMES.

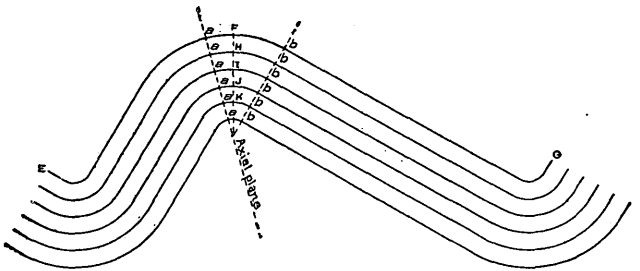
The present report describes most of the anticlines and domes of the border belt of the basin south of the latitude of Cody and Greybull. These folds range from simple anticlines such as the Thermopolis anticline (No. 27, Pl. I; see also Pl. XXI, p. 146) with sharply defined crest lines that may be followed for 25 miles or more to domes such as Little Grass Creek dome (No. 36, Pl. I; see also Pl. XXIV,

p. 160) almost circular in outline and therefore without well-defined crest lines. One structure, the Half Moon anticline (No. 42, Pl. I; see also Pl. XXIX, p. 178), may be regarded as half of a simple anticline broken by a fault parallel to the crest line. As the extent of an anticline, slope of the limbs, and age of the oldest formations that outcrop along the crest indicate the depth to which a fold probably persists, there is little doubt that some of the larger anticlines, such as Sheep Mountain (No. 1), Thermopolis (No. 27), and perhaps Cottonwood (No. 32), involve pre-Cambrian rocks. Others, such as Shoshone (No. 48), Sunshine (No. 40), Waugh (No. 31), Lake Creek (No. 22), Bonanza (No. 11), and Manderson (No. 10) are so narrow and have limbs so steep that although they may go down to the Chugwater they probably do not persist to the Big Horn and Deadwood formations. Other small folds, such as the Gooseberry dome and anticline (No. 36), may not persist below the Madison limestone. Some of the minor structures, such as the terrace in the southeastern part of T. 45 N., R. 98 W., clearly lie on the limbs of larger anticlines.

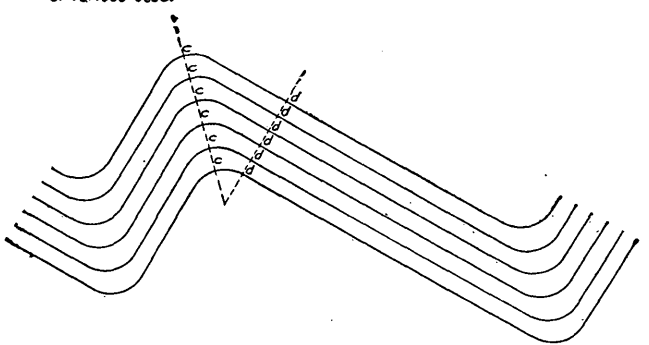
In parts of the basin, particularly on the southeast, the crest lines of adjacent anticlines are approximately parallel, but in much of the region the crest lines, even where well defined, curve in broad arcs whose alignment bears little resemblance to that of those near by. Locally, several anticlines, such as the Lucerne (No. 28), Sand Draw (No. 30), and Waugh (No. 31), have nearly parallel crest lines and are successively offset (arranged in echelon), an arrangement that is common over large areas adjacent to the east front of the Rocky Mountains. This arrangement is uncommon in the northwestern part of Big Horn Basin.

It is an interesting fact that the dips on the anticlines and domes of the region are usually much steeper on one limb than on the other—that is, the folds are unsymmetrical. A line drawn N. 30°–40° W. through the middle of the basin will separate the anticlines and domes into two groups, one northeast of the line in which the limbs nearest the central part of the basin are much flatter and broader than the limbs toward the Big Horn Mountains, and the other group southwest of the middle axis, in which the limbs nearest the basin are much flatter and broader than the limbs nearest the Owl Creek and Shoshone mountains. There are a few exceptions to this general rule. (See fig. 2.)

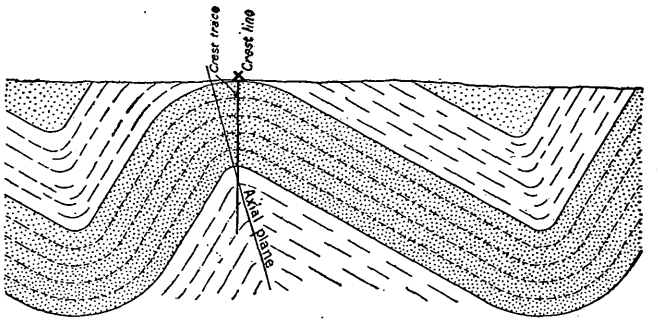
On account of great difference between the dips of the opposite limbs of several of the anticlines of the Big Horn Basin it is desirable at this place to call attention to the effect of these relations on the location of drill holes. (See fig. 2.) Evidence has been collected in several parts of the basin which tends to show that the thickness of the Cody shale is not constant throughout the extent of an anticline, and that the beds are generally thicker on the steep than on the flat



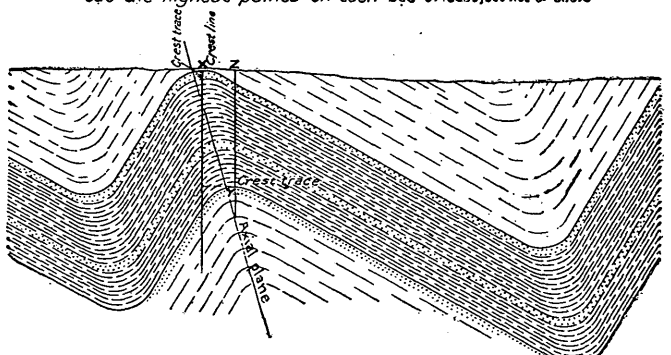
1. Parallel fold. Probably only occurs in strong massive beds, such as sandstone and limestone. F, H, I, J, K, crests, and a, a, a, axes of various beds.



3. Similar fold. Thin beds of weak rocks, such as shale and thin sandstone, tend to assume this form.



2. Parallel fold in massive sandstone beds. A drill hole at X will cut the highest points on each bed of sand, but not of shale



4. Similar fold in shale and thin sandstone. A drill hole at X will fall to the left of the crest line of the bed at Y. In order to strike this point, the well should be drilled at Z

FIGURE 2.—Cross sections of inclined folds of two types, showing the relations of wells drilled at the crests of the folds.

limb. Thus the thickness of the Cody shale on the west limb of the Sunshine anticline is 3,400 feet, whereas the average of two measurements on the east limb is 2,600 feet. It seems highly probable that there are similar variations in thickness of the Thermopolis and Mowry shales and the Frontier formation. These relations suggest that the parts of the anticlines that include these formations are "similar" rather than "parallel" folds. (See p. 35.) It is an important feature of similar folds that the highest parts or crest traces of their component beds lie not vertically one above the other but along a plane that dips in the same direction as the flat limb. One important consequence of these relations is shown in figure 2, diagram 4, where a well drilled at X, on the crest trace of the outcropping bed, falls to the left of the crest trace of a lower bed at Y. In order to strike the crest of the buried bed at Y the well must be located at Z.

A very interesting question that has some economic importance is whether the pronounced folds of the border belt persist toward the trough of the basin under the cover of the Wasatch and younger rocks. The evidence that bears upon this question will not be summarized here, but reference may be made to two significant factors. In most parts of the basin the folds of the border belt are successively shorter and narrower and the dips lower the closer they are to the trough of the basin; and there is reason for inferring that these lower and smaller folds do not persist so deeply in the rocks as the larger folds. It seems probable, therefore, that any folds that involve the oil-bearing formations under the cover of the Wasatch and younger rocks are much less pronounced than those of the border belt. Several folds, whose crest lines trend northwest and are therefore roughly parallel to the folds of the border belt, have been noted in the areas of the Wasatch and younger rocks, but are probably not so pronounced in rocks as deeply buried as the Frontier. It is well to bear in mind, however, that very low anticlines may aid the accumulation of oil and very low synclines may affect the direction of its migration.

FAULTS.

Faults occur in many of the anticlines of the basin. Most of them appear to be closely related to the movements by which the anticlines of the border belt were produced, for they displace the beds along the limbs. Thus, an important fault in sec. 2, T. 50 N., R. 100 W., trends toward the syncline that separates the Oregon Basin North and South domes. The maximum stratigraphic displacement along this fault is 1,500 feet and the horizontal offset of the lower Mesaverde sandstone is 3,000 feet. Most displacements along these faults, however, range from 150 to 200 feet. Several faults,

such as two in the northeast part of T. 45 N., R. 99 W., are much more recent than the faults along the folds, for they displace the beds of Tertiary volcanic tuffs that unconformably overlie the older folded rocks.

In some localities, such as the Greybull dome (No. 4, fig. 5, p. 57), groups of parallel faults trend nearly at right angles to the crest line of a fold, but in other parts of the basin the faults roughly diverge from the crest of the anticline. This is well shown near the crest of Cottonwood anticline (No. 32) and around Oregon Basin. Viewed broadly, more faults have been recognized that displace the sandstone beds of the Frontier than any other formation; relatively few faults have been found in the areas of Wasatch rocks. No definite relations in the distribution of the faults have been recognized. Thus, there appears to be no reason why faults should be lacking in the Buffalo and Spring Creek basins and numerous and extensive in the Oregon Basin on the north and the Grass Creek Basin on the south.

STRUCTURE CONTOURS AND THEIR USE.

In all matters that pertain to geologic structure it is necessary to bear in mind that although the vertical dimension is important, most observations are made on the surface of the earth and are fixed by horizontal measurements only. Thus, most geologic maps show the surface outcrops, which involve two horizontal dimensions, supplemented perhaps by vertical cross sections which show one horizontal and one vertical dimension. Models may be constructed that show both horizontal and vertical dimensions in their true relationships, but these involve much labor in their preparation and can not readily be duplicated or reproduced in print.

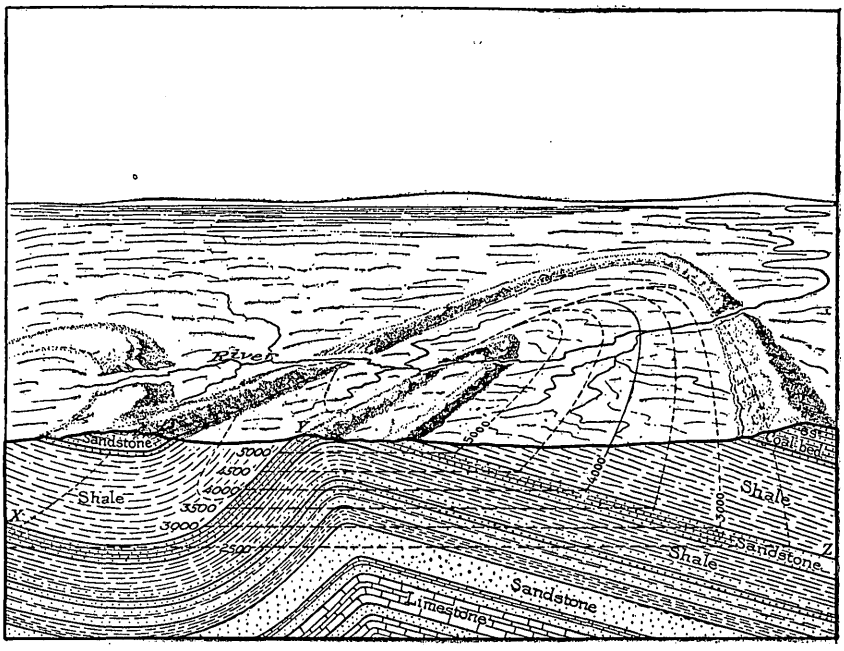
A method of presenting the data of three dimensions, namely, the two surface or horizontal dimensions and the vertical, that has been found to be very useful is that embodied in the structure-contour map. On such a map the structure of beds lying entirely below the surface may be accurately shown. A contour map of any surface, whether the surface of the earth or the surface of a folded bed of sedimentary rock, is one that shows the contours or lines which would be formed if the surface were cut by many equidistant horizontal planes. If the surface considered be a plane or flat inclined surface the contours will be straight, and if it be a folded or irregularly curved surface the contours will be curved or highly sinuous. Such lines have been aptly described as the paths that would be traversed if a person were to walk along the surface, all the while being careful to maintain the same height above sea level. A structure-contour map shows many such lines or paths on the surface of a bed of rock as they would appear if viewed vertically downward from an elevated position.

In general, the accuracy of structure-contour maps depends on the amount and kind of data available. In some oil fields where many well records to a persistent bed are known, exceptionally accurate maps of the buried bed may be made. Fairly accurate interpretations of the structure of buried beds have also been made in fields where only surface outcrops of higher beds were available, but in such cases the distance between the buried and outcropping beds has been measured from near-by outcrops and has been found to be fairly constant over large areas. In fields where surface outcrops are poor structure-contour maps may represent only approximately the form of buried beds but may yet be very useful in locating wells.

Figure 3 illustrates the meaning of a structure-contour map, and shows how it represents the form of an anticline. Figure 3, *a*, is a perspective sketch of a region in which the surface bevels a part of an anticline. This should be compared with Plate X, *A* (p. 98), which is reproduced from a photograph of a similar fold. The aim has been to represent an anticline from which a part of the fold has been eroded, as is common in the Big Horn Basin. The soft rocks are worn down to rolling plains, whereas the thick beds of resistant rock form prominent ridges, which form roughly elliptical outcrops around the end of the anticline. Figure 3, *a*, also shows a vertical cross section through the anticline. This type of anticline, where one limb has a low dip and the other a relatively steep dip, is common in the Big Horn Basin. If the anticline were cut horizontally by a knife at intervals of 500 feet, beginning at sea level, the position of some of these cuts would be represented by the horizontal lines at 3,000, 3,500, 4,000, 4,500, and 5,000 feet elevation; for instance, the line along which the knife cuts the top of the sandstone *XYZ* would be represented by the curved lines shown in the sketch. These lines not only show how the bed of sandstone would be cut, but collectively they also represent the form of the bed that is cut—that is, they are what are generally known as structure contours on the bed. Figure 3, *b*, shows the structure contours on the upper surface of the bed of sandstone *XYZ* as they would appear if viewed from a point vertically above the area. The contours are represented as solid lines below the surface and as broken lines where they are drawn on that part of the bed which once existed above the present surface but which has been removed by erosion. It is apparent that the distance between the contours is a measure of dip of the beds at that point; that where the distance between the contours is great the dip of the beds is low; and that where the contours are close together the dip is steep.

In addition to showing the form of a bed a structure-contour map may be used to determine, at any point on the surface whose elevation is known, the depth to the bed on which the structure contours are drawn. The depth to a bed either higher or lower in the section

than that on which contours are drawn may also be obtained from the map, provided its distance above or below the contoured bed is



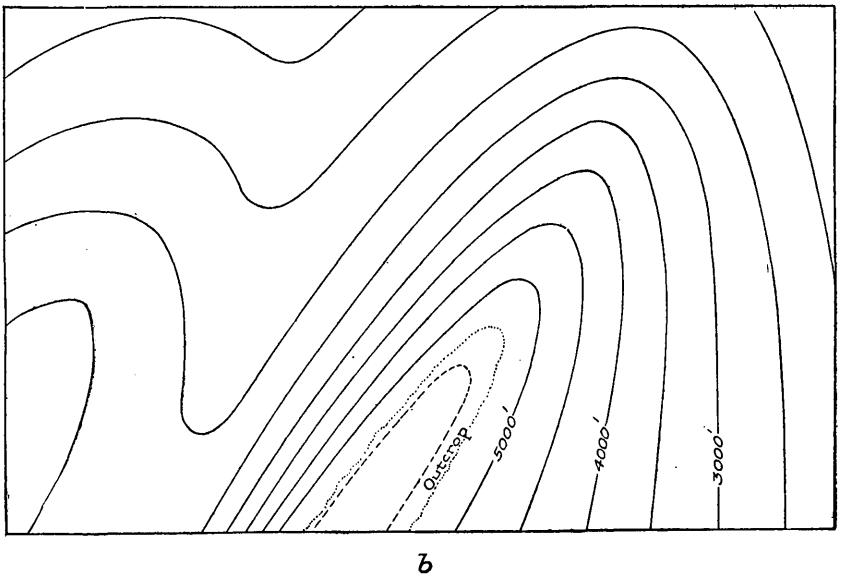


FIGURE 3.—*a*, Cross section and perspective sketch of an anticline, showing meaning of structure contours; *b*, structure-contour map of the anticline shown in the sketch.

known. In the maps of most of the fields considered in this report the structure contours are drawn on the top of the Greybull sand, but

in others they are drawn on the top of the Madison limestone, the Embar formation, or the coal beds in the lower part of the Mesaverde formation. Figure 4 has been prepared to show how the elevation above sea level and hence the depth from the surface of beds higher or lower than that on which contours are drawn, may be determined. If (see fig. 4) the bed *pqrs* lies below the bed *lmno*, on which the structure contours are drawn, the vertical distance from a given point, *b*, on the surface of the ground, to the top of the lower bed at *r* will be found by adding to the depth to the contoured bed *bn* an amount approximately equal to the stratigraphic distance *nr* between the surfaces of the two beds, provided the beds are practically horizontal. The depth to a bed *above* the contoured stratum may be obtained by *subtracting* the stratigraphic distance, provided the beds are practically horizontal. If, however, the beds at the

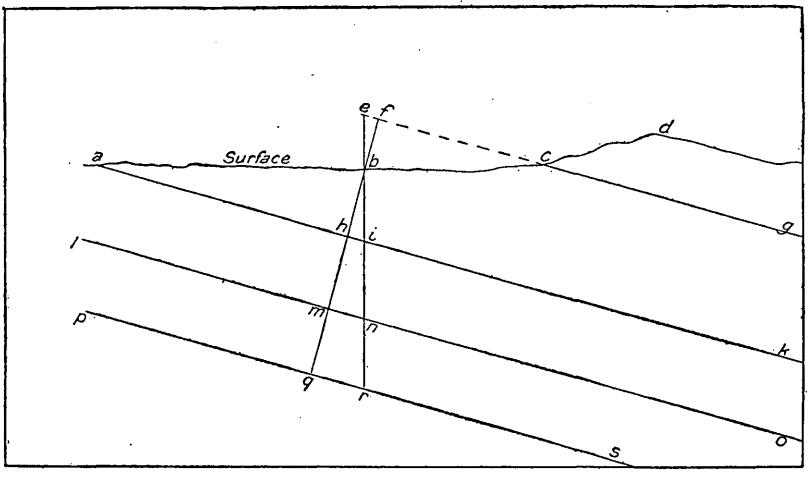


FIGURE 4.—Diagram showing the relation of a bed that is contoured to other beds either above or below.

given point dip more than 5°, the distance *nr* will appreciably exceed the stratigraphic distance between the beds. It will be equal to the stratigraphic distance divided by the cosine of the angle of dip.

In many of the fields described in this report a part of the bed on which contours are drawn and of the overlying beds has been removed by erosion and the contours represent the inferred position of the surface of the bed (above the existing surface of the ground) before it was eroded. Thus, the structure of large parts of several fields is shown by contours on a coal bed of the Mesaverde formation, which has been restored in those areas from which the bed has been eroded. In these fields the sands in which there is some prospect of finding oil and gas occur in the Frontier or lower formations. The calculation of the depth to these lower sands is not so simple as it is where the contoured bed is uneroded. If in figure 4 there are known the elevations of a point *b*, on the surface of the ground, and that of the

point *e*, vertically over it on the restored surface of a contoured bed, the depth *bi* to the point *i* on a lower bed is the distance *ei* (the stratigraphic distance *fh* between the two beds divided by the cosine of the angle of dip) minus the distance *be* (the difference in the elevation of the surface of the ground and that of the restored bed).

The foregoing discussion is based on the assumption that the beds are parallel, which is equivalent to saying that the shortest distance between the two beds is equal throughout the fold. There may be areas in which the beds are not parallel, and for these the calculations are only approximately correct.

OIL AND GAS.

MODE OF OCCURRENCE.

DATA CONSIDERED.

In order to determine whether or not any particular anticline or dome in the Big Horn Basin is probably a reservoir for large quantities of oil or gas the authors have considered three classes of data—(1) specific information that has been obtained by drilling on each anticline, in so far as it relates to the character of the rocks that remain buried beneath the surface on the crests of anticlines, and the areal relations of the anticlines; (2) general knowledge of the occurrence of oil and gas in districts in Wyoming where stratigraphic and structural conditions are similar to those existing at the particular anticline; and (3) hypotheses relating to the accumulation of oil and gas in anticlinal folds.

SPECIFIC INFORMATION OBTAINED BY DRILLING.

The beds that have yielded most of the oil and gas in Big Horn Basin are Cretaceous in age and are parts of the Cloverly formation, Thermopolis shale, Mowry shale, and Frontier formation. Gas is reported also from a sand in the Morrison formation in well No. 4 on the Shoshone anticline. An oil seep is known near the base of the Chugwater formation on the Red Spring anticline and another is reported by Washburne [1] in T. 52 N., R. 90 W., in beds that may be part of the Amsden, Tensleep, or Embar formations. It is extremely uncertain at present, however, whether any of the beds lower than the Cloverly formation will prove to be important sources of oil or gas. Only one well (on the Nieber anticline) has tested, under favorable structural conditions, beds higher than the Cody shale, which overlies the Frontier formation, but on account of the origin and lithologic character of the higher beds the prospect that any of them will yield important quantities of either oil or gas is not good.

[1] Washburne, C. W., Gas fields of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 340, p. 361, 1908.

The results of drilling to date in the Big Horn Basin show that the sands of the Frontier formation yield the greatest part of the oil and that the sands of the Mowry shale and the Greybull sand yield oil as well as most of the gas now produced in the basin. These facts are cited to indicate not that other formations offer no prospect for successful drilling, but that preliminary exploration should be confined to these formations. Areas that are structurally favorable should not be considered to be proved valueless until all of the sands of these formations, which include from 1,600 to 1,800 feet of beds, have been tested.

Some of the anticlines and domes in the Big Horn Basin are not regarded as good reservoirs for oil and gas because the beds that are most likely to serve as reservoirs have been eroded from the crests, thereby permitting the escape of the oil and gas, if those substances were ever present.

Some anticlines in this region are considered by the writers to be unpromising as oil and gas reservoirs for the additional reason that they pitch in such a way that any oil or gas in them would escape to the surface at the outcrops of the oil and gas sands. A good example is the southeast end of the Lucerne anticline (No. 28, Pl. I), which is developed on the north side of the large Thermopolis anticline (No. 27, Pl. I) and which pitches northwest as far as the cross syncline separating it from the part designated the Gebo dome. Any oil or gas that originally may have been in the strata in this anticline could have migrated up the beds and escaped at the outcrop on the north side of the Thermopolis anticline.

The wells that have struck large quantities of oil and gas in the Big Horn Basin are near the crests of anticlines and domes. Of those wells drilled near synclines or where the beds are nearly flat over large areas a few have struck small quantities of oil and gas and a few have failed to yield oil, gas, or water, but most have yielded water. In several of the productive fields that are on anticlines water is found in sands both above and below the oil and gas sands.

In general, the relations of gas, oil, and water in the anticlines are those demanded by the simplest interpretation of the "anticlinal" theory, as set forth by Orton[1] in 1886:

> If one of these sandstone strata filled with salt water, oil, and gas and freely permeable laterally and horizontally for miles at a time were thrown into a system of low folds, what effect would this movement have upon the contents of the stratum? Would not a separation of gas, oil, and water be sure to follow, the gas finding its way to the summits of the arches and the salt water sinking to the bottoms of the troughs? Such a result would be inevitable under the conditions assumed.

According to the theory, if gas, oil, and water are present in large quantities and if the adjustment in the pervious bed according to the

[1] Orton, Edward, Preliminary report upon petroleum and inflammable gas, p. 13, Ohio Geol. Survey, 1886.

specific gravities of the substances were complete the gas would occupy a zone at the highest part of the folded beds and be limited below by the roughly horizontal upper surface of a zone of oil. The zone of oil, in turn, would be limited below by the roughly horizontal upper surface of a zone of water. If the proportion of gas were relatively low it is conceivable that all of it could be dissolved in oil under the existing pressures, and the oil rise to the highest part of the fold. The available information from the productive fields of Big Horn Basin shows that in this region much less gas is present than is commonly associated with productive oil pools.

The limits of the oil-producing areas of several of the important fields of the basin have been approximately determined and in comparison with most oil pools are rather sharply defined. Thus, after two years' operations, the limits of the productive areas of the Grass Creek field are rather closely determined, and it appears that a broadly sinuous line may now be drawn which will separate the inner area, within which all wells that penetrate the productive part of the Frontier formation will yield oil with little if any water, from the outer area, within which all wells will yield water from the same zone of sands. The limits of the other fields of the basin are not yet so closely known. Each prominent anticline that contains oil appears to hold but a single pool.

In the three most productive fields in the area covered by this report, the Greybull, Torchlight, and Grass Creek, the zone in the prolific sands that yields the oil extends much lower along a part of the flat basinward limb of the fold than on the steep mountainward limb. Thus at Grass Creek the sands are prolific at a lower altitude in the southeastern part of the field than in the southwestern or western part. This relation must be considered in formulating any hypothesis to explain accumulation of valuable pools of oil.

In one well (No. 31, fig. 5, p. 57) in the Greybull field the oil which was first produced by pumping has given way to water, and in another well (No. 32, fig. 5) the gas has gradually given way to oil. The latest well is near the line separating oil and gas.

A summary of the results of drilling throws light on the possible relation of productiveness of anticlines and domes to their position with respect to near-by larger basins and upfolds. Fifty fairly distinct upfolds have been described, but it should be recognized that it is not possible to distinguish sharply between simple isolated upfolds and outlying parts of complex upfolds. Thus, the Lucerne anticline is regarded as a single distinct upfold, although it includes the Gebo dome, which lies along the extension of its crest line. Wells have been drilled sufficiently near the crest lines of 24 of the 50 upfolds to indicate the prospect for production from the structures. In the following summary, compiled from the descriptions in this report,

upfolds are considered to dip basinward if their beds descend without reversed dips to the middle trough of the Big Horn Basin. In several upfolds—as in Little Grass Creek dome, for instance—the area within which the beds dip continuously toward the middle of the basin is only a small part of the total area of the basinward-dipping limb of the fold, but such upfolds are nevertheless included among the basinward group.

Upfolds in Big Horn Basin.

East side of middle trough.

BASINWARD UPFOLDS.		MOUNTAINWARD UPFOLDS.	
Tested by drill:		Tested by drill:	
Greybull dome	OG	Shell Creek dome	d
Lamb anticline	OG	Cherry anticline	d
Torchlight anticline	OG	Dry dome	W
Manderson anticline	?	Mercer anticline	w
Bonanza anticline	o	Paintrock anticline	W
Sherard dome	o	Not tested:	
No Wood anticline	w	Zeisman dome.	
Not tested:		Brokenback anticline.	
Tensleep anticline.			
Bud Kimball anticline.			
Well area.			
Sheep Mountain anticline.			

West side of middle trough.

BASINWARD UPFOLDS.		MOUNTAINWARD UPFOLDS.	
Tested by drill:		Tested by drill:	
Nieber anticline	?	Lucerne anticline	w
Grass Creek anticline	OG	Waugh anticline	W
Little Grass Creek dome	W	Cottonwood anticline	d
East Buffalo anticline	g	Wagonhound anticline	W
West Buffalo anticline	g	Enos Creek anticline	W
North Oregon Basin dome	g	Spring Creek anticline	W
South Oregon Basin dome	g	Gooseberry anticline	W
Shoshone anticline	og	Not tested:	
Not tested:		Zimmerman Butte anticline.	
Mahogany Butte anticline.		Blue Spring anticline.	
Lysite Mountain anticline.		Red Spring anticline.	
Black Mountain anticline.		Wild Horse anticline.	
Lake Creek anticline.		Thermopolis anticline.	
Sand Draw anticline.		Gooseberry dome.	
		Sunshine anticline.	
		South Sunshine anticline.	
		Fourbear anticline.	
		Pitchfork anticline.	
		Half Moon anticline.	
		Frost Ridge anticline.	

OG Important oil and gas field.
og Unimportant oil and gas field.
o Unimportant oil field.
g Wells near crest line yield gas only.
W Wells near crest line yield water.
d Wells "dry"; yield no oil, gas, or water.
w Well some distance from highest part of crest yields water.
? Well near crest line not deep enough to test important sand.

The data given above may be summarized as follows:

Basinward upfolds tested by wells:		
Important oil and gas fields	4	
Unimportant oil and gas fields	1	
Unimportant oil fields	2	
Fields that yield gas only	4	
Fields with shallow wells that do not reach productive sands	2	
Fields that yield water only	2	
		15
Basinward upfolds untested		9
Mountainward upfolds tested by wells:		
Fields that yield water near crest	7	
Fields that have dry wells	3	
Fields that yield water remote from crest	2	
		12
Mountainward upfolds untested		14
		50

The preceding summary is statistical and does not contain many details that should be included in a complete review of the results of the drilling, but its significance should not be overlooked in considering the chance for success in drilling in this region. It can hardly be merely a coincidence that every tested field in the Big Horn Basin which has yielded appreciable quantities of oil and gas lies near the principal trough of the Big Horn Basin, and that every tested upfold which is separated from this trough by other folds has either yielded water and the merest traces of oil and gas or is barren of either oil, gas, or water. These relations of course do not necessarily indicate that every basinward anticline should yield either oil or gas and that no mountainward anticline will yield oil or gas in commercial quantities. They do suggest, however, that basinward upfolds offer more favorable prospects for exploitation and should be tested in advance of the others.

OCCURRENCE IN OTHER FIELDS IN WYOMING.

There are many anticlines and domes in Wyoming that are of nearly the same size as those described in this report and that, like them, lie in belts between much larger anticlines or between regions of uplift and regions of depression. As the structure of the Cretaceous beds in large areas near these depressions or basins is obscured by unconformable younger beds it is not possible to be sure in each locality whether the upfolds adjacent to the limits of the later beds are basinward, as the word is used in this report, or not. It may be noted, however, that the most productive oil field in the State, Salt Creek,[1] is basinward with respect to the Powder River

[1] Wegemann, C. H., The Salt Creek oil field, Natrona County, Wyo.: U. S. Geol. Survey Bull. 452, p. 37, 1911.

basin, and that several minor oil fields, such as Moorcroft, [1] in Crook County; Big Muddy,[2] in Natrona County; Byron,[3] in Big Horn County; and Elk Basin,[4] in Park County, are among folds that are nearest to the larger structural depressions.

Wegemann[5] has called attention to the relation of the Salt Creek dome to the structural basin which lies on the east between the Big Horn Mountains and the Black Hills. He has noted that this dome is an important factor in the accumulation of the oil because it has a large area from which oil might be collected through the selective action of the differences in specific gravity of oil and water or through other agencies. Though the sandstones that contain the important pools of oil in the Salt Creek anticline rise to the surface in the Powder River anticline, 15 miles to the northwest, it appears that the larger accumulations in the Salt Creek field, as shown by the success attending drilling to date, may be attributed in part to the more favorable position of the Salt Creek dome with reference to the structural basin on the east.

HYPOTHESES AS TO ACCUMULATION.

No hypothetical considerations as to which anticlines are apt to yield oil and gas are to be compared with those which may be drawn from the foregoing statistical inquiry as to which fields are likely to be productive. If with further exploration it should prove true that basinward folds are much more productive than mountainward folds it would suggest, as Wegemann has pointed out, that large accumulations of oil and gas in the Cretaceous beds of Wyoming are possible only where upfolds are adjacent to large areas of gently rising beds. In other words, the quantity of oil and gas in the upfolds bears a close relation to the area of beds from which it is possible for oil and gas to rise.

If much were known concerning the chemical character of the water in the Big Horn Basin oil fields, and concerning the pressure of the water in many wells that tap persistent sandstones, it might be possible to draw inferences concerning the movement of water in the beds. Although the beds in which most if not all of the oil and gas are found were laid down in the sea, the waters which some of the beds in the oil fields now contain are not strongly salty and are apparently feebly alkaline. This suggests that there have been accessions of surface waters to the beds, probably from the outcrops; and if such movement has taken place on a large scale it would be reasonable to conclude that it might produce accumulations of oil and gas in

[1] Barnett, V. H., The Moorcroft oil field, Crook County, Wyo.: U. S. Geol. Survey Bull. 581, p. 94, 1913.
[2] Barnett, V. H., Possibilities for oil in the Big Muddy dome, Natrona County, Wyo.: Idem, p. 105.
[3] Washburne, C. W., Gas in Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 340, p. 357, 1908.
[4] Personal communication from C. J. Hares.
[5] Wegemann, C. H., op. cit., p. 76.

upfolds accessible to the paths of movement. If this had taken place to any great extent some of the mountainward folds should yield important quantities of oil and gas; but not one of the 12 (out of a total of 26) mountainward folds that have been tested has yielded more than a trace of oil and gas.

From all the information now available, therefore, it appears that the large accumulations of oil and gas in this region have been formed by slow adjustment of the oil, gas, and water once disseminated in the beds. As the productive areas of the most important anticlines of the basin extend lowest in the sands of the limb nearest the middle trough of the basin, it seems that the adjustment of the mobile substances is not yet complete.

If the foregoing hypothesis is correct it may be noted, in conclusion, that a possible explanation of the extraordinary natural flow and consequent large yield of the wells in the Salt Creek field, in contrast with the practical absence of flowing wells in the Big Horn Basin fields, may be due to the fact that although the structural depressions of the Powder River and Big Horn basins are almost equal in size, there are many more, possibly six times as many, upfolds adjacent to the Big Horn Basin than there are adjacent to the Powder River basin.

The following table summarizes the principal facts known about the domes and anticlines:

Anticlines and domes in the south half of the Big Horn Basin, Wyo.

No. on map (Pl. I).	Name.	Wells.			Formation exposed at top of dome or anticline.	Formations.		Anticline cut by faults.	Remarks and character of field work.
		Date of first well.	Number.	Product of wells.		Oil-bearing.[b]	Possibly oil-bearing.		
1	Sheep Mountain				Madison				Not examined.
4	Greybull	1907	53+	Oil and gas	Mowry	Cloverly		X	Detailed.
2	Shell Creek	1915	1	Nonproductive	Morrison				Do.
3	Cherry	1915	1	do	Sundance		Embar		Do.
5	Lamb	1907	11	Oil and gas	Cody	Frontier, Mowry	Cloverly		Do.
6	Torchlight	1904	53+	do	Frontier	do			Do.
8	Dry	1914	1	Nonproductive	Cody				Do.
7	Mercer	1910?	1	do	Sundance		Embar		Do.
10	Manderson	1900	3	do	Cody		Frontier, Mowry, Cloverly.		Do.
9	Paintrock	1888	3	do	Sundance				Do.
11	Bonanza	1898?[a]	6	do	Thermopolis				Oil seep; detailed.
14	No Wood				Chugwater		Embar	X	Detailed.
12	Ziesman				Tensleep		Madison		Do.
13	Brokenback				do		do	X	Do.
16	Sherard	1914	7	Oil and gas	Frontier	Frontier	Mowry, Cloverly	X	Oil seep; detailed.
15	Well area				Cody		Frontier, Mowry, Cloverly.	?	Detailed.
17	Tensleep				Mowry		Mowry, Cloverly	X	Do.
18	Bud Kimball				Chugwater		Cloverly, Embar	X	Do.
19	Mahogany Butte				Madison		Frontier, Mowry, Cloverly.	X	Do.
20	Lysite Mountain				Mowry		Cloverly	X	Oil seep; detailed.
21	Black Mountain				do		do	X	Detailed.
22	Lake Creek				Frontier		Mowry, Cloverly		Do.
25	Zimmerman Butte				Cody		Frontier, Mowry, Cloverly.		Do.
24	Blue Spring				Thermopolis		Cloverly	X	Do.
26	Red Spring				Embar		Embar, Madison	X	Oil seep; detailed.
23	Wildhorse Butte				Chugwater		do		Detailed.
28	Lucerne	1915	1	Nonproductive	Morrison		Frontier, Mowry, Cloverly.		Do.
29	Neiber	1915	1	do	Fort Union		Mesaverde, Frontier.		Do.
30	Sand Draw				Cody		Frontier, Mowry, Cloverly.		Do.
31	Waugh	1914	4	Nonproductive	do				Do.
27	Thermopolis	1910?	1	do	Embar		Embar	X	Not examined.
32	Cottonwood	1912	2	do	Thermopolis			X	Detailed.
33	Wagonhound	1915	3	do	Cody		Cloverly	X	Do.

34	Grass Creek	1913?	81+	Oil and gas	do	Frontier	do	X	Do.
35	Enos Creek	1916	1	Nonproductive	do		do		Reconnaissance.
36	Little Grass Creek				do		Frontier, Mowry, Cloverly.	X	Detailed.
37	Buffalo Basin	1913?	4	Gas	do	Frontier	do		Do.
38	Gooseberry			Nonproductive	do		do		Do.
39	South Sunshine				Morrison		Cloverly		Reconnaissance.
40	Sunshine				do		Embar		Detailed.
41	Fourbear				Frontier		Mowry, Cloverly		Reconnaissance.
42	Pitchfork				Mowry		do	X	Do.
43	Spring Creek	1915	1	Nonproductive	do		do		Part detailed; part reconnaissance.
44	Frost Ridge				Mesaverde		Mesaverde, Frontier.		Reconnaissance.
46	Halfmoon				Frontier		Mowry, Cloverly	X	Do.
45	South Oregon Basin	1912	3	Gas	do	Thermopolis	Cloverly	X	Detailed.
47	North Oregon Basin	1912	3	?	do			X	Do.
48	Shoshone	1909	3	Oil and gas	do	Mowry, Thermopolis, Cloverly.			Do.

[a] Oil was discovered in a seep here about 1884.
[b] "Oil" in the remainder of the table is intended to include both oil and gas.

PHYSICAL AND CHEMICAL CHARACTERISTICS.

Most of the oil of the Big Horn Basin is of high grade, averaging about 45° Baumé. It ranges in specific gravity from 0.8982 to 0.7856 (25.9° to 48.2° Baumé), and yields from 3.5 to 35 per cent of gasoline by the usual fractionation method. The kerosene content of the oil as it comes from the wells ranges from 22.5 to 55.7 per cent. The lightest oil is transparent and has a deep wine color in transmitted light and a dark-green color by reflected light. The heavier oil is opaque and varies from green to dark green by reflected light. Oil from the Lamb anticline near Basin, Wyo., according to one analysis, is heavier than that known from any other part of the Big Horn Basin. It contains no gasoline and much less kerosene than the oil of Torchlight dome a few miles to the south. The small quantity of oil that has been obtained from the Embar and Madison formations is also very heavy. Near Lander, Wyo.,[1] the Embar yields commercial quantities of oil that ranges in specific gravity from 0.9198 to 0.9091 (22.2° to 24° Baumé) and that contains less than 3 per cent of gasoline and at no place more than 25 per cent of kerosene.

The gas of the Big Horn Basin is much less valuable at present than the oil, because it occurs in small quantities and can not be utilized to a large extent. Large quantities of gas have been tapped in drilling on the Lamb anticline, Greybull dome, East and West Buffalo anticlines, North and South domes of Oregon Basin, and Byron anticline. A well recently drilled by the Ohio Oil Co. near Byron in the northern part of the basin but not described in this report is said to have yielded 40,000,000 cubic feet of gas during the first 24 hours. Plans are already being made to pipe gas from some of these fields to the nearest large cities, such as Billings and Butte, Mont., and Salt Lake City, Utah.

Analyses of gas from the Greybull and Byron fields show that it is partly "wet"—that is, that it contains in addition to methane considerable quantities of gases from which gasoline can be derived by compression, as stated by Burrell.[2] Calvert[3] believes that the gas of the Big Horn Basin is not promising as a source of gasoline because the greater part of it is under high pressure, and "the gas from the high-pressure well is adapted only for use as fuel and illuminant." However, gas may yet be discovered in the Big Horn Basin that may have especial value as a source of gasoline.

All known analyses of oil and gas in the Big Horn Basin are given in the following tables. All samples, unless otherwise stated, were collected by members of the United States Geological Survey.

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[1] Woodruff, E. G., The Lander oil field, Wyo.: U. S. Geol. Survey Bull. 452, pp. 7–36, 1911.

[2] Burrell, G. A., The suitability of natural gas for making gasoline: Bur. Mines Tech. Paper 57, p. 20, 1913.

[3] Calvert, W. R., A preliminary report on the utilization of petroleum and natural gas in Wyoming: Bur. Mines Tech. Paper 57, pp. 12, 14, 1913.

Analyses of oils from the Big Horn Basin, Wyo.

[Made in chemical laboratory of the Bureau of Mines.]

Anticline or dome.				Physical properties.			Distillation by Engler's method.							
				Gravity of crude oil at 60° F.				By volume.						
Name.	No. on map (Pl. I).	No. of well.	Depth of well.	Specific.	Baumé (°).	Color in reflected light.	Begins to boil (° C.).	To 150° C. (gasoline).		150°–300° C. (kerosene).		Residuum.		Total (cubic centimeters).	Remarks.
								Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.	Cubic centimeters.	Specific gravity.		
1. Greybull	2	29	975	0.7856	48.2	Dark green	3	31	0.7120	32.5	0.7900	36.5	0.8579	100	Deep wine red in transmitted light. Unweathered. Sulphur, 0.04 per cent.
2. Lamb [a]	5	20	1,088	.8889	27.5	Brownish green	180	.....	.....	22.5	.8476	77.5	.9038	100	Opaque. Weathered.
3. Torchlight [a]	6	27	1,350	.8260	39.5	Dark green	75	26	.7444	34.5	.8104	39.5	.8935	100	Slightly weathered. Deep wine red in transmitted light.
4. Torchlight [a]	6	9	1,264	.7955	45.98	do	34	30.5	.7216	38	.8102	31.5	.8425	100	Unweathered. Deep wine red in transmitted light.
5. Sherard	15	6	102	.8982	25.9	Brownish green	68	3.5	.7948	27	.8590	69.5	.9130	100	Opaque. Weathered. Sulphur, 0.2 per cent.
6. Grass Creek	33	35	1,053	.8187	41	Very dark green.	80	22	.7530	42	.8175	36	.8553	100	Opaque. Weathered.
7. Grass Creek	33	28	987	.7984	45.3	Olive green	28	35	.7290	32	.8150	33	.9028	100	Opaque. Unweathered. Sulphur, 0.1 per cent.
8. Shoshone [b]	45	2	585	.8454	35.6	Dark green	190	.....	.....	37	.8169	59.6	.9278	96.6	Contains 7.6 per cent paraffin.
9. Shoshone [b]	45	2	1,028	.8335	37.98	Green	160	.....	.....	48	.8009	52.4	.8696	100.4	Contains 8 per cent paraffin.
10. Byron [c]	(d)	(1)	(?)	(At 15° C.) .8174	42	Olive green	(e)	4.7	(e)	55.7	(e)	35.6	(e)	(e)	Opaque. Deep wine red in transmitted light.
11. Byron	(d)	(2)	400±	.8187	41	Dark green	44	29	.7444	42.5	.8310	28.5	.8860	100	Unweathered. Deep wine red in transmitted light.

[a] Published in U. S. Geol. Survey Bull. 621, pp. 182, 183, 1916.
[b] Published in U. S. Geol. Survey Bull. 541, p. 113, 1914.
[c] Published in Bur. Mines Tech. Paper 57, p. 10, 1913.
[d] Byron anticline is not described in the present report.
[e] These data were not furnished in the published report.

1. Greybull dome, well 29. Sample collected on June 12, 1915, from the George Alford No. 2 well of the Bighorn Oil & Gas Co., NW. ¼ SE. ¼ sec. 17, T. 52 N., R. 93 W.

2. Lamb anticline, well 20. Oil collected from the Wilson No. 1 well of the Greybull Oil Co., NW. ¼ NW. ¼ sec. 1, T. 51 N., R. 93 W., in June, 1914, and stored in an air-tight barrel until October 15 of the same year, when a sample was sent to the laboratory for analysis.

3. Torchlight dome, well 27. Sample collected on October 15, 1914, from the Jackson No. 3 well of the Greybull Oil Co., NE. ¼ SW. ¼ sec. 24, T. 51 N., R. 93 W. This sample reached the laboratory unsealed and probably some of the gasoline had evaporated.

4. Torchlight dome, well 9. Sample collected on October 15, 1914, from the Kimball No. 3 well of the Greybull Oil Co., lot 13, sec. 19, T. 51 N., R. 92 W.

5. Sherard dome, well 6. Sample collected on August 30, 1915, from well No. 6, drilled by H. M. Sherard for an association of persons in Greybull and Basin, in the NE. ¼ NE. ¼ sec. 19, T. 47 N., R. 89 W. The sample was dipped from the top of the casing and undoubtedly some of the volatile constituents had escaped.

6. Grass Creek anticline, well 35. Sample collected from well of the Valentine interests in the N. ½ N. ½ sec. 20, T. 46 N., R. 98 W., on September 11, 1914, before the well was completed.

7. Grass Creek anticline, well 28. Sample collected on July 26, 1915, from the Phelps well of the Ohio Oil Co., SW. ¼ NW. ¼ sec. 19, T. 46 N., R. 98 W.

8. Shoshone anticline, well 2. Sample collected in October, 1911, from well No. 2 of the Shoshone Oil Co., SE. ¼ SW. ¼ sec. 21, T. 53 N., R. 10 W.

9. Shoshone anticline, well 2. Sample collected in October, 1911, from well No. 2 of the Shoshone Oil Co., SE. ¼ SW. ¼ sec. 21, T. 53 N., R. 10 W.

10. Byron anticline, well 1. Sample collected by W. R. Calvert in the winter of 1912–13 from well No. 5 of the Montana-Wyoming Oil Co., on the E. E. Jones lease in sec. 34, T. 56 N., R. 97 W.

11. Byron anticline, well 2. Sample collected on October 22, 1914, from well No. 12 of the Montana-Wyoming Oil Co., on the E. E. Jones lease in sec. 34, T. 56 N., R. 97 W.

Oil from the Bonanza seep in the NW. ¼ SW. ¼ sec. 23, T. 49 N., R. 91 W., has been studied by E. E. Slosson, of the University of Wyoming, who gives the following results of his investigation:

Distillation of Bonanza petroleum.[a]

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

Boiling point (° C.)	Gravity of distillate.	
	Specific.	Baumé (°).
60–157	0.762	53.5
157–200	.792	46.5
200–237	.822	40.3
237–273	.843	36.1
273–297	.853	34.1
297–329	.857	31.4
329–371	.876	29.8
371–391	.861	36.6

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

Five samples of natural gas collected by displacement of air from wells in the Big Horn Basin have been analyzed in the laboratory of the Bureau of Mines, as follows:

Analyses of natural gas from the Big Horn Basin, Wyo.

[G. A. Burrell, analyst.]

Laboratory No.	Anticline. Name.	Anticline. No. on map. (Pl. I)	No. of well.	Specific gravity (air free).	Carbon dioxide (CO_2).	Oxygen (O_2).	Methane (CH_4).	Ethane (C_2H).	Nitrogen (N_2).	Heating value at 0° C. and under 760 mm. pressure (calculated).	Remarks.
3224	Greybull..	2	9	0.64	0.20	0.00	81.70	17.3	0.75	1,192 B. t. u..	Claroline absorption 26.
3222	.....do....	2	2	.77	.00	.00	51.55	47.20	1.25	1,427 B. t. u..	Claroline absorption 22.6.
6851	.....do....	2	24	.85	.10	3.20	38.70	42.50	15.50	1,203 B. t. u..	Amount of O_2 and N_2 present suggest that bottle contained some air.
5722	Lamb....	5	23	.59	.04	.00	93.5	3.5	2.6	1,061 B. t. u..	
3220	Byron....	.....	.....	.68	.47	.00	64.05	32.28	3.20	1,282 B. t. u..	Claroline absorption 18.2.

3224. From Island No. 1 well (No. 9 on fig. 5, p. 57) in the NW. ¼ SW. ¼ sec. 16, T. 52 N., R. 93 W. Collected by W. R. Calvert, winter of 1912–13.

3222. From an unknown oil well in the same field from which some gas escapes. Collected by W. R. Calvert, winter of 1912–13.

6851. From Thomas Alford No. 1 (No. 24 on fig. 5), in the SE. ¼ SW. ¼ sec. 17, T. 52 N., R. 93 W., in the Greybull field. Collected, June, 1915.

5722. From Lamb No. 1 well (No. 23 on Pl. IX, p. 78) in the SE. ¼ SE. ¼ sec. 12, T. 51 N., R. 93 W., on the Lamb anticline.

3220. From an unknown well in the Byron field. Collected by W. R. Calvert, winter 1912–13.

GENERAL DEVELOPMENT.

Details of development are described later in connection with the individual anticlines and only a chronologic record of the development of the fields is here presented. Exceptions are made, however, in certain fields (Byron, Elk Basin, and others) that lie outside of the area covered in detail in this report.

TESTED DISTRICTS.

BONANZA REGION.

The first discovery of oil in the Big Horn Basin is believed to have been made at the Bonanza oil seep in the NW. ¼ SW. ¼ sec. 23, T. 49 N., R. 91 W., in 1884 by Edward Lloyd. No drilling was done in this locality until 1888, when a well (No. 12, Pl. XI, p. 98) sunk to about 1,200 feet encountered a little artesian water but no oil or gas. Since 1888 a number of wells have been drilled in this

general locality, but none has found oil and gas in commercial quantities. The total production of this field is estimated to be not more than 50 barrels.

TORCHLIGHT DOME.

The Torchlight dome was the second field in the Big Horn Basin to be tested. In 1905 two shallow wells (Nos. 1 and 2, Pl. IX, p. 78) drilled on the top of this dome encountered gas and a showing of oil. Since 1905 the field has been tested sufficiently to outline the pool, the development being due largely to the efforts of the Greybull Oil Co. The daily production of the field on the basis of 50 producing wells was estimated early in 1915 to be not less than 1,500 barrels.

BYRON ANTICLINE.

Gas was discovered in the Byron field, in the northern part of the Big Horn Basin, but outside the area covered by this report, in the winter of 1903 and 1904, but no drilling was done until 1906, when a well sunk by the Montana-Wyoming Oil Co. found oil. Since 1906 the development of the field has been continuous, and some high-grade oil and a large amount of gas have been produced. The largest gas well in the State, said to yield 40,000,000 cubic feet of gas daily, was brought in by the Ohio Oil Co. in 1915. The daily production of oil was estimated in 1915 to be 300 to 400 barrels.

LAMB ANTICLINE.

The Lamb anticline was first tested in 1907, but only a showing of oil and gas was obtained, and it was not until 1913 that a large flow of gas was discovered, and not until 1914 that a heavy oil was struck. No oil is being produced at the present time.

GREYBULL DOME.

The Greybull field was first drilled in 1907, gas being discovered first and oil the following year. After 1908 many gas wells were brought in and the field was considered preeminently a gas field; later, however, wells farther from the top of the dome produced large quantities of oil, so that now the field is best known for its oil production. The daily production of oil in the Greybull field on April 1, 1916, was estimated to be 3,000 to 4,000 barrels.

SHOSHONE ANTICLINE.

The Shoshone anticline near Cody was first tested in the winter of 1909 and 1910. Oil and gas in commercial quantities have not been discovered in any of the wells and probably not more than 200 barrels of oil has been produced during a period of two or three years.

OREGON BASIN DOMES.

The Oregon Basin field was tested first in 1912. Considerable gas was encountered in two wells which have, however, yielded only traces of oil.

GRASS CREEK ANTICLINE.

The first drilling in the Grass Creek anticline is reported to have been done in 1913, but the first well to find oil in commercial quantities was not brought in until 1914. In October, 1916, about 193 wells had been drilled, 129 of which were pumping. It is estimated that if all the oil wells in this field were pumped the production would be between 6,000 and 7,000 barrels daily.

BUFFALO BASIN ANTICLINE.

The Little Buffalo Basin field, like the Grass Creek field, is reported to have been tested first in 1913; but the first well to produce gas in commercial quantity was not drilled until 1914. The gas wells have been capped and several new wells were being drilled in October, 1916.

ELK BASIN ANTICLINE.

Oil in the Elk Basin anticline, situated on the State line between Wyoming and Montana, was discovered in October, 1915. A number of wells are producing oil and more are being drilled at the present time. A pipe line has been constructed from this field to Frannie, a station on the Chicago, Burlington & Quincy Railroad, where there is a tank farm and loading racks. On July 1, 1916, it was reported that 21 wells were producing and that the pipe line was transporting 1,000 barrels of crude oil daily.

OTHER DISTRICTS.

Drilling has been done on a number of other anticlines. The greatest development is being prosecuted on the Sherard dome on the east side of the basin, where in 1914 and 1915 seven wells were drilled, six of which found oil in small quantity. Probably not more than 25 barrels have been obtained in this locality.

Four wells have been drilled on the Waugh anticline, but none are productive.

The Cherry anticline, Shell Creek dome, Neiber anticline, Gebo dome on the Lucerne anticline, and Spring Creek anticline were tested in 1915 and the Wagonhound, Enos Creek, and Gooseberry anticlines and Little Grass Creek dome in 1916, but all have thus far failed to yield oil or gas in commercial quantities.

REFINERIES.

The oldest refinery in the Big Horn Basin is at Cowley, on the Chicago, Burlington & Quincy Railroad, in the northern part of Wyoming, outside of the area described in this report. This plant has been in operation for six years or more and is said to have a capacity of 160 barrels of crude oil a day. It is connected with the Byron oil field by means of a pipe line about 7 miles in length. Up to 1915 this plant was able to refine practically all the crude oil from the Byron field.

The largest refinery in the basin is at Greybull. It was begun in the spring of 1915 and was ready for operation by the end of that year. On July 1, 1916, it was reported to be refining 2,800 barrels of crude oil daily. It is now being enlarged and will soon have a capacity of 7,500 barrels of crude oil daily. This refinery is now under the control of the Midwest Refining Co. Before it was in operation the crude oil was shipped principally to the refineries at Casper.

It is reported that a refinery is contemplated at Chatham, on the Chicago, Burlington & Quincy Railroad, the eastern terminus of the pipe line from the Grass Creek oil field.

PIPE LINES.

Four pipe lines (from the Byron field to the Cowley refinery, from the Torchlight dome to the Greybull refinery, from the Grass Creek field to Chatham, and from the Elk Basin field to Frannie) have been constructed in the Big Horn Basin.

THE ANTICLINES AND DOMES.

SHEEP MOUNTAIN ANTICLINE.

By CHARLES T. LUPTON.

The Sheep Mountain anticline (No. 1, Pl. I), the southeast end of which is shown on the general map, is in the northeastern part of the Big Horn Basin. It was not examined in detail, and only a few general statements regarding it can be given.

The anticline is represented on the surface by a prominent ridge known as Sheep Mountain, the top of which corresponds approximately to the crest of the anticline. It is about 15 miles long and is cut by Big Horn River. The canyon thus formed is known as Sheep Mountain (Black) Canyon and has a maximum depth of about 1,000 feet. The Chicago, Burlington & Quincy Railroad follows the west side of the river through this canyon.

The lowest rocks outcropping in the anticline belong to the lower part of the Madison limestone. They dip more steeply on the east

or mountain side than on the west or basin side, as is shown by Plate I.

A well drilled for oil and gas to a depth of 1,000 feet near Spence, on Big Horn River a short distance northeast of the anticline, penetrated the Madison limestone and is reported to have found a trace of oil in the Embar and Amsden formations. The mouth of

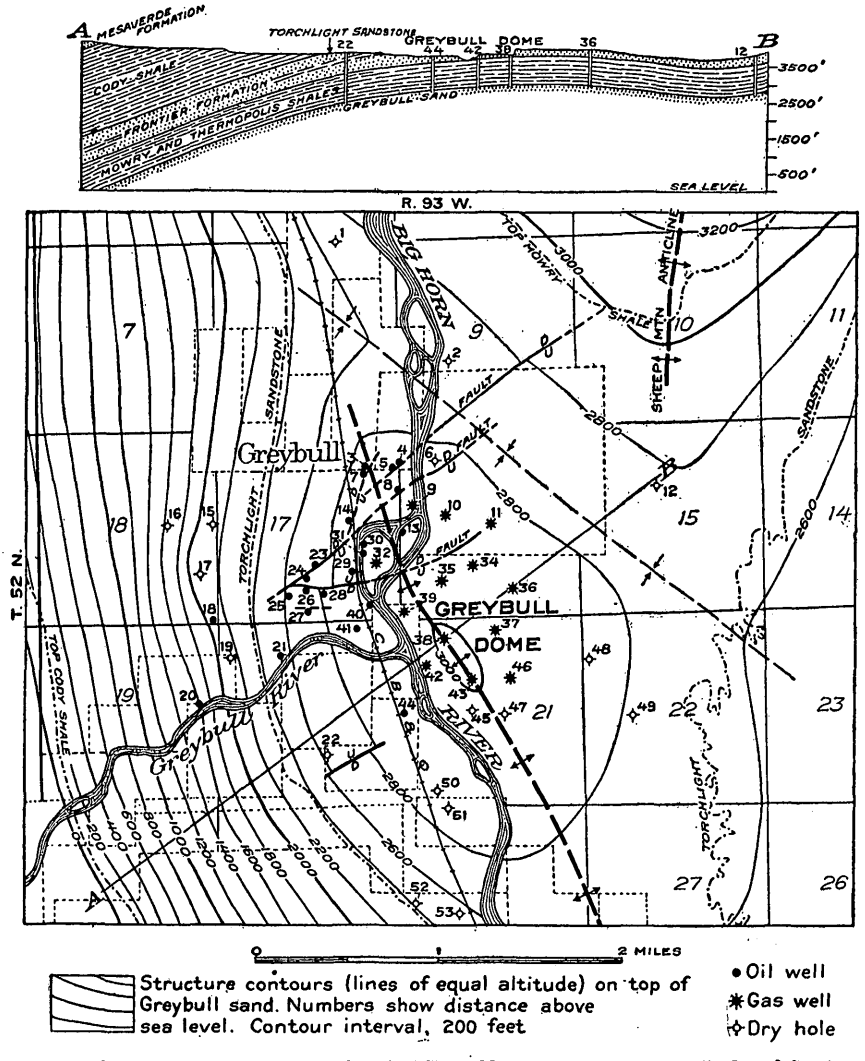


FIGURE 5.—Structure-contour map of south end of Sheep Mountain anticline (No. 1, Pl. I) and Greybull dome (No. 4, Pl. I) and structure section. The outcrops of sands are mapped as sandstone.

the well is said to be 200 feet below the top of the Chugwater formation ("Red Beds").

This anticline is of doubtful importance as a reservoir for oil and gas, as all the formations known to contain these substances in Wyoming and adjacent States are exposed at the surface.

GREYBULL FIELD.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Greybull oil and gas field (No. 4, Pl. I), discovered in 1907, yields not only a high-grade paraffin oil but also a large amount of gas. The productive area (see fig. 5), which is nearly circular in outline, with a diameter of about 2 miles, is fairly well defined by the drill holes on the eastern and southern sides. Until recently the oil has been transported to refineries in tank cars by the Chicago, Burlington & Quincy Railroad, which crosses the central part of the producing area, but now it is handled by a refinery, estimated to cost $2,500,000 and probably large enough to refine the entire production, which has just been constructed in Greybull, at the northern edge of the field. The gas from this field is used in Greybull for lighting and heating.

This field is in the northeastern part of the Big Horn Basin near the junction of Greybull and Big Horn rivers in the western part of T. 52 N., R. 93 W. It is the most easily accessible oil and gas field in the State, as no other producing field is crossed by a railroad. The most productive wells are within a mile of the railroad station, and no part of the proved field is more than 2 miles from the business section of Greybull, a town of 600 or 800 inhabitants. Wagon roads lead to all parts of the field.

The surface features of the Greybull field consist of broad comparatively shallow trenches worn in the rocks by Big Horn and Greybull rivers and of the terraces adjacent to them. The trenches range in depth from 75 feet throughout the greater part of the field to nearly 300 feet just east of the mouth of Greybull River, and in width from half a mile south of the mouth of Greybull River to 1½ miles just north of Greybull. As the terrace west of the river has not been greatly dissected by streams the surface on that side of the river is lower and much more even than it is east of the stream. For 1½ to 3 miles east of the river the surface rock is the thick sandstone which outcrops as a conspicuous cliff along the river. (See Pl. V, *A*, p. 21.) It has been upfolded with the other rocks and its upper surface, which has been only slightly worn away, now consists in most places of smooth rounded slopes. Northeast of the top of the dome there is a structural depression in which a canyon has been cut by an intermittent stream.

The elevation of the surface of the field above sea level is of importance in determining the depth to any particular sand. (See p. 39.) It ranges from about 3,775 feet at the northern edge near Big Horn River to 4,070 feet at the Wilkinson No. 3 well (No. 43, fig. 5). The

highest point in the area represented by figure 5 is about 4,400 feet at the southeast corner, but this is outside the oil and gas field.

The Greybull field has an abundance of excellent water during the entire year. The waters of Big Horn and Greybull rivers, the only perennial streams, can be used for drilling and, except during flood seasons when the water is too muddy, for domestic uses. The water supply at Greybull is derived from two deep wells situated near the river at the northeast edge of the town. Water is found in some of the oil wells in the thick sandstone (Peay), which is conspicuous in the east bluff near Greybull and on the west side of Big Horn River directly south of the refinery, but in some wells it is alkaline and sulphurous and hence is not suitable for domestic use or even for generating steam. Water is found in some of the sands in which oil and gas are absent but the water best suited for use in boilers is obtained from the rivers.

The Greybull field is a part of the area examined by Eldridge,[1] Fisher,[2] and Washburne,[3] of the United States Geological Survey, and Hintze,[4] of the Wyoming Geological Survey.

STRUCTURE OF THE DOME.

The Greybull dome is an upfold or bulge which has affected all of the rocks down to and including the principal oil-bearing sands of this region. Its shape and extent are shown in figure 5 by structure contours drawn on the Greybull sand. (See p. 57.) It is roughly elliptical with its narrow end extending northwest and its broad end on the southeast. Its southwest slope is much steeper than any other, as indicated by the close spacing of the contour lines on that side. The beds are nearly flat at the top of the dome in the NW. ¼ sec. 21. They slope gently, not over 3½°, northwest to the end of the dome; north, northeast, and east to the depression in the rocks or the syncline separating this dome from the Sheep Mountain anticline; southeast to a shallow syncline separating the Greybull dome from the Lamb anticline. On the south, southwest, and west sides of the dome the beds dip gently to a line about one-half mile from the top of the dome; here the dips rapidly increase and reach a maximum of 35° in the northwestern part of sec. 19. The depression in the rocks or syncline to the northeast of the Greybull dome is comparatively shallow, being about 250 feet in depth.

The cross section (see fig. 5) shows the positions of the rocks as they would appear on the sides of a deep trench, if one were cut

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

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

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

[4] Hintze, F. F., jr., The Basin and Greybull oil and gas fields, Bighorn County, Wyo.: Wyoming Geol. Survey Bull. 10, 1914.

northeast and southwest across the dome at its highest point. In this section the Greybull sand, which contains the oil and gas, is the lowest bed represented. At the highest point of the dome it is about 850 feet below the surface and at the southwest end of the cross section about 4,100 feet. This difference in depth is due in part to a difference in the surface elevation but more largely to the bulging of the strata, which has brought the Greybull sand, as well as other formations, nearer the surface at the top of the dome than at other places.

Gas is found in the top of the dome and oil in a lower zone on the west and northwest sides. Its accumulation there may be due in part to the presence of a low wrinkle on the dome, as is suggested by the irregularity in the structure contours in the E. ½ sec. 18, or to the presence of water in the Greybull sand close to the gas wells on the north, east, and southeast sides. In the writer's opinion the latter is the more probable explanation, the water having perhaps pushed the oil toward the west and northwest. Water can easily enter the oil and gas sand at its outcrop around the south end of Sheep Mountain 3 to 4 miles north of the Greybull dome. It is well known that water in a well will prevent the oil and gas from entering the hole, especially when the rock pressure is less than the pressure of the water. Hence it seems reasonable to assume that water in the Greybull sand may have crowded the oil away from the northeast, east, and southeast sides of the dome and confined it to the northwest and west sides, where it now occurs.

Faults may have had some effect on the accumulation of oil on the west and northwest sides of the dome. Several faults of slight throw cut the beds in the north half of the dome, but they can not be traced far from the river bluffs. Five of these are shown on the map. Others not apparent on the surface are known from well logs to be present west of Big Horn River, where the larger part of the surface is covered with a veneer of alluvium on the flood plain and of gravel on the terrace. They trend northeast and are of the step-fault variety, having the downthrow mainly on their northwest sides.

The planes of these faults are cut by several wells drilled in this field. Wherever a well cuts the plane of a normal fault the distance between recognizable beds is less than where the strata are undisturbed. This condition is illustrated by figure 6. In this ideal figure, wells 1 and 3 do not cut the fault plane; but well 2 does, and in it the distance between the two beds of sandstone is less than in wells 1 and 3. A careful study of the well logs in the Greybull field reveals the fact that the distance between the top of the Peay sand and the top of the Greybull sand is in places 170 feet less than normal. In wells 3, 5, 14, 23, 26–28, figure 5, the distance between the sands

mentioned is less than normal, and it is therefore believed that the wells cut the planes of normal faults. Faults in the midst of a proved oil and gas field like the Greybull tend to show that under certain conditions sands adjacent to fault planes may become sealed and thus prevent the migration of oil and gas into the faults.

At the highest part of the dome the rocks exposed along Big Horn River belong to the lower part of the Frontier formation and the upper part of the Mowry shale. The prominent sandstone (see Pl. V, *A*) exposed in the bluff directly east of Greybull is the Peay sand, which occurs in the lower part of the Frontier formation. The base of the Peay is about 75 feet above the top of the Mowry shale, which outcrops near the water's edge in the western part of sec. 21. The Mowry shale is not fully exposed in this vicinity but is shown by

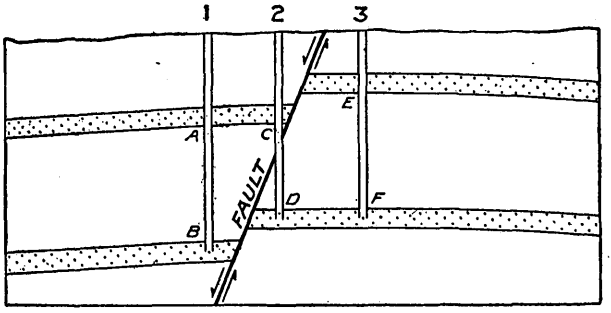


FIGURE 6.—Diagram showing the effect of a fault on the apparent thickness of a formation.

many wells to be about 175 feet thick and to embrace two sandy beds, the Kimball and Octh Louie sands, which in this field contain small quantities of oil. In the Torchlight dome (see pp. 75–81) these sands are the principal reservoirs for oil. Underlying the Mowry is the dark Thermopolis shale, about 700 feet thick. It contains, about 300 feet above the base, a very persistent sandstone known as the Muddy sand, which contains a little gas. Directly underlying the Thermopolis shale is the Greybull sand, which contains the oil and gas in the Greybull field. It has an average thickness of about 20 feet and constitutes the upper part of the Cloverly formation, which in this locality is about 115 feet thick.

The logs of one gas well and one oil well are given below in order to show the character of the rocks intervening between the surface and the Greybull sand, the reservoir of the gas and oil in this field. The log of the Minor well (No. 38, fig. 5), the first to find gas, in the NW. ¼ NW. ¼ sec. 21, T. 52 N., R. 93 W., is reported by the drillers as follows:

Record of Minor well, Greybull field, Wyo.[a]

	Thickness.	Depth.
	Feet.	*Feet.*
Shale	17	17
Shale, hard, dark; probably the ridge-making layer of the Mowry	3–4	20
Shale, dark	300	320
Clay, soft, white; probably bentonite: caused the well to cave badly	3	323
Shale, dark	127	450
Clay, white, sandy; Muddy sand	40–50	495
Shale, black	155	650
Shale, hard	? 1	651
Shale, black	49	700
Rock, very hard	1	701
Shale, black	49	750
Rock, very hard	7	757
Shale, black	38	795
Rock, hard	5	800
Sandstone (Greybull sand), containing gas under high pressure	20	820
Shale, red, bottom of hole	5	825

[a] Mainly from the log given by Washburne, C. W., Gas fields of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 340, p. 352, 1908.

The well was drilled originally 801 feet deep, or to the top of the Greybull sand. The mouth of the well is about 3,800 feet above sea level and would be 165 feet below the base of the Peay sandstone were that sandstone extended from its outcrop in the high bluffs east of the river to the vicinity of the well.

The Meade No. 1 well (No. 8, fig. 3) of Bighorn Oil & Gas Co., in the SE. ¼ NE. ¼ sec. 17, T. 52 N., R. 93 W., is near the refinery but on the east side of the railroad, in Greybull. The log follows:

Record of Meade No. 1 well, Greybull field, Wyo.

	Feet.
Top of Muddy sand	583
Top of Greybull sand (contains oil)	915
Bottom of Greybull sand (bottom of hole)	935

The mouth of this well is 3,810 feet above sea level. Water was encountered down to a depth of a little more than 100 feet and was cased off at 115 feet.

DEVELOPMENT.

The first well in this field (Minor No. 38) was drilled in July, 1907, and produced only gas, whose initial flow has been estimated at 8,000,000 to 10,000,000 cubic feet daily. The gas became accidentally ignited soon after the well was completed and burned for more than a year and a half. Fifteen months after this first well was drilled a well (the George Alford No. 1, No. 40 on fig. 5) yielding high-grade oil and a little gas was brought in. Since 1908 about 70 wells have been drilled in this field, mainly by the Bighorn Oil & Gas Co., of Greybull. The following table, complete up to October 10, 1915, shows considerable data regarding the development of the field. If a well yields neither oil nor gas in commercial quantities it is shown

on the map as a dry hole. In this table if it contains water, but no oil or gas, "Water" is placed in the "Result" column. If it yields neither oil, gas, nor water, "Dry" is placed in the "Result" column.

Wells in T. 52 N., R. 93 W., of Greybull field, Wyo.[a]

No. on map (fig. 5, p. 57)	Name.	Owner.	Result.[b]	Depth to Greybull sand.	Date drilled.	Location.
1	Node No. 1	Bighorn Oil & Gas Co.	Water	1,092	Jan. and Feb., 1911.	SW. ¼ SE. ¼ sec. 5.
2	Well north of school section.	do	do	1,114	(?)	NE. ¼ SW. ¼ sec. 9.
3	Stubbs No. 2	Lincoln Land Co.	Oil	971	Sept., 1915	NE. ¼ NE. ¼ sec. 17.
4	Stubbs No. 1	do	A little oil	970	do	Do.
5	Stubbs No. 3	do	Oil	980	do	NW. ¼ NE. ¼ sec. 17.
6	School section No. 2.	Bighorn Oil & Gas Co.	Dry	1,100±	May, 1910	NW. ¼ NW. ¼ sec. 16.
7	(?)	do	Oil	940±	Sept., 1915	NE. ¼ NE. ¼ sec. 17.
8	Meade No. 1	do	do	915	Mar., 1910	Do.
9	Island No. 1	do	Gas and a little oil.	882	Nov., 1910	SW. ¼ NW. ¼ sec. 16.
10	School section No. 1.	do	Gas	1,060	(?)	Do.
11	School section No. 3.	do	do	1,066	(?)	NW. ¼ SE. ¼ sec. 16.
12	Hoodoo	do	Water	1,043	Aug., 1909	SE. ¼ NW. ¼ sec. 15.
13	Island No. 5	do	Oil	879	Sept., 1914	SW. ¼ NW. ¼ sec. 16.
14	Stony Point	do	do	977	Mar., 1909	SW. ¼ NE. ¼ sec. 17.
15	Brickyard No. 1	do	Dry	1,730	Mar., 1910	SE. ¼ NE. ¼ sec. 18.
16	Rubel	do		(c)	June and July, 1914.	SW. ¼ NE. ¼ sec. 18.
17	Juell (never completed).	do		(c)	Dec., 1909	SE. ¼ SE. ¼ sec. 18.
18	Juell No. 1	do	Oil	1,795	Mar. and Apr., 1911.	Do.
19	Ohio Oil Co. No.	Ohio Oil Co	Dry	1,700	Sept., 1915	NW. ¼ NW. ¼ sec. 20.
20	(?)	(?)	(Oil reported in Kimball sand.)	(?)	(?)	NW. corner lot 60.
21	Cusick	Bighorn Oil & Gas Co.	Oil	1,260	Aug., 1910	NE. ¼ NW. ¼ sec. 20.
22	Alderdice	Champion Oil Co.	Water	1,185	Mar., 1914	NW. ¼ SE. ¼ sec. 20.
23	George Alford No. 3.	Bighorn Oil & Gas Co.	Oil	1,080	Nov. and Dec., 1914.	NW. ¼ SE. ¼ sec. 17.
24	Thomas Alford No. 1.	do	do	1,140	Sept., 1909	SE. ¼ SW. ¼ sec. 18.
25	Thomas Alford No. 3.	do	do	1,255	May and June, 1915.	SE. ¼ SW. ¼ sec. 17.
26	Thomas Alford No. 2.	do	do	1,125	Mar., 1915	Do.
27	Thomas Alford No. 4.	do	do	1,115	June and July, 1915.	Do.
28	George Alford No. 4.	do	do	1,035	do	SW. ¼ SE. ¼ sec. 17.
29	George Alford No. 2.	do	do	975	Aug. and Sept., 1909.	Do.
30	Island No. 3	do	do	897	Aug., 1914	SW. ¼ NE. ¼ sec. 17.
31	Island No. 4	do	do	899	Aug. and Sept., 1914.	NE. ¼ SE. ¼ sec. 17.
32	Island No. 2	do	Gas and a little oil.	880	Feb., 1909	Do.
34	Armstrong No. 1	do	Gas	1,075	May, 1909	NE. ¼ SW. ¼ sec. 16.
35	Wilkinson No. 4	do	do	852	Oct. and Nov., 1912.	SW. ¼ SW. ¼ sec. 16.
36	Armstrong No. 2	do	do	1,075	Oct., 1912	SW. ¼ SE. ¼ sec. 16.
37	Durham No. 1	do	do	1,072	May, 1909	NW. ¼ NE. ¼ sec. 21.
38	Minor	do	do	825±	July, 1907	NW. ¼ NW. ¼ sec. 21.
39	Homestead No. 1	do	do	841	Feb., 1910	SW. ¼ SW. ¼ sec. 16.
40	George Alford No. 1.	do	Oil	887	Oct., 1908	SE. ¼ SE. ¼ sec. 17.
41	Rusk No. 1	do	do	944	(?)	NE. ¼ NE. ¼ sec. 20.
42	Wilkinson No. 1	do	Gas	815	Jan., 1910	SW. ¼ NW. ¼ sec. 21.
43	Wilkinson No. 2	do	do	1,067	Sept., 1910	SE. ¼ NW. ¼ sec. 21.

[a] About 20 additional wells were drilled on this dome between Oct. 10, 1915, and Apr. 1, 1916.
[b] The results given in this column pertain to the Greybull sand only.
[c] Not reported.

Wells in T. 52 N., R. 93 W., of Greybull field, Wyo.—Continued.

No. on map (fig. 5, p. 57).	Name.	Owner.	Result.	Depth to Greybull sand.	Date drilled.	Location.
44	Smith No. 1	Bighorn Oil & Gas Co.	Oil	854	Aug., 1912	NW. ¼ SW. ¼ sec. 21.
45	Wilkinson No. 3	do	A little gas	1,065	Sept., 1912	NW. ¼ SE. ¼ sec. 21.
46	Durham No. 2	do	Gas	1,078	Sept. and Oct., 1912.	SW. ¼ NE. ¼ sec. 21.
47	Lamb No. 1	do	Water	1,070	July, 1909	NW. ¼ SE. ¼ sec. 21.
48	Neuenschwander No. 1.	do	Trace of oil	1,116	June, 1910	SW. ¼ NW. ¼ sec. 22.
49	Madison No. 1	do	Dry	1,197	July, 1910	NW. ¼ SW. ¼ sec. 22.
50	Maloney No. 1	Jones & Buell, Okla.	Water	936	(?)	SW. ¼ SW. ¼ sec. 21.
51	Skinner No. 1	Bighorn Oil & Gas Co.	do	952	Feb., 1910	NE. ¼ NE. ¼ sec. 28.
52	Ahrens No. 1	Mid-Continent Oil Co.		(a)	(?)	NW. ¼ SW. ¼ sec. 28.
53	Himes No. 1	do	A little gas	1,200	(?)	NE. ¼ SW. ¼ sec. 28.

a Not reached.

During the summer and autumn of 1915 an impetus was given to drilling operations by the discovery in Greybull of larger oil wells than any previously known in this field. Some of these wells are reported to have at first yielded as much as 500 barrels daily, but the production is said to have dwindled to about 100 barrels daily after they had been pumped for a few weeks and to have diminished greatly since that time.

It is estimated that the daily oil production of the Greybull field on October 1, 1915, was 1,500 barrels, or at the rate of slightly more than a half million barrels annually. On April 1, 1916, the production was estimated to be 3,000 to 4,000 barrels daily, but in the fall of 1916 it had declined greatly.

QUALITY OF OIL AND GAS.

The oil is high grade and has a paraffin base. In reflected light it has a dark-green color and in transmitted light a dark wine color. The specific gravity of the oil is 0.7856 or about 48° Baumé. An analysis made by the Bureau of Mines of a sample of oil collected from the George Alford No. 1 well (No. 40, fig. 3) in this field is as follows:

Analysis of oil from George Alford No. 1 well, in the SE. ¼ SE. ¼ sec. 17, T. 52 N., R. 93 W.

Began to boil at 30° C.

Gasoline:	Per cent.
To 50° C	3.5
50° to 75°	4
75° to 100°	7.5
100° to 125°	9
125° to 150°	7
	31

Kerosene:	Per cent.
150° to 175°	6
175° to 200°	5
200° to 225°	5
225° to 250°	5
250° to 275°	5
275° to 300°	6.5
	32.5
Residuum	36.5
Sulphur	.04

Specific gravities at 60° F.:	
Crude oil (48.2° Baumé)	0.7856
Gasoline (66.6° Baumé)	.7120
Kerosene (47.2° Baumé)	.7900
Residuum (33.2° Baumé)	.8579

A sample of gas (laboratory No. 6851) from the Thomas Alfred No. 1 well (No. 24, fig. 5), in the SE. ¼ SW. ¼ sec. 17, T. 52 N., R. 93 W., was analyzed by the Bureau of Mines. The analysis shows a high percentage of nitrogen and much oxygen, suggesting that the bottle in which the gas was collected must have contained some air with the gas, because in the analyses of samples of natural gas collected from the Greybull field by W. R. Calvert [1] the oxygen content is zero and the maximum nitrogen content 1.25.

Analysis of natural gas from Thomas Alfred No. 1 well, in the SE. ¼ SW. ¼ sec. 17, T. 52 N., R. 93 W.

[G. A. Burrell, analyst.]

Specific gravity (air=1)	0.85
Carbon dioxide (CO_2)	.10
Oxygen (O_2)	3.20
Methane (CH_4)	38.70
Ethane (C_2H_6)	42.50
Nitrogen (N_2)	15.50
	100.00

The heating value of this gas at 0° C. and 760 millimeters pressure (calculated) is 1,203 British thermal units.

The analysis by the Bureau of Mines of a sample of gas collected by W. R. Calvert [1] from Island No. 1 well (No. 9, fig. 5) is given below:

[1] Calvert, W. R., A preliminary report on the utilization of petroleum and natural gas in Wyoming: Bur. Mines Tech. Paper 57, p. 13, 1913.

Analysis of natural gas from Island No. 1 well, in the SW. ¼ NW. ¼ sec. 16, T. 52 N., R. 93 W.

[Laboratory No. 3224. G. A. Burrell, analyst.]

Specific gravity	0.64
Carbon dioxide (CO_2)	.20
Oxygen (O_2)	.00
Methane (CH_4)	81.70
Ethane (C_2H_6)	17.35
Nitrogen (N_2)	.75
	100.00

CONCLUSIONS.

The productive and possibly productive areas of the Greybull field are limited definitely in places by dry holes. This is particularly true of the southern part, where dry wells 22, 45, 47, 50, and 51 are near productive wells 43, 44, and 46. It is probable that wells drilled within one-fourth mile southwest, south, southeast, and east of well 44 may yield some oil, but it is doubtful if the quantity will be large. Little gas will be found in this locality unless faults or some other factor not noticeable on the surface create conditions favorable for its accumulation. Dry holes (48 and 49, in the W. ½ sec. 22) limit the field to the southeast. Possibly other gas wells or small oil wells may be found as far as one-fourth mile east of wells 36, 37, and 46. Well 48 showed a trace of oil which suggests that more may be found farther up the slope of the dome or to the west and northwest. Between the synclinal axis and wells 10, 11, 34, and 36 oil and gas wells of slight production may be brought in.

The west side of the dome is the most promising for future development. The recent discovery of oil in wells (Nos. 3, 4, 5, and 7) in the northeastern part of sec. 17 suggest that the oil pool may extend north nearly to the synclinal axis. The position of oil wells Nos. 23–28, inclusive, in the southern part of sec. 17, and No. 18 in the southeastern part of sec. 18, indicates that the west boundary of the oil-producing territory may follow the 2,400-foot structure contour from a point near the synclinal axis south to a point east of dry hole 15. From this point it probably swings west and south around wells 18–21, and thence goes nearly east, keeping north of well 22 to the line A–B (fig. 5, p. 57), and thence southeast to a point midway between wells 22 and 44, there connecting with the line above described. Well 19, belonging to the Ohio Oil Co., is reported to be absolutely dry, this suggesting that the productive area is "spotted."

The northwest boundary of the field, as indicated above, has not been determined. It seems probable to the writer that the productive area extends farther toward the southwest than in any other direction, because in this field the best wells seem to be associated with faults and the fault zones trend northeast-southwest. At the

northeast the field is limited by the synclinal axis. The presence of dry holes 15 and 16 on the north and 22, 50, and 52 on the south of oil wells 17–21 indicates that the productive belt extending to southwest is about a mile in width. It seems doubtful if the productive territory extends far southwest of well 20.

Close drilling within the area outlined above may increase the present output of oil, but the enormous amount of gas that escaped from the Minor well in 1907 and 1908 has so reduced the pressure and quantity that it seems doubtful whether the production of gas will be greatly increased by further drilling.

SHELL CREEK DOME AND CHERRY ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Shell Creek dome (No. 2, Pl. I) and the Cherry anticline (No. 3, Pl. I) are closely connected upfolds in the drainage basin of Shell Creek, about 8 miles northeast and east of Greybull, a town of 600 or 800 inhabitants on the Chicago, Burlington & Quincy Railroad. The Shell Creek dome has been fully tested for oil and gas, with negative results. The Cherry anticline has been tested by one well, which presumably penetrated the Embar formation, in this locality the most promising reservoir for oil and gas. According to report, oil was thought to have been found in this formation, but the quantity must have been so small as to be negligible. As the probability of obtaining oil and gas in these upfolds is extremely doubtful, their descriptions will necessarily be brief. They are considered together, as they are closely related structurally.

The Shell Creek dome lies in secs. 29–32, T. 53 N., R. 92 W., and the Cherry anticline mainly in secs. 3–5, 8–10, T. 52 N., R. 92 W., about 2½ miles southeast of the Shell Creek dome and 8 miles east of Greybull.

Both anticlines are easily accessible, as a good road leading from Greybull to Shell, a town on Shell Creek near the west base of the Big Horn Mountains, follows in general the course of Shell Creek and lies between the two folds. Numerous secondary roads enable one to examine both areas with comparative ease.

The principal surface feature in this locality is the valley of Shell Creek, which crosses the south edge of Shell Creek dome. The surface along the crests (formerly called axes) of the anticlines is characterized by basin-like depressions, formed by the wearing away of the soft rocks by streams tributary to Shell Creek, surrounded by low walls of variegated sandstone and shale. In places, particularly along the west side of the Cherry anticline, long, straight, narrow hogbacks trend northwest. At many places along the smaller tributary

streams and particularly near their heads badlands make travel difficult.

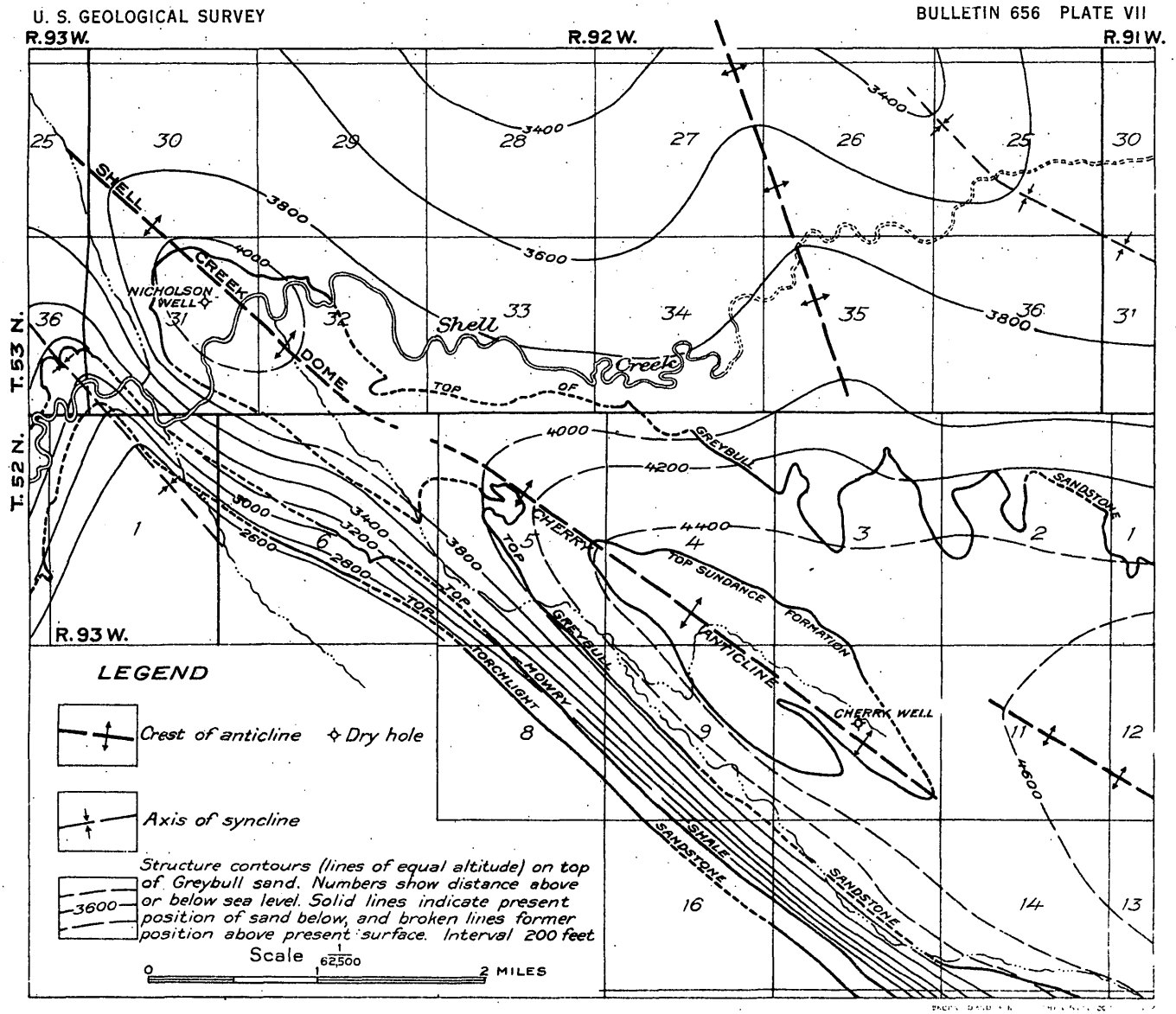
The water supply of both anticlines is abundant, as Shell Creek crosses Shell Creek dome, and an irrigation canal from Shell Creek, 8 or 10 miles distant, crosses the Cherry anticline near its middle. Water from this canal and from Shell Creek is used for drilling, camp, and domestic purposes. Water was also found, according to report, in the well drilled in the Shell Creek dome, being probably derived from some of the sands in the Chugwater formation ("Red Beds"), which overlie the limestone in which the oil and gas were thought to occur.

SHELL CREEK DOME.

The Shell Creek dome is elliptical in outline and trends northwest and southeast. Its steepest slope is on the southwest side, where the beds dip as much as 25°. At the south end of the dome the beds dip gently southeast into the low sag separating the dome from the Cherry anticline. On the northeast side of the Shell Creek dome the beds are much more nearly flat than they are on the southwest side, ranging from zero on the crest to about 9° one-half mile distant. From this region they gradually flatten to 2° in the NW. ¼ sec. 29, T. 53 N., R. 92 W. On the northwest side of the dome the beds dip slightly for 2 miles to a shallow syncline or depression in the rocks that separates the Shell Creek dome from the large anticline of Sheep Mountain (No. 1, Pl. I).

The lowest rocks exposed in this dome belong to the Morrison formation, which consists of 200 to 300 feet of variegated shale and sandstone. Overlying the Morrison is the Cloverly formation, about 125 feet thick, which consists of an upper sandstone—the Greybull sand—which carries the oil and gas in the Greybull field. Underlying this bed there are about 75 feet of variegated shale, mainly red in color, and underlying this shale is a conglomeratic sandstone about 25 feet in thickness. Overlying the Cloverly formation and surrounding the dome on the southwest and northeast is the Thermopolis shale, a dark bluish-gray shale 600 or 700 feet thick with a sandstone bed (Muddy sand) about 275 feet above its base. This sand is not known to contain oil or gas in commercial quantities except in the Oregon Basin (p. 185).

Directly underlying the Morrison formation, the upper part of which constitutes the surface rocks at the top of the dome, is the Sundance formation, about 300 feet thick, consisting mainly of light-green sandstone and shale. Below these rocks is the Chugwater formation ("Red Beds"), 900 to 1,000 feet thick, and directly underlying the Chugwater is the Embar formation, embracing the limestone in which oil and gas were thought to occur in this locality.



STRUCTURE CONTOUR MAP OF SHELL CREEK DOME AND CHERRY ANTICLINE
(Nos. 2 AND 3, RESPECTIVELY, ON PLATE I)

The outcrops of sands are mapped as sandstones

By Charles T. Lupton

The structure contours drawn on the top of the Greybull sand (top of the Cloverly formation) show the shape and extent of the Shell Creek dome. (See Pl. VII.) From these and from the surface elevations, which range from about 3,925 feet in the SW. ¼ sec. 31, T. 53 N., R. 92 W., to about 4,550 feet near the center of sec. 11, T. 52 N., R. 92 W., the approximate depth to the top of the Greybull sand or to any other sand whose relation to the Greybull is known may be determined. (See pp. 39–41.)

CHERRY ANTICLINE.

The Cherry anticline is a northwestward-pitching wrinkle on the west flank of the Big Horn Mountains. It is unsymmetrical, with its southwest limb narrower than its northeast limb. The beds on this flank at points about a mile from the crest, however, have an average dip of 42° and attain a maximum dip of 50° in the SE. ¼ sec. 15, T. 52 N., R. 92 W. The dips decrease to zero at the crest of the anticline and also in the opposite direction to the axis of the syncline separating this anticline from that of Greybull dome to the southwest. A mile or more southeast of the Cherry well the pitch of the anticline to the northwest is less than it is farther southeast, thus forming a terrace-like structure.

The lowest rocks exposed along the crest of the anticline belong to the upper part of the Sundance formation, which, with other formations outcropping and lying beneath the surface in this locality, as well as the structure contour, are described in connection with the Shell Creek dome (p. 67). (See also p. 18.)

DEVELOPMENT.

Two wells have been drilled on these anticlines. One, the Nicholson well, near the center of Shell Creek dome, in the SW. ¼ NE. ¼ sec. 31, T. 53 N., R. 92 W., is about 2,000 feet deep and is reported to have penetrated the Embar formation, which was thought to have contained oil or gas. Its mouth is about 3,975 feet above sea level. The other, the Cherry well, on the Cherry anticline, in sec. 10, T. 52 N., R. 92 W., is well located near the crest line of the anticline and is reported to have reached a depth of about 700 feet but found no oil or gas. According to careful estimates, the drill did not reach the limestone but went only a little more than halfway through the Chugwater formation ("Red Beds"). Its mouth is about 4,100 feet above sea level. Both wells were drilled during the spring and summer of 1915, that on the Shell Creek dome by O. W. Nicholson, of Basin, Wyo., and that on the Cherry anticline, according to report, by Scott Mills, of Basin, Wyo., for the Cleveland-Wyoming Oil Co.

CONCLUSIONS.

As the Shell Creek dome has already been tested by a well at the top of the dome and found not to be a reservoir for oil or gas, further drilling is inadvisable. The Cherry anticline has not been thoroughly tested, but the presence of water in the Shell Creek dome and the general northwesterly pitch of the Cherry anticline make the occurrence of oil or gas in commercial quantities doubtful. Hence, the writer advises against the expenditure of more money in further attempts to test either anticline.

LAMB ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Lamb anticline (No. 5, Pl. I) and Torchlight dome are shown on the same map (Pl. IX, p. 78), as they are very closely related structurally.[1] They are, however, described separately. The Lamb anticline yields not only large quantities of gas from wells drilled near the crest line but also some heavy lubricating oil. The productive area of this anticline has not been definitely outlined by wells except on the east and south. To the west and northwest there is a broad area a mile or more in width and about 2 miles in length in which no wells have been sunk. The anticline may yield some gas and probably considerable oil of a type heavier than that found in Torchlight dome.

The Lamb anticline is about 3½ miles northeast of Basin and about the same distance from the south edge of the Greybull field. It lies principally in secs. 7, 17, and 18, T. 51 N., R. 92 W., and secs. 1, 2, 11–14, T. 51 N., R. 93 W. It can be reached most easily from Basin, on the Chicago, Burlington & Quincy Railroad, from which place good roads to all parts of the anticline make easy the transportation of machinery and supplies.

The central part of the anticline is represented on the surface by a depression formed by the wearing away of the rocks by a small intermittent stream, which after flowing south through Torchlight dome empties into Big Horn River in the western part of sec. 26, T. 51 N., R. 93 W. The walls of this basin-like depression consist of ridges of shale from 200 to 400 feet in height. In places, especially on the eastern side of the anticline, these inward-facing walls of shale are very steep, and near the heads of gulches the slopes have been cut into typical badlands, across which it is almost impossible to travel except on foot. The high ridge on the west whose eastern

[1] A more complete description of these anticlines is given in U. S. Geol. Survey Bull. 621, pp. 157-190, 1916.

slope is more gentle than its western, separates the depression from the flood plain of Big Horn River; and the ridge on the east slopes gently and merges with the broad rolling country which constitutes the greater part of the area between the anticline and the southwest base of the Big Horn Mountains.

The surface elevations range from about 4,150 feet in the SE. ¼ sec. 12, T. 51 N., R. 93 W., to about 4,550 feet near the north quarter corner of sec. 11 of the same township. From these elevations the approximate depths to the various sands may be calculated. (See p. 39.)

The main water supply comes from well No. 18 (Columbia No. 1) in the SE. ¼ NE. ¼ sec. 12, T. 51 N., R. 93 W., which produces fresh water from the lower part of the Peay gas sand. It is pumped to the Torchlight camp 2½ miles to the south for domestic purposes. Water has been found in this sand by many of the wells on the anticline, but in none of them is it known to be so fresh as in Columbia No. 1. An almost inexhaustible supply of water is found the year round in Big Horn River, 3 miles to the west. At no time since the discovery of fresh water in Columbia No. 1, however, has water been derived from this source for drilling or camp purposes in the Lamb anticline. A few reservoirs, made in this general locality, to catch and hold the surface run-off, have all been successful, as the water in them does not escape easily through the dense shale.

STRUCTURE.

The Lamb anticline is about 5 miles in length and trends in general northwest, but its crest line is curved, with the concave side facing the northeast. The beds dip more steeply on the northeast flank of the anticline than in any other part, reaching a maximum of 10° at a point about half a mile northeast of the axis in the SW. ¼ sec. 7, T. 51 N., R. 92 W. From this point northeastward the dip is less for a mile or more, beyond which it increases again to flatten once more west of the axis of the syncline separating this structure from the southeast extension of the Cherry anticline. (See Pl. VII.) The beds at the southeast end of the anticline do not dip more than 5° but become steeper near the synclinal axis separating the Lamb anticline from the Torchlight dome. To the west the dips are gentle (not exceeding 5°) for 2 miles from the crest line, beyond which they increase rapidly. To the northwest the dips are very gentle, not exceeding 1½° at any known point south of the south boundary of secs. 35 and 36, T. 52 N., R. 93 W.

A shallow structural sag separates the northwest end of the Lamb anticline from a small dome about a mile in diameter which lies in secs. 30 and 31, T. 52 N., R. 92 W., and secs. 25 and 36, T. 52 N., R. 93 W. The beds dip as much as 3° northwest of well No. 24 in

the southern part of sec. 25, T. 52 N., R. 93 W. A shallow cross syncline lying northwest of the Lamb anticline and of the small dome which constitutes its northeast extension separates the two from the Greybull dome.

The structure contours drawn on the Greybull sand show approximately the shape and position of the anticline. Those for the north end shown on Plate IX differ from those for the same locality shown on Plate XVIII of United States Geological Survey Bulletin 621, the positions on Plate IX being based on more detailed examinations. The cross section on the map (Pl. IX) represents the shape of the Lamb anticline and of the southern end of the Torchlight dome.

The surface rocks of Lamb anticline consist of the dark-gray Cody shale, which is a little over 3,000 feet thick and contains a few sandstone beds near the top and one near the base. None of these sandstones are exposed in or around the Lamb anticline, except the lower lenticular bed, which outcrops a mile farther south in the Torchlight dome, and the upper beds which outcrop 2 or 3 miles farther south.

The rocks directly underlying this shale compose the Frontier formation and consist of about 550 feet of beds of sandstone separated by sandy shale and clay. Two sandstones are present in this formation—an upper one, known as the Torchlight sand, found at a depth of about 160 feet below the surface in Columbia No. 1 well (No. 18 on Pl. IX), and a lower and thicker one, known as the Peay sand, about 400 feet lower. It is this lower sand that contains the gas and some of the oil. Directly underlying the Peay sand 75 to 100 feet of shale, similar to that found between the Torchlight and Peay sands, constitutes the lower part of the Frontier formation. The rocks directly below the Frontier formation—the Mowry shale—consist of 160 feet of hard, dark-gray platy shale, with two or more sandy beds, characterized by large numbers of fish scales. The uppermost of the sands is known as the Kimball, and the other, about 50 feet lower, as the Octh Louie. Both of these sands and the intervening shale are known to contain oil in the Torchlight dome but contain little in the Lamb anticline. Below the Mowry shale there is about 700 feet of dark shale, known as the Thermopolis shale, which contains a bed of sandstone (Muddy sand) 10 to 20 feet thick about 300 feet above its base. The Muddy sand is not known to carry oil or gas in commercial quantities except in the Oregon Basin. (See p. 181.) Directly below the Thermopolis shale is the Cloverly formation, about 125 feet thick, the top sandstone of which (Greybull sand) carries the oil and gas in the Greybull field. It is uncertain, however, whether or not it contains oil in this field, as it has never been tested except at well No. 24 in sec. 25, T. 52 N., R. 93 W., where it is dry. In the Torchlight dome a mile or more to the south two wells to the Greybull sand found water, proving

almost conclusively that oil and gas are lacking in the Greybull sand, in the Torchlight dome, and probably in the Lamb anticline.

The following logs of wells drilled in the Lamb anticline are given to show the depths to the sands that contain oil, gas, and water:

Log of Lane No. 1 well (No. 23, Pl. IX), SE. ¼ SE. ¼ sec. 12, T. 51 N., R. 93 W.

	Feet.
Top of Torchlight sand	5
Shale, sandy, dark	200±
Top of stray sand; contains a little gas	225
Shale, dark, sandy	200±
Top of Peay sand; contains much gas	435
Bottom of hole	445

Log of Ruth well (No. 24, Pl. IX), SW. ¼ SE. ¼ sec. 25, T. 52 N., R. 93 W.

	Feet.
Top of Peay sand; contains water	940
Top of Kimball sand, dry	1,140
Top of Muddy sand; shows a little gas	1,735
Top of Greybull sand; dry	2,060
Bottom of hole	2,100

DEVELOPMENT.

Thirteen wells have been drilled in the Lamb anticline, seven of which are dry,[1] two yield oil, and four gas. The first well, No. 29, was drilled on the edge of this anticline in 1907 by the Union Oil & Gas Co. A little gas was found but not enough to encourage further drilling, and no other development work was done until November or December, 1913, when Lane No. 1 well (No. 23, Pl. IX) near the crest was drilled to the Peay sand. A large amount of gas was found, the original flow according to information from H. T. Lamb, manager of the Greybull Oil Co., being 5,000,000 cubic feet daily. The average rock pressure at present is said to be about 145 pounds. The well was not drilled entirely through the sand, but it is doubtful if further drilling would have obtained a greater flow of gas. Near the crest line of the anticline the Peay sand is entered by the drill at a depth of 450 feet, but this depth increases with the distance from the crest line. The accompanying table furnishes information regarding the wells drilled on this anticline:

[1] The term "dry" as used in this report means, unless otherwise explained, barren of oil and gas in commercial amounts.

Wells in Lamb anticline.

No. on map (Pl. IX).	Name.	Owner.	Result.[a]	Depth to Peay sand.	Date drilled.	Location.
				Feet.		
15	Durham No. 1	Greybull Oil Co	Sulphur water	670	Apr., May, 1914	Lot 11, sec. 18, T. 51 N., R. 92 W.
16	Cushing No. 1	do	A little gas and water	735	Mar., Apr., 1914	Lot 6, sec. 18, T. 51 N., R. 92 W.
17	Harvey No. 1	do	Record lost	.....	Record lost	Lot 12, sec. 7, T. 51 N., R. 92 W.
18	Columbia No. 1	do	Gas and fresh water	630	Dec., 1913, to Feb., 1914	SE. ¼ NE. ¼ sec. 12, T. 51 N., R. 93 W.
19	Griggs No. 1	do	Water	770	July, Aug., Sept., 1914	NW. ¼ SE. ¼ sec. 1, T. 51 N., R. 93 W.
20	Wilson No. 1	do	Oil and little water	840	June, July, 1914	NW. ¼ NW. ¼ sec. 1, T. 51 N., R. 93 W.
21	Lane No. 2	do	Oil in Kimball Water in Peay	630	June, 1914	SW. ¼ SW. ¼ sec. 12, T. 51 N., R. 93 W.
22	Jennings No. 1	do	Gas	550	Dec., 1913	Lot 8, sec. 7, T. 51 N., R. 92 W.
23	Lane No. 1	do	do	440	Nov., Dec., 1913	SE. ¼ SE. ¼ sec. 12, T. 51 N., R. 93 W.
24	Ruth	do	Water	.....	Dec., 1914	SW. ¼ SE. ¼ sec. 25, T. 52 N., R. 93 W.
25	Armstrong No. 1	do	Fresh water	.....	May, 1914	NW. ¼ NW. ¼ sec. 20, T. 51 N., R. 92 W.
28	Padmore	Valentine interests	Water and a showing of oil	(b)	May, June, July, 1914	SE. ¼ NE. ¼ sec. 10, T. 51 N., R. 93 W.
29	Union Oil & Gas Co. well	Union Oil & Gas Co	Water and a little gas	440	1907	NW. ¼ NW. ¼ sec. 11, T. 51 N., R. 93 W.

[a] The results given in this column pertain only to the Peay sand.

[b] Information withheld by owners.

The gas from wells Nos. 18, 22, and 23 is piped to Basin and Greybull for domestic use. The oil in wells Nos. 20 and 21 is not being utilized. It is doubtful if drilling will be continued in this anticline outside the tracts now being drilled until a leasing law has been passed by Congress, as the area including the anticline is, for the most part, withdrawn from entry by the Government.

CONCLUSIONS.

Dry holes (Nos. 15–17, 19, 24, 25, 28, and 29) define in a very general way the outline of the productive area of the Lamb anticline. It seems very doubtful if oil and gas wells of importance will be discovered at any place more than one-fourth mile east and northeast of the crest line. The presence of dry holes Nos. 15 and 25, both of which are near the southeast end of the crest, suggests strongly that this part of the anticline is barren of both oil and gas in commercial quantities. The same is probably true of the area lying south and west of both of these wells, at least as far as the synclinal axis separating the Lamb anticline from Torchlight dome. It seems reasonable to assume that the area for more than a mile west of wells Nos. 18, 19, 22, and 23 is worthy of investigation. The presence of an oil well (No. 21) at a point nearly a mile west of gas well 23 suggests strongly that the intervening area, as well as an area lying one-fourth to one-half mile west of well 21, may contain oil. Gas wells are likely to be found adjacent to the crest line of the anticline north and northwest of well 23. It is questionable if the gas-bearing area is more than three-fourths of a mile to 1¼ miles in length from northwest to southeast or more than one-half to three-fourths of a mile wide from northeast to southwest.

TORCHLIGHT DOME.

By CHARLES T. LUPTON.

GENERAL FEATURES.

A high-grade paraffin oil and a little gas are produced from the Torchlight dome (No. 6, Pl. I), which within certain boundaries is a good producer.[1] The oil is obtained from the Kimball and Octh Louie sands of the Mowry shale and is reached by the drill at depths ranging from 400 to 600 feet.

The Torchlight dome is about 3 miles east of Basin—a town of about 1,000 inhabitants—with which it is connected by good roads. The dome lies principally in secs. 19 and 30, T. 51 N., R. 92 W., and in secs. 13, 14, 23–25, T. 51 N., R. 93 W.

[1] A more complete description of this dome and of the Lamb anticline is given in U. S. Geol. Survey Bull. 621, pp. 157–190, 1916.

The surface of the dome is characterized by a basin-like depression eroded in shale and surrounded by nearly concentric inward-facing walls with shale above and sandstone below. In places the basinward slopes are cut into badlands. This depression, which in places is 300 feet deep, has been formed mainly by the wearing away of the rocks by a stream, which begins near the north end of the Lamb anticline, flows along the crest of that upfold for more than 3 miles, crosses through the center of the Torchlight dome, and joins Big Horn River about 2 miles southeast of the town of Basin. The depression of the surface directly on the upfold of the rocks is shown in the cross section (Pl. IX).

The surface elevation ranges from about 4,000 feet above sea level at well 14, in the southern part of sec. 25, T. 51 N., R. 93 W., to about 4,450 feet near the east quarter corner of sec. 19, T. 51 N., R. 92 W. The elevations of the structure contours subtracted from the surface elevations give the approximate depths to the Greybull sand on which the structure contours are drawn.

The water supply in an oil and gas field in a semiarid region is an important factor in development. In this part of the Big Horn Basin the rainfall is unusually small, being about 6 inches annually. At present the main supply is derived from Columbia No. 1 well (No. 18, Pl. IX) situated on the Lamb anticline, 2 or 3 miles to the north of the dome. Fresh water from this well is pumped to a large reservoir and tanks in the central part of the Torchlight dome. A few reservoirs to catch surface water have been made and afford an additional supply for drilling purposes. In some of the sands, particularly the Peay, water is found, which lessens the quantity that must be pumped or brought from other places for drilling. Most of it, however, is sulphurous. Previous to the discovery of fresh water in the Columbia No. 1 well (No. 18, Pl. IX), water for domestic and drilling purposes was pumped or hauled from Big Horn River.

STRUCTURE.

The Torchlight dome is an elliptical upfold in the rocks trending northwest, with its broad end facing southeast. It is about 3 miles long and 2 miles wide, and is separated from the Lamb anticline by a shallow syncline, a depression in the rocks 200 to 300 feet deep. Along the crest of the dome the beds lie nearly flat, dipping gently outward. On the north limb the maximum dip (11°) of the rocks is reached about one-fourth mile away from the crest line; beyond this the beds gradually flatten to the axis of the syncline. The dips are comparatively low, averaging 3° to 4° at the northwest and southeast ends of the dome. On the southwest the beds gradually increase in dip from zero at the crest line to 25° near Big Horn River. The dip is comparatively regular, but here and there changes, particularly in

the SW. ¼ sec. 25, where a dip of 22° was noted, bordered on either side by dips of 13°, 15°, and 17°. The structure contours on the Greybull sand at intervals of 200 feet above sea level up to 2,800 feet represent the shape and extent of the dome.

The rocks at the surface in the center of the Torchlight dome belong to the upper part of the Frontier formation, which in this locality is a little more than 550 feet thick. A prominent sandstone of this formation encircles the central part of the dome in a line of cliffs and has been given the name Torchlight sand. It was first described by Washburne[1] as the "B" sand, and later named the Torchlight sand by F. F. Hintze, jr.,[2] because of its prominent exposure on this dome. It is not known to contain oil or gas at any place in this general region. A thicker and more prominent sandstone, the Peay, in the lower part of the Frontier formation, is not exposed in this dome but is well shown along Big Horn River near Greybull. Although it contains gas and some oil in the Lamb anticline it is of no importance in the Torchlight dome. Directly underlying the Frontier formation is the Mowry shale, a hard platy shale about 160 feet thick in which numerous fish scales occur and which contains two sands—Kimball and Octh Louie—that yield all of the oil obtained in this dome. The entire formation, according to H. T. Lamb, manager of the Greybull Oil Co., yields some oil. Under the Mowry shale is the Thermopolis shale, about 700 feet thick, mainly of shale but including a persistent sandstone—the Muddy sand, which contains a little gas in some wells—about 300 feet above its base.

Directly beneath the Thermopolis shale is the Cloverly formation, about 125 feet thick, the top sandstone of which is about 20 feet thick and is known as the Greybull sand. This bed of sand yields all the oil and gas in the Greybull field. Although the oil and gas in the Torchlight dome are found in higher beds, it seems advisable to describe the underlying rocks down to and including the Greybull sand, because the structure contours are drawn on this sand. The rocks below the Cloverly formation are fully described in the first part of this report.

Logs of two wells in the Torchlight dome, Jackson No. 7 (No. 34, Pl. IX) and Kimball No. 2 (No. 11, Pl. IX), are given below in order to show the positions of some of the beds beneath the surface. The bottom of the Jackson well is probably about the base of the Mowry shale. This well was "shot" while the writer was in the field. (See Pl. VIII, *A*.)

[1] Washburne, C. W., Gas fields of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 340, p 350, 1908.
[2] Hintze, F. F., jr., The Basin and Greybull oil and gas field, Bighorn County, Wyo.: Wyoming Geol. Survey Bull. 10, p. 23, 1914.

Log of Jackson No. 7 well (No. 34, Pl. IX), in the SE. ¼ NW. ¼ sec. 24, T. 51 N., R. 93 W.

	Feet.
Top of Peay sand; contains water	220
Top of Kimball sand; oil bearing	438
Top of Octh Louie sand; oil bearing	485
Bottom of hole	538

Log of Kimball No. 2 well (No. 11, Pl. IX), in lot 14, sec. 19, T. 51 N., R. 92 W.

	Feet.
Top of Torchlight sand	5±
Base of Torchlight sand	80
Top of Peay sand	358
Base of Peay sand	458
Top of Kimball sand; oil bearing	560
Base of Kimball sand	580
Bottom of hole	588

The Octh Louie sand was not penetrated by the drill in this well.

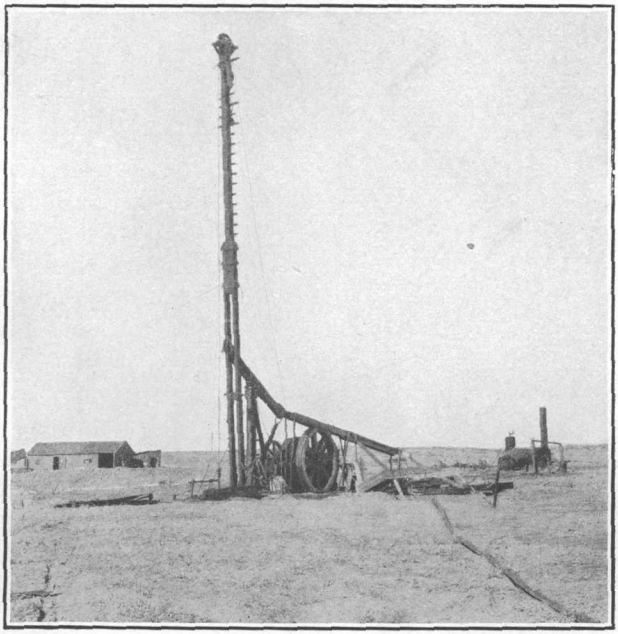
DEVELOPMENT.

The first well (No. 1, Pl. IX) in the Torchlight dome was drilled in 1905. It penetrated to a depth of 106 feet and encountered a little gas. Soon a second well (No. 2) 222 feet deep was drilled near the first and penetrated the Peay sand, in which gas, water, and a little oil were found. No development work was done from 1905 to 1913, at which time Jackson No. 1 (No. 6, Pl. IX) was drilled to a depth of 410 feet, reaching the base of the Kimball sand and proving that this sand is oil bearing. This discovery encouraged further prospecting, and from 1913 to October 1, 1915, 37 wells were drilled, the Greybull Oil Co. keeping two strings of tools in use continually. Most of the drilling has been done by this company on the Jackson and Kimball claims, the former including 160 acres in the E. ½ W. ½ sec. 24, T. 51 N., R. 93 W., and the latter including an equal area in the west range of lots (Nos. 7, 8, 13, and 14) in sec. 19, T. 51 N., R. 92 W. The Valentine interests drilled five additional wells (Nos. 53–57) along the east line of the SE. ¼ sec. 24, from October 16, 1915, to January 5, 1916, all of which encountered oil. A common type of portable drilling rig in use on the Torchlight dome, as well as other parts of the Big Horn Basin, is shown in Plate VIII, *B*.

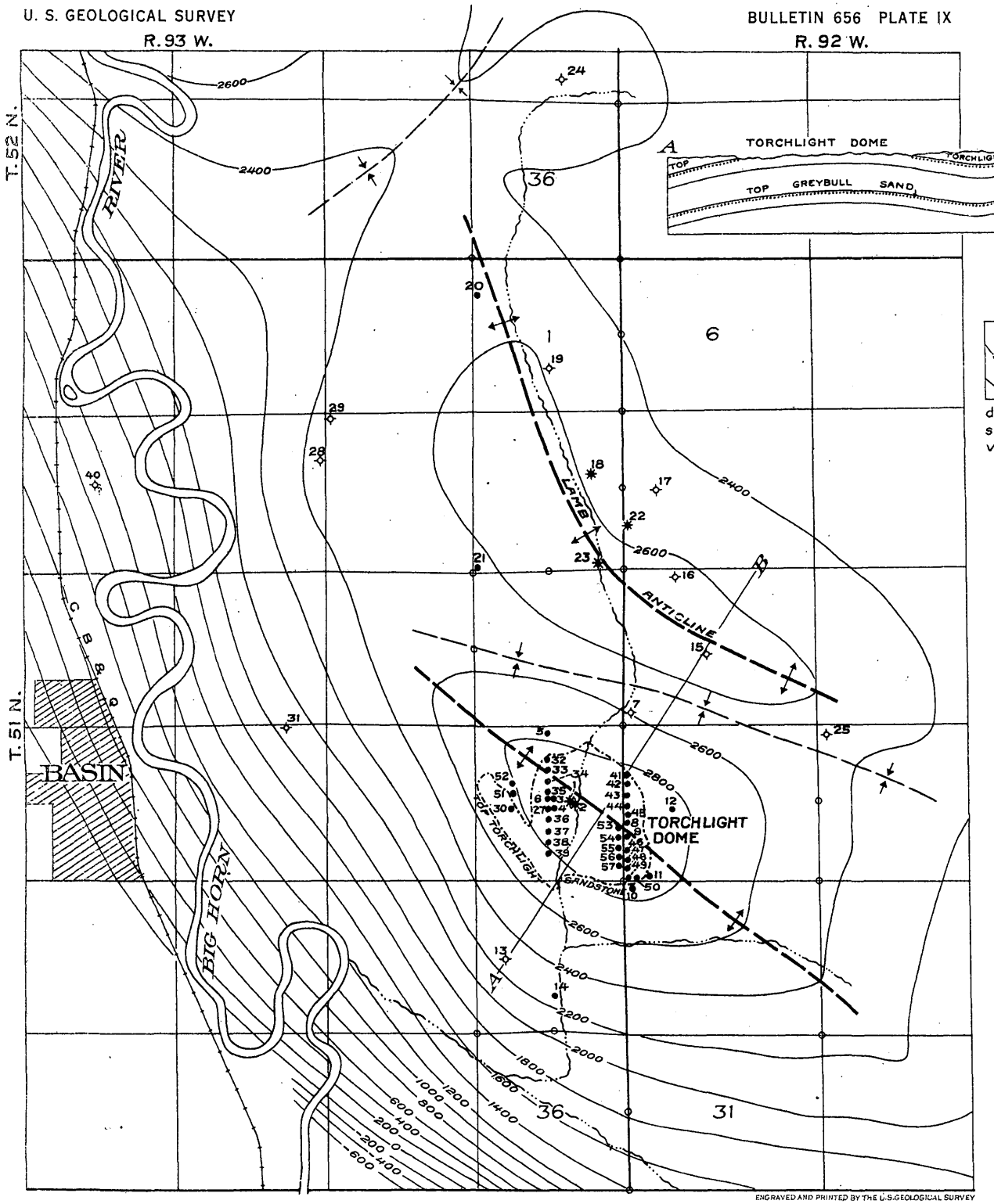
The daily production of oil from the Torchlight dome in October, 1915, was believed to be between 800 and 1,000 barrels, but by October, 1916, it had greatly declined and was reported to be about 200 barrels a day. It is transported through a 4-inch pipe line to the refinery at Greybull. The gas from the Torchlight dome is used only at the camp near the center of sec. 24, T. 51 N., R. 93 W.

The following table furnishes information regarding the wells drilled in Torchlight dome up to October, 1915:

A. OIL THROWN INTO AIR WHEN WELL WAS "SHOT" ON TORCHLIGHT DOME.



B. PORTABLE DRILLING RIG ON TORCHLIGHT DOME.



STRUCTURE CONTOUR MAP OF LAMB ANTICLINE AND TORCHLIGHT DOME (Nos. 5 AND 6, RESPECTIVELY, ON PLATE I) AND STRATIGRAPHIC SECTION

The outcrops of sands are mapped as sandstones

By Charles T. Lupton

Scale 1/62,500

0 1 2 3 MILES

Wells of Torchlight dome, Wyo.

No. on map (Pl. IX).	Name.	Owner.	Result.[a]	Depth to Kimball sand.	Date.	Location.
				Feet.		
1	.....	Torchlight Drilling & Mining Association.	Gas from Peay sand.....	Not reached.	1905.....	NW. ¼ SE. ¼ sec. 24, T. 51 N., R. 93 W.
2	.....	....do.....	Water, gas, and a little oil from Peay sand.	Not reached.	1905.....	Do.
3	Torchlight No. 1.....	Valentine interests.....	Gas and oil.....	380	Apr., 1914.....	SW. ¼ NE. ¼ sec. 24, T. 51 N., R. 93 W.
4	Torchlight No. 2.....	....do.....	Oil.....	380	Apr. and May, 1914.....	NW. ¼ SE. ¼ sec. 24, T. 51 N., R. 93 W.
5	Jackson No. 2.....	Greybull Oil Co.....	Oil and a little water.....	615	Aug., 1913.....	NE. ¼ NW. ¼ sec. 24, T. 51 N., R. 93 W.
6	Jackson No. 1.....	....do.....	Oil.....	390	July and Aug., 1913.....	SE. ¼ NW. ¼ sec. 24, T. 51 N., R. 93 W.
7	.....	Champion Oil Co.....	Water.....	800±	May, 1914.....	Lot 14, sec. 18, T. 51 N., R. 92 W.
8	Kimball No. 1.....	Greybull Oil Co.....	Oil.....	435	Aug., 1913.....	Lot 13, sec. 19, T. 51 N., R. 92 W.
9	Kimball No. 3.....	....do.....	....do.....	450	Sept. and Oct., 1913.....	Do.
10	Hiatus No. 1.....	Valentine interests.....	....do.....	(b)	May and June, 1914	Lot 7, sec. 30, T. 51 N., R. 92 W.
11	Kimball No. 2.....	Greybull Oil Co.....	....do.....	560	Sept., 1913.....	Lot 15, sec. 19, T. 51 N., R. 92 W.
12	.....	Cleveland - Wyoming Oil Co.	....do.....	575±	Sept. and Oct., 1914.....	Lot 12, sec. 19, T. 51 N., R. 92 W.
13	Shafer No. 1.....	Greybull Oil Co.....	Water.....	1,058	1913–14.....	NW. ¼ SW. ¼ sec. 25, T. 51 N., R. 93 W.
14	Blakesly.....	Champion Oil Co.....	Oil reported in Torchlight sand.	Not reached.	Apr., 1914.....	SW. ¼ SE. ¼ sec. 25, T. 51 N., R. 93 W.
27	Jackson No. 3.....	Greybull Oil Co.....	Oil.....	405	Oct. and Nov., 1913.....	NE. ¼ SW. ¼ sec. 24, T. 51 N., R. 93 W.
30	.....	Cleveland - Wyoming Oil Co.	....do.....	400±	Dec.,1914–Jan., 1915.....	NW. ¼ SW. ¼ sec. 24, T. 51 N., R. 93 W.
31	Tillard.....	....do.....	(?).....	Not reached.	May and June, 1915.....	NE. ¼ NE. ¼ sec. 22, T. 51 N., R. 93 W.
32	Jackson No. 9.....	Greybull Oil Co.....	Oil.....	475	June and July, 1915.....	NE. ¼ NW. ¼ sec. 24, T. 51 N., R. 93 W.
33	Jackson No. 8.....	....do.....	....do.....	455	June, 1915.....	SE. ¼ NW. ¼ sec. 24, T. 51 N., R. 93 W.
34	Jackson No. 7.....	....do.....	....do.....	428	....do.....	Do.
35	Jackson No. 4.....	....do.....	....do.....	404	Dec., 1914.....	Do.
36	Jackson No. 6.....	....do.....	....do.....	432	Feb., 1915.....	NE. ¼ SW. ¼ sec. 24, T. 51 N., R. 93 W.
37	Jackson No. 6.....	....do.....	....do.....	425	Feb. and Mar., 1915.....	Do.
38	Jackson No. 10.....	....do.....	....do.....	440±	July, 1915.....	Do.
39	Jackson No. 11.....	....do.....	....do.....	450±	Aug., 1915.....	SE. ¼ SW. ¼ sec. 24, T. 51 N., R. 93 W.
40	(?).....	(?).....	(?).....	Not reached.	Spring, 1916.....	Near center, sec. 9, T. 51 N., R. 93 W.
41	Kimball No. 12.....	Greybull Oil Co.....	Oil.....	490±	Sept., 1915.....	Lot 8, sec. 19, T. 51 N., R. 92 W.
42	Kimball No. 11.....	....do.....	....do.....	480±	Aug., 1915.....	Do.
43	Kimball No. 10.....	....do.....	....do.....	475±	July, 1915.....	Do.
44	Kimball No. 9.....	....do.....	....do.....	468	June, 1915.....	Lot 13, sec. 19, T. 51 N., R. 92 W.
45	Kimball No. 8.....	....do.....	....do.....	455	....do.....	Do.
46	Kimball No. 4.....	....do.....	....do.....	458	Nov. and Dec., 1914.....	Lot 14, sec. 19, T. 51 N., R. 92 W.
47	Kimball No. 5.....	....do.....	....do.....	465	Dec., 1914–Jan., 1915.....	Do.
48	Kimball No. 6.....	....do.....	....do.....	482	Jan. and Feb., 1915.....	Do.
49	Kimball No. 7.....	....do.....	....do.....	500	Feb., 1915.....	Do.
50	Kimball No. 13.....	....do.....	....do.....	530±	Sept., 1915.....	Do.
51	Jackson No. 12.....	....do.....	....do.....	450±	....do.....	SE. ¼ NW. ¼ sec. 24, T. 51 N., R. 93 W.
52	Jackson No. 13.....	....do.....	....do.....	560±	....do.....	Do.
53	Valentine.....	Valentine interests.....	....do.....	430±	....do.....	NE. ¼ SE. ¼ sec. 24, T. 51 N., R. 93 W.

[a] Results given in this column pertain only to Kimball sand.

[b] Information withheld by owners.

The following analysis, made in the laboratory of the Bureau of Mines, of oil from Kimball No. 3 well (No. 9, Pl. IX) in lot 13, sec. 19, T. 51 N., R. 92 W., is believed to be typical of all oil derived from the Torchlight dome:

Analysis of oil from the Kimball No. 3 well (No. 9, Pl. IX), lot 13, sec. 19, T. 51 N., R. 92 W.

Began to boil at 34° C.

	Per cent.
Gasoline:	
To 50° C.	2½
50° to 75°	4½
75° to 100°	6
100° to 125°	10
125° to 150°	7½
	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
	38
Residuum	31½
Specific gravities at 60° F.:	
Crude oil (49.98° Baumé)	0.7955
Gasoline (64.00° Baumé)	.7216
Kerosene (42.80° Baumé)	.8102
Residuum (36.20° Baumé)	.8425

CONCLUSIONS.

The limits of the productive area of the Torchlight dome are accurately known only in one small area along the northeast side and two or three small areas along the southwest side. Drilling has been carried on for the most part in proved territory. Owing to the withdrawal of the public land by the Government only a few claims (Jackson, Kimball, and Minor) are open for drilling and it is doubtful if the field will be definitely outlined until a suitable leasing law affords an opportunity to continue drilling to the south, southeast, east, northwest, and west. Conditions in the Greybull field and in the Lamb anticline suggest that the productive territory probably extends farther down the slope on the southwest and west than on the east and northwest. It therefore seems probable that the line separating the productive from the nonproductive oil land follows approximately the 2,400-foot contour line along the southwest flank. The discovery of dry holes (wells 15 and 25) along the south flank of the Lamb anticline and one (No. 28) on the north flank of the Torchlight dome shows

that the oil-producing area is not everywhere bounded by the 2,400-foot contour, because these dry holes are within that contour, hence it seems reasonable to assume that possibly near the center of sec. 30 the line swings north, connecting the 2,400 and 2,600 foot contours, and that from that point, near the intersection of the crest line of the Torchlight dome with the 2,600-foot contour, it probably keeps slightly inside the 2,600-foot contour to the northwest end of the dome, where it connects again with the 2,400-foot contour, probably near the south quarter corner of sec. 14, T. 51 N., R. 93 W.

DRY DOME.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The dry dome (No. 8, Pl. I), so named because it is probably barren of oil and gas, is a small bulge in the rocks about 5 miles southeast of Torchlight dome and 8 miles southeast of Basin, on the Chicago, Burlington & Quincy Railroad. It may be easily reached from Basin by a good road from which a secondary road leads for 2 miles to and across the dome near its center.

The dome represented in figure 7 lies mainly in secs. 34 and 35, T. 51 N., R. 92 W., and secs. 1–3, T. 50 N., R. 92 W. The surface near by is gently rolling for the most part, with a shallow stream course extending southeast along the east flank. The water supply in and adjacent to the dome is exceedingly scanty. There are no springs or perennial streams, and water must be obtained either from Big Horn River or No Wood Creek or from reservoirs adjacent to stream courses in which flood waters have been ponded.

A well drilled in the NE. ¼ NW. ¼ sec. 2, T. 50 N., R. 92 W., obtained water in three sands.

STRUCTURE.

The Dry dome is a nearly symmetrical bulge in the rocks, trending northwest and southeast, with its broad end facing the northwest. The upfold here is slight, not exceeding 500 feet, and is shown by the structure contours drawn on the Greybull sand. The dips on the southwest side range from nearly flat at the crest line to 10° in the center of sec. 3, T. 50 N., R. 92 W., a mile to the southwest. The maximum dip on the north is 9° in the NE. ¼ sec. 35, T. 51 N., R. 92 W., about half a mile from the axis. The dips at the southeast and northwest ends are less than those on the sides.

The surface rocks to a depth of about 300 feet below the surface at the top of the dome belong to the dark-gray Cody shale, which has a thickness of about 3,200 feet in this locality. Directly below

the Cody shale is the Frontier formation, 500 to 600 feet thick, which contains two principal sands, the Torchlight and Peay, the latter being the only one recognized by the drillers in the well log below. Beneath the Frontier is the Mowry shale, about 160 feet thick, which contains two sands, the Kimball and Octh Louie, which carry the greater part of the oil in Torchlight dome. Beneath the Mowry is the Thermopolis shale, about 700 feet thick, which is

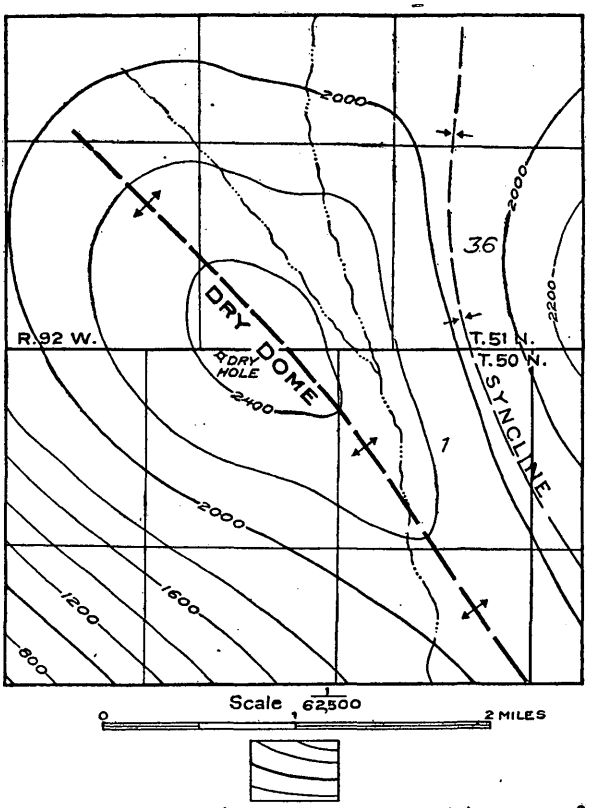


FIGURE 7.—Structure-contour map of Dry dome (No. 8, Pl. I). The outcrops of sands are mapped as sandstone.

characterized by a persistent sandstone, the Muddy sand, that lies about 300 feet above its base. This shale is dark gray and forms an excellent impervious cap to the sandstone bed lying directly beneath. Below the Thermopolis shale is the Cloverly formation, the top sandstone of which (the Greybull sand) carries oil and gas in the Greybull field. The different sands recognized by the drillers, as indicated by the log given below, carry water but no trace of oil or gas.

Log of dry hole in the NE. ¼ NW. ¼ sec. 2, T. 50 N., R. 92 W.

	Feet.
Top of Peay sand (water)	735
Top of Muddy sand (water)	1,475
Top of Greybull sand (water)	1,800

This well was drilled in the early part of 1914 by the Greybull Oil Co., of Greybull, Wyo. The elevation of the mouth of the well above sea level is 4,240 feet.

CONCLUSIONS.

As the dome has been tested by a well at a point within one-fourth mile of the crest line, it seems doubtful if further drilling would yield better results. Hence the writer advises against the further expenditure of money to make a more thorough test.

MERCER ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Mercer anticline (No. 7, Pl. I) is not at all promising as a reservoir of oil and gas, as all the oil sands known in the Big Horn Basin are exposed on its flanks. It is 16 to 18 miles nearly due east of Basin, 8 to 10 miles northwest of Hyattville, and about the same distance northeast of Bonanza. It is included in secs. 28–30, 32, and 33, T. 51 N., R. 90 W., and secs. 3–5, 8–10, T. 50 N., R. 90 W. Manderson, a town of about 200 inhabitants, on the Chicago, Burlington & Quincy Railroad, is the nearest railroad point. From it the anticline is easily reached, as a good road leads through Bonanza to Hyattville and a secondary road, branching near Hyattville, follows a stream valley to the crest of the anticline.

The surface of the anticline (see fig. 8) consists of a basin-like depression bounded by inward-facing walls of sandstone and shale. This depression has been formed by the wearing away of the rocks by the stream, which crosses the anticline in a southerly direction. The surface elevations range from about 4,690 feet above sea level at the well in the SE. ¼ SE. ¼ sec. 5, T. 50 N., R. 90 W., to about 5,150 feet in the east part of sec. 33, T. 51 N., R. 90 W.

The only water supply is derived from small springs and the intermittent stream, which, for the greater part of the year, contains only a few water holes. Water is reported to have been found in the well drilled in the SE. ¼ SE. ¼ sec. 5, T. 50 N., R. 90 W., on the southwest side of the anticline, but its quality is unknown.

STRUCTURE.

The Mercer anticline is oblong, being about 3 miles long and 1 mile wide, measured on the outcrop of the Greybull sandstone. It trends northwest and is slightly unsymmetrical, with its steeper limb on the mountain or northeast side. At the northwest end the crest swings

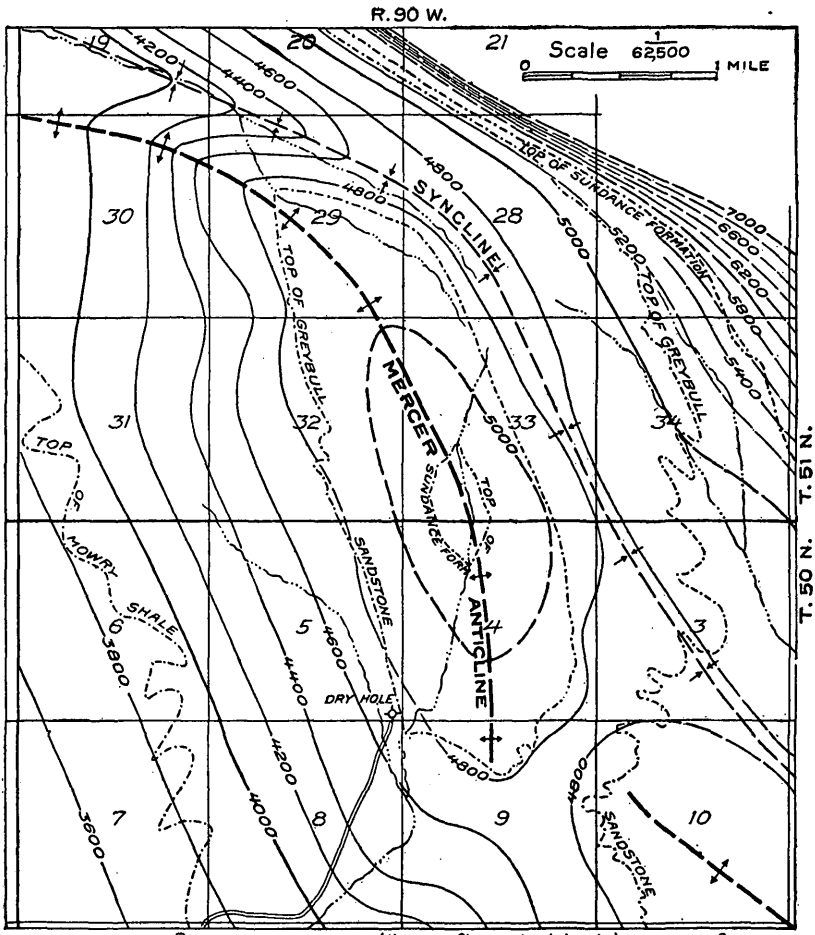


FIGURE 8.—Structure-contour map of Mercer anticline (No. 7, Pl. I). The outcrops of sands are mapped as sandstones.

more nearly west and at the southeast end more nearly south than it does through the middle of the upfold. The maximum dip on the northeast side is 25° in the northern part of sec. 33, T. 51 N., R. 90 W., but such steep dips are rare. The steep dips occur in the sandstone beds near the top of the Cloverly formation, the highest sand-

stone of which is known as the Greybull, on which the structure contours are drawn. Most of these contours are on that part of the Greybull sand which lies below the surface, but those above the 5,000-foot contour (which coincides approximately with the outcrop of the top of the Cloverly formation) are above the surface on the restored surface of the Greybull sand, which has been eroded away. The pitch of the crest at the northwest end of the anticline in sec. 29 is gentle, ranging from 3° to 9°, but farther northwest the dips are steeper. At the southeast end, in secs. 4 and 9, however, the pitch is steeper than it is at the northwest end, ranging from 9° to 15°. On the southwest slope the dips are gentle, ranging from nearly flat along the crest line of the anticline to 10° or 11° near the outcrop of the Greybull sandstone. From this outcrop west and southwest the dips gradually flatten.

The structure contours drawn on the Greybull sand show the shape and extent of the dome. With these contours and surface elevations the approximate depths of the possible oil sands in any part of the dome may be ascertained. (See p. 39.)

The lowest and oldest rocks exposed on the anticline belong to the Sundance formation of Jurassic age, about 250 feet thick, which is characterized by beds of sandstone and shale and a little fossiliferous limestone, all of which have a slightly greenish tint. Overlying the Sundance formation are beds of the Morrison formation, about 200 feet thick, which are strikingly variegated in color with maroon prevailing. Overlying the Morrison is the Cloverly formation, about 125 feet thick. At its base in most places is a fine conglomerate or coarse-grained sandstone and at its top a sandstone about 20 feet thick—the Greybull sand. Between the Greybull sand and the conglomerate below are beds of reddish color, mainly shale. Overlying the Cloverly is the Thermopolis shale, about 700 feet thick, consisting mainly of dark shale.

The rocks beneath the surface belong to the lower part of the Sundance formation, the Chugwater formation, the Embar formation (in which oil and gas may be present), and lower formations.

DEVELOPMENT.

A well that obtained water only was drilled several years ago in the southeast corner of the SE. ¼ SE. ¼ sec. 5, T. 50 N., R. 90 W., to a depth, according to Asa Mercer, jr., of Hyattville, of about 900 feet. In it the drill penetrated part of the dark shale of the lower part of the Thermopolis shale; the Cloverly formation, about 125 feet thick; the Morrison shale, about 200 feet thick; the Sundance formation, about 300 feet thick; and went about 200 feet into the Chugwater formation. Much water was encountered in the lower rocks, and the well was abandoned on that account. It is said to have

risen to within 200 feet of the top of the well and was very alkaline. No trace of oil or gas was found, but the well is so far from the crest line of the anticline that it can not be regarded as certainly indicating the absence of oil.

The formation in which oil or gas is most likely to be found in this locality is the Embar formation, which directly underlies the Chugwater formation ("Red Beds") and which yields oil in the vicinity of Lander, Wyo., but in the Big Horn Basin is not known to contain oil or gas in commercial quantities. It lies about 700 feet below the bottom of the well.

CONCLUSIONS.

The most advisable point at which to sink a well with the least cost is along the crest line of the anticline in the SE. ¼ SW. ¼ sec. 33, T. 51 N., R. 90 W., near the same stream on which the well above described was drilled. The Embar formation at this point would probably be encountered at a depth of about 1,100 feet. However, as the Embar formation is not known to contain oil or gas in commercial quantities in the Big Horn Basin, anyone drilling on this anticline with the hope of obtaining oil or gas in the Embar limestone does so at the risk of loss of the cost.

The oil, if present, is most likely to be heavy, more nearly like the California oil than the light oil obtained in the Torchlight dome at Grass Creek or at Greybull. This judgment is based on conditions in the Lander field and the existence of the seepage of heavy oil in the Red Spring anticline. In both these localities the oil is probably derived from the Embar limestone.

MANDERSON ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Manderson anticline (No. 10, Pl. I) is a northwestward-pitching upfold in the eastern part of T. 50 N., Rs. 92 and 93 W., and T. 49 N., Rs. 91 and 92 W. (See Pl. XI, p. 98.) Although two wells have been drilled and a third one is being drilled in this anticline, it has not been adequately tested for oil and gas, as not one of the wells penetrates the possible oil and gas bearing sands. The anticline is about 12 miles long, and whereas on its southwest limb the rocks dip gradually southwestward into the deeper parts of the Big Horn Basin, its northeast limb ranges from one-fourth of a mile to 1¼ miles in width.

The anticline is easily accessible. The nearest railroad point, Manderson, a small village near the mouth of No Wood Creek, on the Chicago, Burlington & Quincy Railroad, is not more than 5 miles

from the crest of the anticline, which is reached by a good road that runs parallel with the creek. Secondary roads and trails and the gently undulating surface of the country make it possible to reach with ease every part of the anticline.

The principal surface feature in the vicinity of this anticline is the valley of No Wood Creek, which is cut about 200 feet below the general level of the upland surface. South of that valley are rolling hills of dark-gray shale, with here and there conspicuous sandstone hogbacks. In places badlands occur along intermittent streams. North of No Wood Creek for several miles the surface is comparatively smooth, being in part a gravel-covered terrace. Adjacent to Big Horn River bluffs of sandstone and shale are conspicuous.

The main water supply of this locality comes from Big Horn River and No Wood Creek. Both streams are perennial and carry a large volume of water throughout the year. Springs are not known at any place along the anticline, and water for drilling and domestic purposes must be taken from the streams, unless it is obtained from wells that pass through the sandstones of the Frontier formation, which yields water in most places where they have been tested along the east side of the Big Horn Basin. The two wells drilled, however, are not deep enough to reach the Frontier formation.

STRUCTURE.

The Manderson is an unsymmetrical anticline which pitches from southeast to northwest. Near the southeastern end of the crest, however, there is a terrace-like structure where the pitch is less than it is either to the north or south. Locally the beds dip more steeply on the northeast limb than on the southwest limb of the anticline. Adjacent to the crest line the dips are comparatively slight, being not more than 10° at any place, but farther away they increase for half a mile or more to a maximum of 33° near the northeast corner of sec. 1, T. 49 N., R. 92 W., and then flatten abruptly near the axis of the syncline. On the southwest limb of the anticline the dips gradually increase from zero at the crest to 28° at a distance of about 1 mile and then gradually decrease to the southwest. The highest dips, as indicated by the nearness of the structure contours, occur mainly in the eastern part of T. 49 N., R. 92 W., and the western part of T. 49 N., R. 91 W.

The structure contours and the structure section (see Pl. XI) show the extent and shape of the anticline. The contours are drawn on the top of the Greybull sand, in which the oil and gas occur in the Greybull field. The surface elevations range from about 3,940 feet above sea level on No Wood Creek, near Jordan's mill, in the NW. ¼ sec. 34, T. 50 N., R. 92 W., to about 4,570 feet near the center of sec. 16, T. 49 N., R. 91 W. From these elevations and from the

Greybull sand contours the approximate depth to the possible oil and gas sands at any place on the anticline may be determined. (See pp. 39–41.)

The surface rocks along the anticline belong for the most part to the Mesaverde formation and the Cody shale. Near the northwest end beds of younger formations are present, but it is probable that this part of the anticline is of little importance, as the depth to the sands which may carry oil and gas is so great as to make them almost inaccessible. For a mile or more along the crest northwest of No Wood Creek the Mesaverde formation is concealed beneath the alluvium on the flood plain and the gravel on the terraces, but farther northwest it shows at the surface. The Mesaverde formation is about 1,200 feet thick and consists mainly of sandstone interbedded with shale, sandy shale, and a little coal. Directly underlying it the Cody shale, about 3,000 feet thick and dark gray in color, forms an excellent impervious cap for the underlying sands of the Frontier formation. No persistent sandstone beds of any importance are found in the Cody shale except possibly two or three small ones near the top and one thin but persistent bed near the base. Owing to the thickness of the Cody shale, any well located near the outcrop of its top must penetrate 3,000 feet of shale before reaching any sand that may contain oil and gas. Directly underlying the Cody shale is the Frontier formation, about 500 feet thick, which consists mainly of sandstone with beds of sandy shale and shale interbedded. The uppermost bed that needs to be considered is the Torchlight sand, which apparently carries little oil in the eastern part of the Big Horn Basin. In the lower part of the formation there is a thicker and more conspicuous sandstone known as the Peay sand, which in places carries a little oil and gas. Like the Torchlight sand, however, it carries no oil or gas in the eastern part of the Big Horn Basin, except in the Lamb anticline, where it has furnished all the gas derived from that field. Under the Frontier formation is the Mowry shale, about 175 feet thick, which includes two possible oil sands, the Kimball above and the Octh Louie below, which in the Torchlight dome carry high-grade oil. Beneath the Mowry shale is the Thermopolis shale, about 700 feet thick, darker than the Cody shale and containing about 300 feet above its base a very persistent bed of sandstone known as the Muddy sand, which, however, is not known to carry oil or gas in commercial quantities, except in the Oregon Basin. (See p. 181.) Directly underlying the Thermopolis shale is the Cloverly formation, a generally sandy formation 125 feet thick. The top sandstone of this formation, on which the structure contours are drawn (see Pl. XI), is known as the Greybull sand, as it is the sand that contains the oil and gas of the Greybull field. The

Cloverly formation contains, in addition to the Greybull sand, which is about 20 feet thick, a variegated shale and a lower bed which consists, for the most part, of coarse sand but in places is a medium-grained conglomerate. As any oil or gas that may occur in this anticline probably will be found in the Greybull sand or above it, a description of lower formations seems unnecessary.

DEVELOPMENT.

Two wells have been drilled on the Manderson anticline, but neither of them has penetrated the Frontier formation. One well (No. 1, Pl. XI) near the center of sec. 1, T. 49 N., R. 92 W., was drilled during the fall of 1914 by C. E. Stubbs and others to a depth of about 800 feet. It is well located to test the anticline, but was not drilled deep enough to reach the top sand of the Frontier formation. The elevation of its mouth is about 4,100 feet above sea level. Another well (No. 2, Pl. XI), in the SE. ¼ sec. 6, is too near the trough of the syncline to show whether or not oil or gas is present in the anticline. No information is at hand regarding this well except that its mouth is about 4,170 feet above sea level. Both the wells are dry holes, as neither was drilled deep enough to test fully this part of the Manderson anticline. It is reported about December 1, 1916, that in a well being drilled along No Wood Creek near Jordan's mill, and near the crest of the Manderson anticline, neither oil nor gas had been encountered by the drill.

CONCLUSIONS.

It seems to the writer that the best place to begin drilling is on or near the crest line of the anticline south of No Wood Creek, because the sands of the Frontier formation are nearer the surface here than they are at any other point on the anticline, and that the wells should be deep enough to penetrate the Peay sand of that formation. The writer recommends locations near the crest line of the anticline in secs. 8 and 17, T. 49 N., R. 91 W., because the beds here seem to lie on a structural terrace, and this is generally considered favorable for the accumulation of oil and gas. Northwest of No Wood Creek the depth of the oil sands is great, and as the anticline pitches steeply, it is believed that this locality is a poor place to drill.

Although this anticline seems to plunge throughout its entire length, this fact does not preclude it from serving as a reservoir for oil and gas, for a differential cementation of the sands of the Frontier formation, Mowry shale, and Cloverly formation may make parts of these beds suitable reservoirs.

PAINTROCK ANTICLINE.[1]

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Paintrock anticline (No. 9, Pl. I) trends northwest through T. 49 N., Rs. 90 and 91 W., and T. 50 N., R. 91 W., about 12 miles east of Big Horn River and parallel to and a short distance east of No Wood Creek. (See Pl. XI, p. 98.) It is about 2 miles east of Bonanza and by road 15 miles east of Manderson, on the Chicago, Burlington & Quincy Railroad. The anticline has been fairly well tested for oil and gas along Paintrock Creek near its southern end but with negative results. One of the wells drilled to a depth of about 1,900 feet found a strong flow of water, and another, not so deep, failed to yield oil, gas, or water in appreciable quantities.

The anticline is most easily accessible from Manderson over a good road which extends along the valley of No Wood Creek and connects with a similar road extending up Paintrock Creek. Second-class roads and trails and the comparatively smooth surface of the country make the entire anticline easy to examine.

Like many of the upfolds in the Big Horn Basin the Paintrock anticline is represented at the surface for the most part by a depression surrounded by parallel walls and ridges formed by beds of outward-dipping sandstone, with intervening valleys formed in soft shale. In many places adjacent to the streams the soft shale has been cut into badlands which are difficult to cross. The elevation of the surface ranges from about 4,075 feet above sea level in the NE. ¼ sec. 4, T. 49 N., R. 91 W., to about 4,670 feet in the N. ½ sec. 33, T. 49 N., R. 90 W.

The water supply is from the perennial streams, No Wood and Paintrock creeks, and from several that are intermittent. A small spring rises near the northern end of the anticline in the NE. ¼ sec. 27, T. 50 N., R. 91 W., just north of the Hyattville-Basin road; and a few others, very alkaline in character, occur in different parts of the anticline. The strong flows of water from several sands in one well (Catherine No. 2, No. 11, Pl. XI), which was drilled for oil in the SW. ¼ sec. 20, T. 49 N., R. 90 W., compelled the drillers to case the well in five places. The strongest flow and probably the best water is from near the bottom of the hole. This well flows about 100 gallons a minute. Little water was found in well No. 10 (Catherine No. 1) in the NW. ¼ sec. 18 of the same township.

[1] See footnote, p. 94.

STRUCTURE.

The Paintrock anticline is an unsymmetrical upfold about 15 miles long and 4 miles wide. Its narrow steep slope is on the east or mountain side and its broad gentle slope on the west or basin side. In the vicinity of the crest the dips are comparatively slight, but they increase gradually eastward within about half a mile to an average of 40° or 45°. A maximum of 60°, however, was locally noted on a sandy bed in the Mowry shale in the SE. ¼ sec. 36, T. 50 N., R. 91 W. Beyond this the dips become gradually less to the axis of the adjacent syncline, which lies from one-third mile to 1½ miles to the east. The southwest limb of the anticline is much broader than the northeast, ranging from less than one-half mile in the southern part of sec. 33, T. 49 N., R. 90 W., to as much as 4 miles in the southern part of T. 50 N., R. 91 W., and the northern part of T. 49 N., R. 91 W. The beds attain a maximum local dip of 23° about a mile west of the crest line of the anticline, in the W. ½ sec. 2, T. 49 N., R. 91 W., averaging, however, about 15°. West of this zone of maximum tilting the dip gradually decreases to the axis of the syncline. The strata at the south end of the anticline dip rather steeply to the south, but at the north end they flatten and merge with the broad flat-lying area east of the Torchlight dome and the Lamb anticline.

The structure contours on the Greybull sand show that the highest point along the crest line is 2 miles north of Paintrock Creek.

Few faults are known in the anticline. One of slight throw, with downthrow on the west, is between the southeast end and No Wood Creek. Another fault is on the crest at the north end of the outcrop of the Frontier formation in the NE. ¼ sec. 27, T. 50 N., R. 91 W. The downthrow at this place is slight and on the west side.

The lowest rocks exposed in the Paintrock anticline belong to the Sundance formation. This formation outcrops on both sides of Paintrock Creek in the western part of T. 49 N., R. 90 W., and consists of 200 to 300 feet of light-green sandstone with a little shale and thin beds of fossiliferous limestone. Overlying the Sundance are the Morrison and Cloverly formations, Thermopolis and Mowry shales, Frontier formation, and Cody shale. The Morrison consists of about 200 feet of variegated sandstone and shale, the latter predominating. It is overlain by the Cloverly formation of about 125 feet of sandstone and shale, the lower part of which is usually conglomeratic, the middle part very clayey and variegated, and the upper part sandy. This upper sandy part is the Greybull sand, which carries oil and gas in the Greybull field. The Cloverly is overlain by the Thermopolis shale, which is about 700 feet thick and contains in its middle part about 20 feet of soft sandstone—the Muddy sand. The

Thermopolis shale, Mowry shale, Frontier formation, and Cody shale, which are exposed around this anticline, are described on pages 19–25.

Underlying the Sundance and other formations exposed in the anticline is about 900 feet of the Chugwater formation ("Red Beds"), which consists principally of sandstone and sandy shale with a thick bed of gypsum near the top. Underlying the Chugwater is the Embar formation, consisting principally of limestone, but containing in places a thick bed of gypsum near its top. Although this formation is known to carry oil in the vicinity of Lander, Wyo., no evidence is at hand to show that it carries oil in the Big Horn Basin. Below the Embar is the Tensleep sandstone, and underlying that is the Amsden formation, consisting mainly of maroon to red sandstone and sandy shale. Underlying the Amsden is the Madison limestone, consisting entirely of massive to medium-bedded limestone. Neither of the wells drilled on the west limb of the Paintrock anticline is believed to have reached this limestone, but the Catherine No. 2 well (No. 11, Pl. XI), which encountered much water near the bottom of the hole, is believed to have obtained it from the Tensleep sandstone, which carries much water in the region.

Structure contours drawn on the Greybull sand supplemented by the structure section (see Pl. XI) show the shape and extent of the anticline. With those and surface elevations given, the depths of wells penetrating the Greybull sand or any other sand whose position with relation to the Greybull is known may be determined with ease. (See p. 39.)

DEVELOPMENT.

Three wells—the Graves, the Catherine No. 1, and the Catherine No. 2 (Nos. 12, 10, and 11, respectively, Pl. XI)—have been drilled on the west flank of the Paintrock anticline. None of them found oil or gas in commercial quantities, but the Catherine No. 2 struck water at several horizons, the lowest flow being artesian. The Graves well also tapped a little artesian water.

The Graves well, near the east quarter corner of sec. 14, T. 49 N., R. 91 W., was drilled about 1888 by R. J. Coles, of York, Nebr., to a depth of about 1,200 feet (elevation of the mouth, about 4,090 feet above sea level). No oil or gas was reported, but a small quantity of water flows from the well. The rig used was of the standard type and was hauled by wagon from Casper, Wyo., an arduous task at the time.

Catherine No. 1 well (No. 10), in the NW. ¼ sec. 18, T. 49 N., R. 90 W., was drilled to a depth of about 1,000 feet by L. E. Croll and others in May, June, and July, 1914. A little water and a trace of oil were encountered. The altitude of the mouth is about 4,300 feet. According to report the well was abandoned because the tools

were lost in the hole, but it is estimated that the drill penetrated 300 or 400 feet into the Chugwater formation ("Red Beds").

Catherine No. 2 (No. 11) was drilled by L. E. Croll and others to a depth of about 1,900 feet. Drilling was begun in August, 1914, and ceased in November of the same year. According to report, the well contains no trace of oil, but is believed to have encountered water in four or five sands at least, as it contains five casings. Water flows from the well continuously at the rate of about 100 gallons per minute and is used near by for irrigation. It is slightly warm and contains iron and sulphur in solution. It is believed that this water is derived from the Tensleep sandstone, which is an important water bearer of the region. The well is in the SE. ¼ SW. ¼ sec. 20, T. 49 N., R. 90 W., and the altitude of its mouth is about 4,290 feet.

CONCLUSIONS.

As strata as low as the Sundance formation are exposed at the surface in the valley of Paintrock Creek, it seems safe to say that oil will probably not be found in any of the rocks in or adjacent to the anticline above that formation. The next lower bed in which oil and gas may possibly occur is the Embar limestone, which undoubtedly was pentrated in Catherine No. 2 well (No. 11, Pl. XI). As this well, which is near the crest and not far from the highest part of the anticline, did not obtain oil in any of the sands down to and including the Tensleep sandstone, it seems reasonable to believe that the chance for obtaining oil or gas in deeper beds is very doubtful. As the Embar is believed to be of little or no importance as an oil or gas reservoir in this part of the Big Horn Basin, and as direct connection with the interior of the basin is cut off by the Bonanza anticline, the wisdom of expending more money in drilling for oil and gas is doubtful.

BONANZA ANTICLINE.

By Charles T. Lupton.

GENERAL FEATURES.

The Bonanza anticline (No. 11, Pl. I) is situated west of No Wood Creek near the mouth of Paintrock Creek, mainly in T. 49 N., R. 91 W. It is about 12 miles southeast of Manderson, a town on the Chicago, Burlington & Quincy Railroad, and a short distance west of Bonanza post office. (See Pl. XI, p. 98.) Several wells have been drilled on this anticline, but none of them has produced oil or gas in commercial quantities. A seep near the highest part of the anticline, discovered about 30 years ago, has yielded some oil which was used for lighting by the settlers at times when the refined product was scarce.

This anticline is most easily accessible from the railroad at Manderson by means of a good road which follows in general the course of No Wood Creek. From Bonanza a second-class road leads to the crest of the anticline about a mile distant. Another second-class road crosses the north end of the anticline. The southeast end can be most easily visited by following the main road along No Wood Creek as far as the mouth of Cottonwood Creek, where a second-class road leads northwest to the southeast end of the anticline, about 2 miles distant. Many parts of the anticline, however, are accessible only on foot or horseback.

A troughlike depression surrounded by an inward-facing wall of shale, in places 300 feet in height, coincides with the central part of this anticline, and a series of low hogback ridges partly encircle the depression. On the northeast side the shale wall is cut by several canyons, which form easy routes of access into the central part of the upfold. Badlands are common in the region near the heads of streams. The altitude of the surface varies from 4,160 feet above sea level in the NW. ¼ NW. ¼ sec. 23, T. 49 N., R. 91 W., to about 4,650 feet near the center of sec. 36 of the same township. From these elevations and from the structure contours on the Greybull sand (Pl. XI) the depth to the different sands may be determined approximately.

Water is available from No Wood Creek, which carries a large flow the year round. The intermittent streams emptying into No Wood Creek carry water in spring, early in summer, and after heavy rains, but throughout the greater part of the year they are dry except for a few small seeps and water holes.

STRUCTURE.

The Bonanza anticline [1] is an unsymmetrical northwest-pitching upward fold slightly offset on the northwest from the Manderson anticline and on the southeast from the Nowood anticline. Like many of the upfolds on the east and south rims of the Big Horn Basin, Bonanza anticline has steep dips on the mountain side and much more gentle dips on the basin side. For this reason the northeast limb is much narrower than the southwest. The dip on the east ranges from zero at the crest line to 54° locally, about 500 feet east of it, in the NE. ¼ SE. ¼ sec. 36, T. 49 N., R. 91 W., beyond which it gradually decreases to zero at the trough of the syncline one-half mile distant. Farther northwest the dips on the northeast limb

[1] Knight held the opinion that the Bonanza anticline extended several miles south of the mouth of Cottonwood Creek and would have this anticline include the Nowood anticline of the present writer's classification, which is separate and distinct from the Bonanza anticline. The term "Nowood anticline" as used by Knight pertains to the Paintrock anticline of the present report. (See Knight, W. C., and Slosson, E. E., Bonanza, Cottonwood, and Douglas oil fields: Wyoming Univ. Bull., Petroleum ser., No. 6, pp. 6-13, 1903.)

first average about 45° for 2 miles, and then decrease gradually. On the west limb the beds range in dip from zero at the crest line to a maximum of 18° 1½ miles distant in sec. 34, T. 49 N., R. 91 W. Farther southwest for a mile or more the beds increase in dip. At the southeast and northwest ends of the fold the dips are low. A maximum of 12° was noted at the northwest end in the SW. ¼ sec. 9, T. 49 N., R. 91 W. The southern half of this anticline slopes gently northwestward, but the part northwest of the oil seep in the SW. ¼ sec. 23, T. 49 N., R. 91 W., pitches more sharply.

The lowest rocks exposed on the anticline belong to the upper part of the Thermopolis shale. This shale is about 600 feet thick, and contains a persistent bed of sandstone—the Muddy sand—about 250 feet above its base. This sand is exposed only at the extreme southeast end of the anticline and is not known to carry oil or gas of economic importance except in the Oregon Basin (p. 185). Directly overlying the Thermopolis shale is the Mowry shale, a dark-gray, hard, platy shale about 175 feet thick, containing one or more beds of sandstone, which in the Torchlight dome have been given the names Kimball and Octh Louie sands and which contained the greater part of the oil produced in that locality. It is from this formation that the oil seepage referred to above issues. Overlying the Mowry is the Frontier formation, which consists mainly of sandstones with thin layers of sandy shale and bentonite. On the east side of the basin it includes two prominent sandstones—Torchlight and Peay—and at the south and west sides as many as five or six. It is about 600 feet thick, and its sandstones carry oil in some parts of the Big Horn Basin, as, for example, in the Grass Creek and the Little Buffalo basin fields. Directly overlying the Frontier is the Cody shale, the highest formation exposed around the Bonanza anticline. It is about 3,000 feet thick and consists mainly of light-gray shale with thin beds of fossiliferous sandstone near the top and a nonpersistent bed near the base. If a well were drilled at the northwest end of this anticline it would penetrate part or all of the formations described.

Beneath the Thermopolis shale, the lowest outcropping formation, lies the Cloverly formation, about 125 feet thick. The Cloverly consists of a very persistent bed of sandstone known as Greybull sand, on which the structure contours shown on Plate XI are drawn, underlain by about 80 feet of shale and by about 25 feet of conglomeratic sandstone. Beneath the Cloverly is the Morrison formation, about 200 feet thick, consisting mainly of variegated sandstone and shale and not known to contain any oil or gas bearing sands. Underlying the Morrison is the Sundance formation, about 250 feet thick, which is mainly sandstone with minor amounts of shale and in places a little limestone, all slightly grayish. Beneath the Sundance is the Chugwater formation ("Red Beds") about 1,000 feet thick. It consists

mainly of sandstone but includes thin beds of sandy shale and shale and a thick bed of gypsum near the top. Directly underlying the Chugwater is the Embar formation, consisting of limestone, gypsum, and red sandy shale. At Lander, Wyo., the Embar produces a heavy oil, but at no place in Big Horn Basin is it known to be important as a bearer of oil or gas.

The structure contours drawn on the Greybull sand and the structure section (Pl. XI) show the shape and extent of the Bonanza anticline.

DEVELOPMENT.

Seven wells (Nos. 3–9, Pl. XI) have been drilled on and near the Bonanza anticline, but none of them has discovered oil or gas in commercial quantities. An oil seep in sec. 23, T. 49 N., R. 91 W., about three-fourths mile southwest of Bonanza post office, known variously as "Bonanza oil seep" and the "No Wood oil seep," was discovered in the early eighties, and had led to most of the drilling in this as well as other anticlines along the east side of the Big Horn Basin.

The first well (No. 3) on the Bonanza anticline, in the NE. ¼ NE. ¼ sec. 28, T. 49 N., R. 91 W., was drilled about the year 1900 by the Hoosier Oil Co., of Goodland, Ind. For financial reasons the drill was not sunk to the Frontier formation. The elevation of the mouth of the well is about 4,270 feet.

The next drilling on this anticline was in the spring of 1902, when well No. 4 (the Whittier well) was drilled in the NW. ¼ NE. ¼ sec. 27, T. 49 N., R. 91 W., by Gardner Bros., of Knox, Pa., for the Kearn Oil Co. A little water was obtained in the bottom of the hole but no trace of oil or gas. The altitude of the mouth of the well is about 4,225 feet.

In 1903 the same drillers put down a hole (well No. 5) near the oil seep in the NW. ¼ SW. ¼ sec. 23 to a depth of about 800 feet with a standard rig. As this hole is within a few hundred feet of the original oil seep oil and gas were encountered, and gas continues to issue to the surface through the water around the casing. The altitude of the mouth of this well is about 4,260 feet. During the same year another well (No. 6) was drilled a short distance south of well No. 5 by Charles Cole. The depth attained is not known, but the drilling was done, it is reported, by horsepower. There is no evidence that any trace of oil or gas was found. The elevation of the mouth of this well is about 4,300 feet above sea level.

In 1914 B. F. Webster and others, of Colorado Springs, Colo., drilled a hole on the crest line of the anticline in the SE. ¼ NE. ¼ sec. 26, T. 49 N., R. 91 W. (No. 7) to a depth of about 600 feet. The drill probably reached the Cloverly formation for reddish material was found in the mass of sand and shale brought up by the bailer.

A standard rig (see Pl. IV, *B*, p. 20) was used in drilling. The altitude of the well mouth is about 4,380 feet. A well (No. 8) drilled in the NE. ¼ NE. ¼ sec. 36 on the north flank of the anticline did not obtain oil or gas in commercial quantity. No information was obtained regarding the depth of the well, but the altitude of its mouth is about 4,245 feet. In 1914 a well (No. 9) was drilled near the southeast end of the anticline in the NW. ¼ sec. 6, T. 48 N., R. 90 W., but neither oil nor gas was obtained. The elevation of the mouth of this well is about 4,240 feet above sea level.

CONCLUSIONS.

The wells already drilled on the Bonanza anticline have not yielded sufficient oil and gas to encourage further exploration. The fact, however, that oil and gas in commercial quantities have not yet been discovered should not condemn the anticline, as it is entirely possible that some oil may be found at places along the west limb where a flattening of the dips has not been thoroughly tested.

Experience has shown that as a general rule wells on the broad, gentle limb of an anticline adjacent to the crest line are more likely to obtain oil and gas than wells on the narrow steep limb. In this district five of the seven wells are on the narrow steep limb, and the remaining two wells, although half a mile to a mile from the crest line and on the broad gentle flank, were probably not drilled sufficiently deep to penetrate the beds from which the oil issues at the seep in sec. 23. Hence these wells are not sufficient tests for the southwest limb of the anticline.

The writer therefore suggests that wells drilled on this anticline in the future be located on the southwest limb about half a mile from the crest line or near the southeast end of the anticline, in the SW. ¼ sec. 31, T. 49 N., R. 90 W., or in the NE. ¼ sec. 1, T. 48 N., R. 91 W. In the former locality the Greybull sand should be penetrated, and in the latter it possibly would be worth while drilling to the Embar formation.

NO WOOD ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The No Wood anticline[1] (No. 14, Pl. I) is an unsymmetrical upfold lying mainly in the northern part of T. 48 N., Rs. 89 and 90 W., west of No Wood Creek. It has been tested for oil or gas by a deep well near the mouth of Cottonwood Creek in sec. 5, T. 48 N., R. 90 W. Water was reported to have been encountered, but no trace of oil and gas was found.

[1] See footnote under "Bonanza anticline," p. 94.

This anticline (see Pl. X, *A*) is easily accessible from Manderson, a small town on the Chicago, Burlington & Quincy Railroad, by means of a first-class road which follows the valley of No Wood Creek almost its entire length. A daily mail stage runs over this road between Manderson and Tensleep, a town about 12 miles southeast of the anticline. Any detailed examination of the region embraced in the anticline must, however, be made on foot or horseback, as no good roads lead to any part of it.

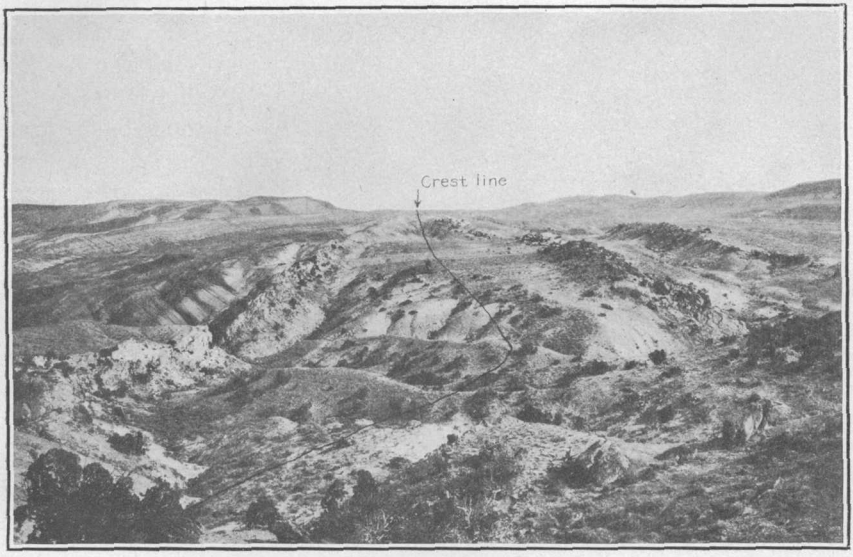
The anticline coincides with a troughlike depression from which the rather broad valley of No Wood Creek lying directly to the east is separated by several cross valleys. The troughlike depression is surrounded by walls of sandstone and shale of differing heights. Outside this wall and encircling the greater part of the anticline are lower, less conspicuous walls formed of the edges of hard beds that dip away from the crest line. Adjacent to stream courses badlands are common.

The water supply for the anticline is derived from No Wood Creek, a perennial stream that carries a large amount of water throughout the year. This can be used at all times for drilling and domestic purposes, except possibly when the stream is unusually muddy. The intermittent streams which cross the anticline can also be counted on to furnish water during the spring and early in summer. No springs of importance are known.

STRUCTURE.

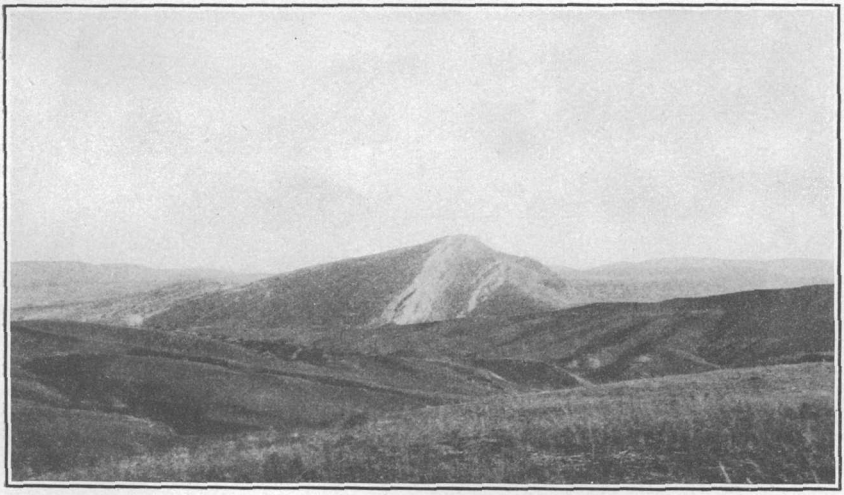
The No Wood anticline is an unsymmetrical upfold about 8 miles long, with its steep slope on the northeast or mountain side. (See Pl. XI.) In this respect it is similar to most of the anticlines of the Big Horn Basin. The east slope ranges in width from about one-third mile near the northwest end of the anticline to as much as 1½ miles near the southeast end. The dips on this limb increase from zero at the crest line of the anticline to as much as 80° one-third mile to the east, beyond which they decrease as the beds descend into the bottom of the syncline. On the southwest limb the dips range from zero near the crest line to as much as 39° locally near the middle of the upfold and less than one-fourth mile west of the axis. They average about 15°, however. From this place the dips gradually decrease southwestward for a mile or more, then increase slightly to the edge of the area represented on Plate XI. The dips at the northwest and southeast ends of the anticline are slight. The northwest end of No Wood anticline is slightly offset from the Bonanza anticline.

The highest part of the anticline is on No Wood Creek, near the mouth of Cottonwood Creek. The structure contours also show a minor upfold on the anticline in secs. 29, 30, and 32, T. 48 N., R. 89 W.

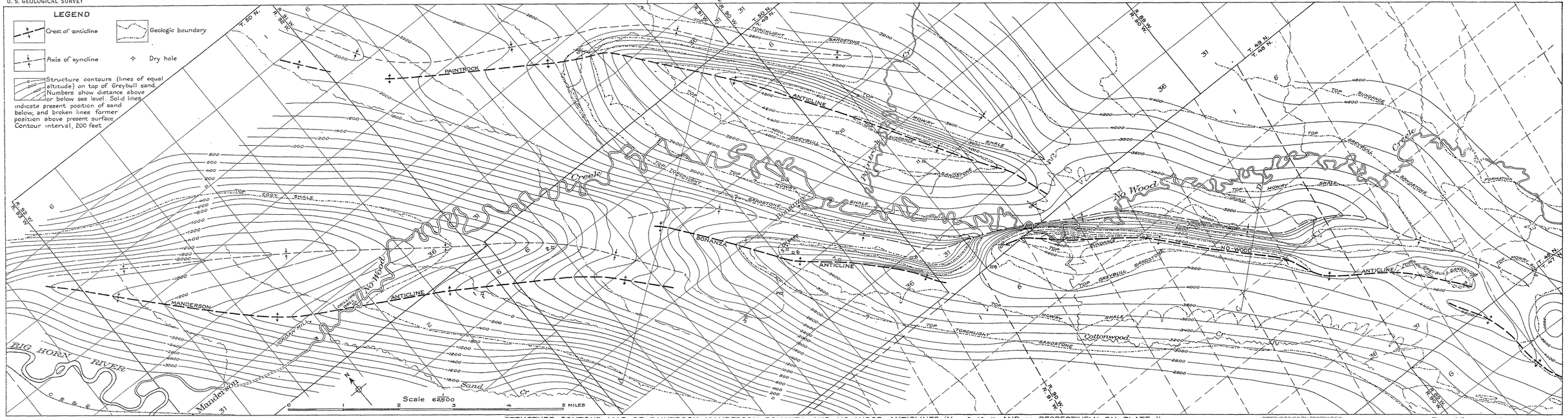


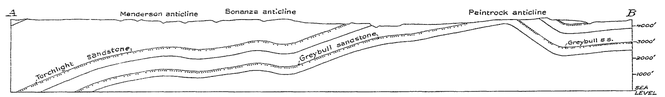
A. SURFACE APPEARANCE OF NO WOOD ANTICLINE WEST OF NO WOOD CREEK, BETWEEN BONANZA AND TENSLEEP.

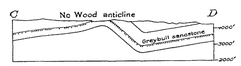
Beds dip in opposite directions from crest line.



B. MAHOGANY BUTTE, EAST OF NO WOOD CREEK, IN SOUTHEASTERN PART OF BIG HORN BASIN.







STRUCTURE CONTOUR MAP OF PAINTROCK, MANDERSON, BONANZA, AND NO WOOD ANTICLINES (Nos. 9, 10, 11, AND 14, RESPECTIVELY, ON PLATE I) AND TWO STRUCTURE SECTIONS

The outcrops of sands are mapped as sandstones

By Charles T. Lupton

The anticlines are numbered 9,10,11, and 14, respectively, on Plate I.

A minor separate anticline is developed at the southeast end of the No Wood anticline, in sec. 32, T. 48 N., R. 89 W., and in secs. 5 and 8, T. 47 N., R. 89 W. This upfold is about 2½ miles long and has a narrow east limb and a broad west limb. The Greybull sand (top of the Cloverly formation) may serve as a reservoir for oil and gas under this upfold.

The lowest rocks exposed at the surface belong to the upper part of the Chugwater formation, which consists mainly of red sandstone and shale about 1,000 feet thick with a thick bed of gypsum near the top. It is of no economic importance as a bearer of oil and gas, but in certain localities on the east side of Big Horn Basin it is known to carry much water. The Sundance formation, which directly overlies the Chugwater formation, is about 250 feet thick. It consists mainly of sandstone with thin layers of shale and in places a little fossiliferous limestone, all greenish. Directly overlying the Sundance is the Morrison formation, about 250 feet thick, consisting mainly of sandstone and variegated shale but containing no beds known to be oil or gas reservoirs. Directly overlying the Morrison is the Cloverly formation, about 125 feet thick. The lower part is usually conglomeratic, the middle part is variegated and clayey, and the upper part is the 20-foot Greybull sand, on which the structure contours on Plate XI are drawn. This sand is not oil-bearing in this anticline, as its edge is exposed at the surface, and any oil that it may have contained has long ago escaped.

Overlying the Cloverly formation is the Thermopolis shale, about 600 feet of dark shale containing a thin sandstone bed, the Muddy sand, which occurs near the middle of the formation. This sandstone is not known to carry oil or gas in commercial quantities at any place in the Big Horn Basin except in the Oregon Basin.

The rocks lying beneath the lowest beds exposed in the anticline include the lower part of the Chugwater formation. Directly beneath the Chugwater is the Embar formation, which in some localities consists of 100 feet or more of limestone and which near Lander, Wyo., bears a heavy oil. In places in the Big Horn Basin the Embar is largely gypsum, thin beds of limestone, red sandstone, and shale, rather than limestone. The formations below the Embar are not known to contain oil or gas.

From the structure contours (Pl. XI) on the Greybull sand and the surface altitudes, which range from about 4,160 feet on No Wood Creek, in the SE. ¼ sec. 32, T. 49 N., R. 90 W., to about 4,900 feet in the SW. ¼ sec. 14, T. 48 N., R. 90 W., the probable depths to the different sands may be determined. A structure section on Plate XI gives additional information regarding the shape of the anticline.

CONCLUSIONS.

There is little prospect, in the writer's opinion, of finding an oil or gas pool in the No Wood anticline in any other part of the structure than that already tested. Any oil or gas would probably be in the Embar limestone, which is comparatively thin and unpromising. It is possible, however, that some of the sandstone beds in the Sundance or Chugwater formations may carry oil in small quantities, but this is doubtful, for these formations are not known to be oil-bearing in this general region. The most favorable location for a well on the No Wood anticline is at the mouth of Cottonwood Creek, in the N. ½ sec. 5, T. 48 N., R. 90 W., as this is the highest place structurally on the anticline. This part of the fold is believed to have been thoroughly tested. Near the south end of the anticline, in secs. 29, 30, and 32, T. 48 N., R. 89 W., as shown by the structure contours, there is also another high place in the anticline, and it is possible that small quantities of oil or gas may have accumulated there. The small gentle anticline at the southwest end of the No Wood anticline, in secs. 5 and 8, T. 47 N., R. 89 W., and sec. 32, T. 48 N., R. 89 W., may carry oil and gas in small amounts.

ZEISMAN DOME.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Zeisman dome (No. 12, Pl. I) is an untested, unsymmetrical anticline of domelike form 4 or 5 miles southeast of Hyattville and about 20 miles east and slightly south of Manderson, on the Chicago, Burlington & Quincy Railroad. It is included mainly within secs. 22–27 and 35, T. 49 N., R. 89 W.

It can be visited with comparative ease, as a good stage road connects Manderson on the railroad with Hyattville, 25 miles to the east, and the main road between Hyattville and Tensleep crosses the west slope of the dome. From this main road a good road ascends the west limb, and another—a second-class road—follows the south and east sides. These roads, together with numerous trails, enable one to examine the region in detail.

The surface of the dome is a large, nearly round hill, ranging in altitude from about 4,600 feet at the Zeisman ranch to about 5,700 feet at the stone cairn on the top of the hill about 2 miles to the north. The dips on the east and southeast side are much steeper than those on the northern and western sides. Deep canyons have been cut by streams on the west and south, but on the north and east the surface is comparatively smooth. In places near the heads of streams badlands are present.

The water supply is derived wholly from an intermittent stream known as Alkali Fork of Buffalo Creek, which drains the greater part of the surface of the dome. On the south fork of this stream several springs of fairly good flow could furnish sufficient water for drilling and camp use in addition to supplying, as at present, the adjacent ranches. Reservoirs to catch and hold the flood waters could be made with but little difficulty along many of the minor valleys. If drilling were done on the top of the dome, however, it would be necessary to haul or pump water from the springs in the valleys until water was reached by the drill.

STRUCTURE.

The Zeisman dome (Pl. XII), as determined by measurements on the outcrop of the Embar formation, is about 2¼ miles long and 1½ miles wide and trends northwest-southeast parallel to the foot of the Big Horn Mountains a few miles to the east. It is unsymmetrical in form, as the northeast limb is much steeper and narrower than the west limb. The dips on the northeast side vary from zero at the crest line to as much as 35° or 40° one-fourth mile distant, and then descend gradually into a shallow syncline about 1½ miles to the northeast. The beds on the west limb dip more gently, and vary from zero at the crest line of the dome to 16° locally at a point about 1½ miles to the west. The average dip on the west limb is about 12°.

A shallow saddle separates this dome from the Brokenback anticline, the north end of which lies within 1½ miles of the highest point in the Zeisman dome.

Structure contours on the top of the Madison limestone supplemented by a structure section (Pl. XII) show the shape and extent of the dome. From these contours and from the surface altitudes (p. 39) the approximate depth to the different sands may be determined.

The lowest rocks exposed in the dome belong to the Tensleep formation, mainly sandstone, which in this locality is about 200 feet thick and commonly contains water. Overlying this formation and encircling the top of the dome is the Embar formation, about 400 feet thick, which in this locality consists of beds of sandstone, limestone, shale, and gypsum. In other parts of the Big Horn Basin, however, it consists mainly of a fossiliferous limestone, which contains traces of asphaltum, suggesting that it may, where covered, carry oil and gas in commercial quantities, as it does in the vicinity of Lander, Wyo. Owing to the fact that this formation is exposed around the dome, any oil that it may have formerly contained has probably evaporated, and therefore it may not at present contain either oil or gas. Overlying the Embar is the Chugwater formation ("Red Beds"),

which forms the surface rock of a belt a mile or more in width on the west, north, and east sides of the dome. It is about 1,000 feet thick, and is mainly red sandstone with small amounts of shale and a thick bed of gypsum near the top.

The rocks that are buried under the dome belong to the lower part of the Tensleep sandstone, the Amsden formation, about 200 feet thick, and the Madison limestone, about 800 feet thick, on the top of which the structure contours are drawn. The Madison limestone is generally dense and massive and affords no opportunity for the collection of oil or gas, but if it should prove to be porous it might serve as such a reservoir. Any oil or gas accumulating in the upper part of the Madison limestone would have been caught and held, where the structure is favorable, under the shale beds in the lower part of the Amsden.

CONCLUSIONS.

No drilling has been done on the Zeisman dome, and, so far as the writer is aware, there are no oil seeps or gas vents at any point on the surface. The only formation believed to be a possible reservoir in this dome is the upper part of the Madison limestone, which is securely capped by the Amsden formation. This limestone is probably too dense to serve as an oil reservoir, but it may contain some gas. The Madison has been carefully tested by the drill near Spence on Big Horn River, just east of Sheep Mountain, about 35 or 40 miles to the northwest, where it contains but small quantities of oil. If drilling should be done on the Zeisman dome, the writer recommends a location near the top of the dome, probably on the wood road, at some point in the SW. ¼ sec. 23, T. 49 N., R. 89 W., where the Madison limestone should be found at a depth of not more than 500 feet.

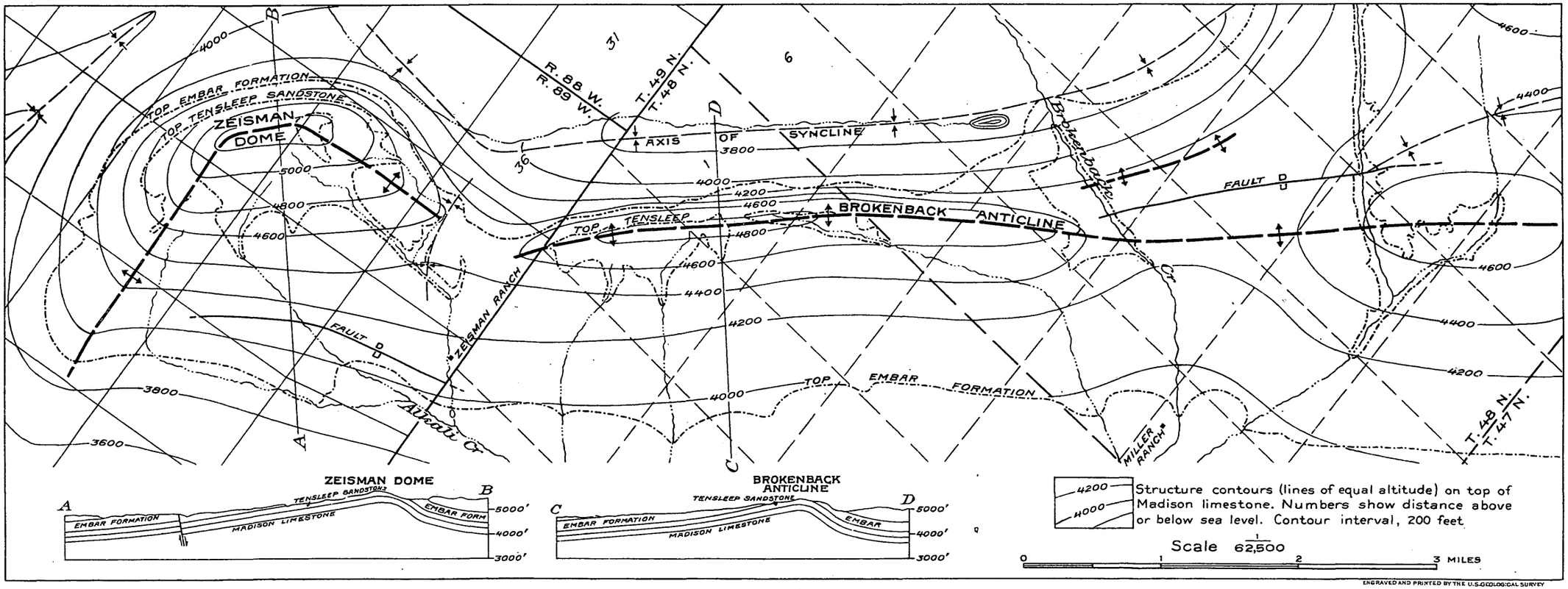
BROKENBACK ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

Brokenback anticline (No. 13, Pl. I) is an untested, unsymmetrical upfold situated on the west flank of Big Horn Mountains between Hyattville and Tensleep. (See Pl. XII.) It is doubtful if it contains oil and gas, because all of the sands, except the Madison limestone, that possibly may carry oil and gas are exposed on its crest.

This anticline can be visited with comparative ease, as a well-traveled road follows along its southwest flank to Hyattville and thence to Manderson and Basin. Near the south end of the anticline a fairly well traveled second-class road crosses the upfold and leads into the Big Horn Mountains. Other parts of the anticline must necessarily be visited on foot or horseback, as the surface is hilly.



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STRUCTURE CONTOUR MAP OF ZEISMAN DOME AND BROKENBACK ANTICLINE (Nos. 12 and 13, RESPECTIVELY, ON PLATE I) AND TWO STRUCTURE SECTIONS

By Charles T. Lupton

This anticline is represented on the surface by a prominent ridge, which coincides closely with the crest line of the fold. The southeast end is crossed by two main branches of Brokenback Creek, which flow in deep ravines. Numerous small intermittent streams here also cut ravines, so that the surface near the anticline is exceedingly rough. Badlands are common, particularly on the southwest limb, where the gypsum and soft shale beds in the upper part of the Chugwater formation form the surface.

The water supply is obtained from the two branches of Brokenback Creek, perennial streams heading in the Big Horn Mountains. At the north end of the anticline there are several springs on a prominent tributary of Alkali Fork of Buffalo Creek; and there are a number of others which rise in a prominent structural valley on the northeast side of the anticline and drain into a large reservoir in sec. 8, T. 48 N., R. 88 W. There are also a number of springs along the two forks of Brokenback Creek. Reservoirs could be made with comparative ease along the intermittent stream courses on the southwest slope of the anticline, where water for domestic use and for drilling could be stored. The Tensleep sandstone, which outcrops on the crest of the anticline, is a prolific water bearer and undoubtedly would furnish sufficient water for use in prospecting when penetrated by the drill.

STRUCTURE.

The Brokenback anticline (Pl. XII) is an unsymmetrical upfold about 8 miles long, with its broad limb on the southwest or basinward side. It is characterized by a local elongated dome developed at its southeast end. Like most of the upfolds along the east side of the Big Horn Basin the northeast limb is narrow, the dips attaining a local maximum of 45° in sec. 1, T. 48 N., R. 89 W., about one-fourth mile northeast of the crest line, and beyond this the beds gradually dip into the syncline, which lies about one-half mile to the northeast. The dips on this limb near the southeast end of the anticline are much less, a maximum of about 5° being observed near the center of sec. 27, T. 48 N., R. 88 W. The dips on the southwest limb are less than those on the opposite limb and attain a maximum of 12° in the SW. ¼ sec. 1, T. 48 N., R. 89 W., about one-fourth mile from the crest line, southwest of which the dips gradually decrease for a mile or more and then increase slightly, to diminish once more to zero at the synclinal trough, a few miles southwest near No Wood Creek. The structural terrace formed by the change in dip may catch and hold any oil or gas migrating up the limb.

At the northwest end of the anticline a shallow saddle separates the Brokenback anticline from the Zeisman dome. At the southeast end on the anticline the beds dip gently southeastward to a shallow

trough, then rise to a low dome, from which they descend to a syncline separating the upfold from the west slope of the Big Horn Mountains.

The beds are faulted for a mile or more on the northeast side of the anticline about half a mile from the crest line. The downthrow, about 75 feet, is on the northeast or mountain side, and the fault is parallel to the crest line of the anticline, thus constituting a strike fault. No other faults are known.

The structure contours drawn on the top of the Madison limestone and the structure section (Pl. XII) show the shape and extent of the Brokenback anticline. From these contours and from the surface elevations, which vary from about 4,500 feet near Zeisman's reservoir in the northern part of sec. 4, T. 48 N., R. 89 W., to about 5,400 feet in the NE. ¼ sec. 2 of the same township, the approximate depths to the different sands may be determined.

The lowest rocks exposed in the anticline belong to the Tensleep formation, about 200 feet thick, mainly of gray to buff, medium to coarse grained sandstone, which in this locality generally contains water. Overlying this formation and encircling the top of the anticline as well as the Zeisman dome is the Embar formation, which in this locality consists of about 400 feet of sandstone, limestone, variegated shale, and gypsum that occurs near the top. In other parts of the Bighorn Basin, however, it consists mainly of fossiliferous limestone, which contains traces of asphaltum, suggesting that it may, where covered, carry oil and gas in commercial quantities, as in the vicinity of Lander, Wyo. Owing to the fact that it is exposed along the crest of this anticline, any oil that it may have contained has doubtless evaporated. Overlying the Embar is the Chugwater formation ("Red Beds"), which forms the surface rock in a belt a mile or more in width on the west, southwest, south, and southeast sides and a narrower belt along the northeast side of the anticline. This formation, having a thickness of about 1,000 feet, consists mainly of red sandstone, with thin layers of shale and a thick bed of gypsum near the top.

The rocks that remain buried along the crest of the anticline belong to the lower part of the Tensleep sandstone, the Amsden formation, about 200 feet thick, and the Madison limestone, about 800 feet thick, on which the structure contours are drawn. The lower part of the Amsden formation is shale and may serve as an impervious cap for the Madison limestone lying beneath. Any oil or gas accumulating in the upper part of this limestone probably would have been caught and held where the structure is favorable under the shale beds in the lower part of the Amsden.

CONCLUSIONS.

No drilling has been done on this anticline, and so far as the writer is aware there are no oil seeps or gas vents in any part of the upfold. The only formation believed to be a possible reservoir for oil or gas in this anticline is the upper part of the Madison limestone, which is securely sealed by the shale in the lower part of the Amsden formation. The Madison limestone has been carefully tested by the drill near Spence, on Big Horn River, just east of Sheep Mountain 40 to 50 miles to the northwest, but showed small quantities of oil. Probably it is too dense to serve as a good reservoir.

If drilling should be done on this anticline the writer recommends that the first well be located on the west slope of the anticline near the crest line, approximately 2 miles southeast of Zeisman's ranch on Alkali Fork of Buffalo Creek, as this part of the upfold is the highest and hence best situated for the accumulation of oil or gas. As this west slope is hilly some difficulty undoubtedly will be found in transporting drilling machinery.

If a well were drilled near the crest line of the elongated dome on the south fork of Brokenback Creek, approximately in the NE. ¼ sec. 28, T. 48 N., R. 88 W., it would, although not at the highest part of the upfold, probably be a good test for this part of the anticline. If a well were located here it would be near water for camp use and for drilling and also could penetrate the top of the Madison limestone much more easily and at less expense than if located on the uplands a mile to the southeast, near the center of the dome.

SHERARD DOME.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Sherard dome[1] (No. 16, Pl. I) is situated in secs. 17–20, T. 47 N., R. 89 W., about 8 miles west of Tensleep and 22 miles east of Worland. (See fig. 9.) It has been known for 30 years or more that oil issued from the ground in a small seep, but no systematic work was done till 1914, when six shallow wells found oil from a few to as much as 100 feet below the surface. A good road, connecting Tensleep, on No Wood Creek, with Worland, on the Chicago, Burlington & Quincy Railroad, lies at the south edge of the dome. The surface features consist of low badland hills, bordered on the south and west by smooth areas and on the north and east by rougher country. Water was found in one of the wells (No. 2, fig. 9) drilled in this dome at a depth of slightly more than 200 feet. It is of poor

[1] Knight called this dome the "Cottonwood oil field." See Knight, W. C., and Slosson, E. E., Bonanza, Cottonwood, and Douglas oil fields: Wyoming Univ. Bull., Petroleum ser., No. 6, pp. 14–17, 1903.

quality but is good enough for use in the boilers. Cottonwood Creek, an intermittent stream, drains the area and throughout the greater part of the year contains a small quantity of water in pools or seeps which may be used for domestic purposes and for drilling. Reservoirs to catch and hold the flood waters could be made easily in the beds of shale adjacent to this stream and its tributaries.

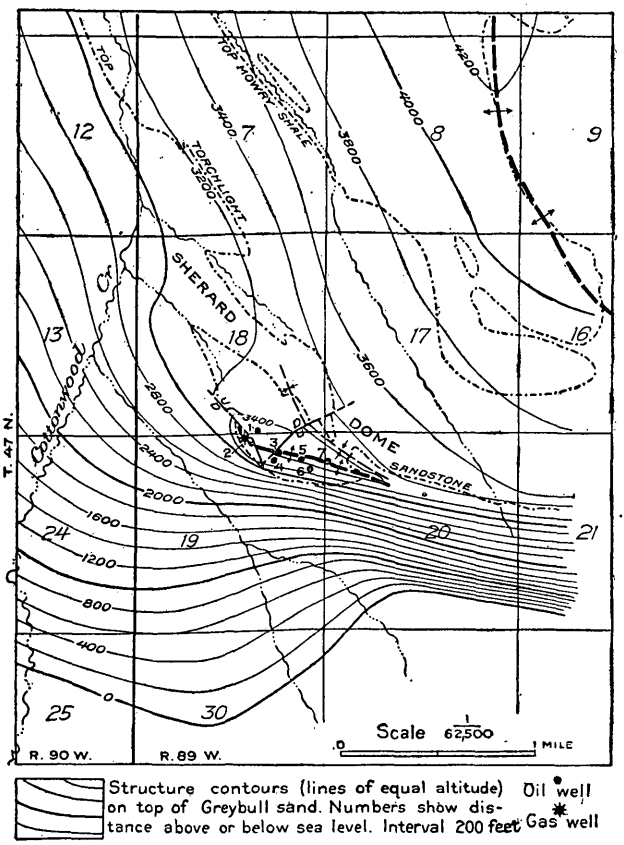


FIGURE 9.—Structure-contour map of Sherard dome (No. 16, Pl. I). The outcrops of sands are mapped as sandstones.

STRUCTURE.

The Sherard dome, a small northwest-southeast wrinkle on a broad westward-dipping slope (see fig. 9), is about a mile long and half a mile wide. It lies at a place where the strike of the beds swings abruptly from northwest to nearly west. A shallow syncline lies a short distance northeast of the crest of the dome and separates it from the monoclinal slope on the east. The steepest dips are on the south limb of the dome, where one-fourth mile southeast of the crest line the beds dip 45° and one-half mile farther southeast 65° S.

Farther south the beds flatten, but continue to dip south and southwest for several miles into the deepest part of the Big Horn Basin. The dips at the southeast and northwest ends of the dome are very slight. On the northeast limb the beds dip in places as much as 10° but generally less.

The structure contours drawn on the Greybull sand (top of Cloverly formation) show the shape and extent of the dome. From these and the surface elevations, which range from about 4,500 feet above sea level, near Cottonwood Creek, in the NW. ¼ sec. 18, to about 4,770 feet in the NW. ¼ sec. 20, T. 47 N., R. 89 W., the approximate depth to the Greybull sand or any other sand whose position with relation to the Greybull is known may be obtained. The northwest half of the dome is broken by faults of slight throw, two of which are shown on figure 9.

The surface rocks belong to the upper part of the Frontier formation, which in this general region is about 550 feet thick. The formations which are concealed below the surface but known to underlie the Frontier formation down to the Embar limestone are the Mowry shale, about 175 feet thick; Thermopolis shale, about 600 feet thick; Cloverly formation, about 125 feet thick; Morrison formation, about 200 feet thick; Sundance formation, about 250 feet thick; and Chugwater formation, about 1,000 feet thick.

DEVELOPMENT.

Oil has been found in six out of the seven wells drilled on the Sherard dome but not in commercial amounts in any of them. Well No. 1, drilled in October and November, 1914, in the SW. ¼ SE. ¼ sec. 18, is 102 feet deep. The first oil was found at a depth of 35 feet, and the well, according to H. M. Sherard, driller, probably would yield 7 to 8 barrels daily after being shot. Wells 2–6 are situated in the NW. ¼ sec. 18, T. 47 N., R. 89 W. Well No. 2 contains no oil, but gas was struck at a depth of 25 feet and was found in all the strata from this depth to the bottom of the hole at a depth of 206 feet. Water of poor quality was found near the bottom. It was drilled in November and December, 1914. Well No. 3 was drilled to a depth of 102 feet in the same months. The first oil was found at a depth of 14 feet and the best flow at about 54 feet. Well No. 4, drilled in October and November, 1914, is about 100 feet deep. The first oil was struck at a depth of about 30 feet, but most of it was found 35 feet below the surface. Well No. 5, drilled in June, 1915, was also drilled to a depth of 100 feet. The first showing of oil was found at 35 feet and the greatest quantity at 70 feet. It is estimated by the driller, H. M. Sherard, that this well will yield 7 or 8 barrels daily after it is "shot." Well No. 6 was

drilled to a depth of 102 feet in June, 1915, and found its first oil at 92 feet. It is believed by Mr. Sherard to be as good as wells 1 and 5. A sample of oil for analysis was collected from this well. (See analysis 5, p. 51.) Well No. 7, in the NW. ¼ NW. ¼ sec. 20, T. 47 N., R. 89 W., was drilled to a depth of 103 feet in June, 1915. The first oil was reached at 30 feet and a greater quantity at 65 feet.

The oil from this dome is not so light in weight or color as the Greybull and Torchlight oils but is similar to that issuing from the seep and well in the Bonanza anticline (p. 96). The fact that the oil is heavier than that from other fields in the basin is probably due to the fact that the sands yielding oil lie near the surface and some of the lighter hydrocarbons may have escaped.

CONCLUSIONS.

The Sherard dome is very small and probably will never be important as a producer of oil and gas. The oil, although of high grade, is found in such small quantities that it is doubtful if further shallow drilling will pay. A deep well testing the Mowry shale and Greybull sand might show a greater flow than any of the shallow wells. Hence it is advised that a well penetrating at least to the Greybull sand, which in the center of the dome lies at a depth of about 1,200 feet, be drilled on the southwest or basinward side, on which, rather than on the mountainward side, this dome, like the Greybull dome and the Lamb anticline, is likely to carry oil.

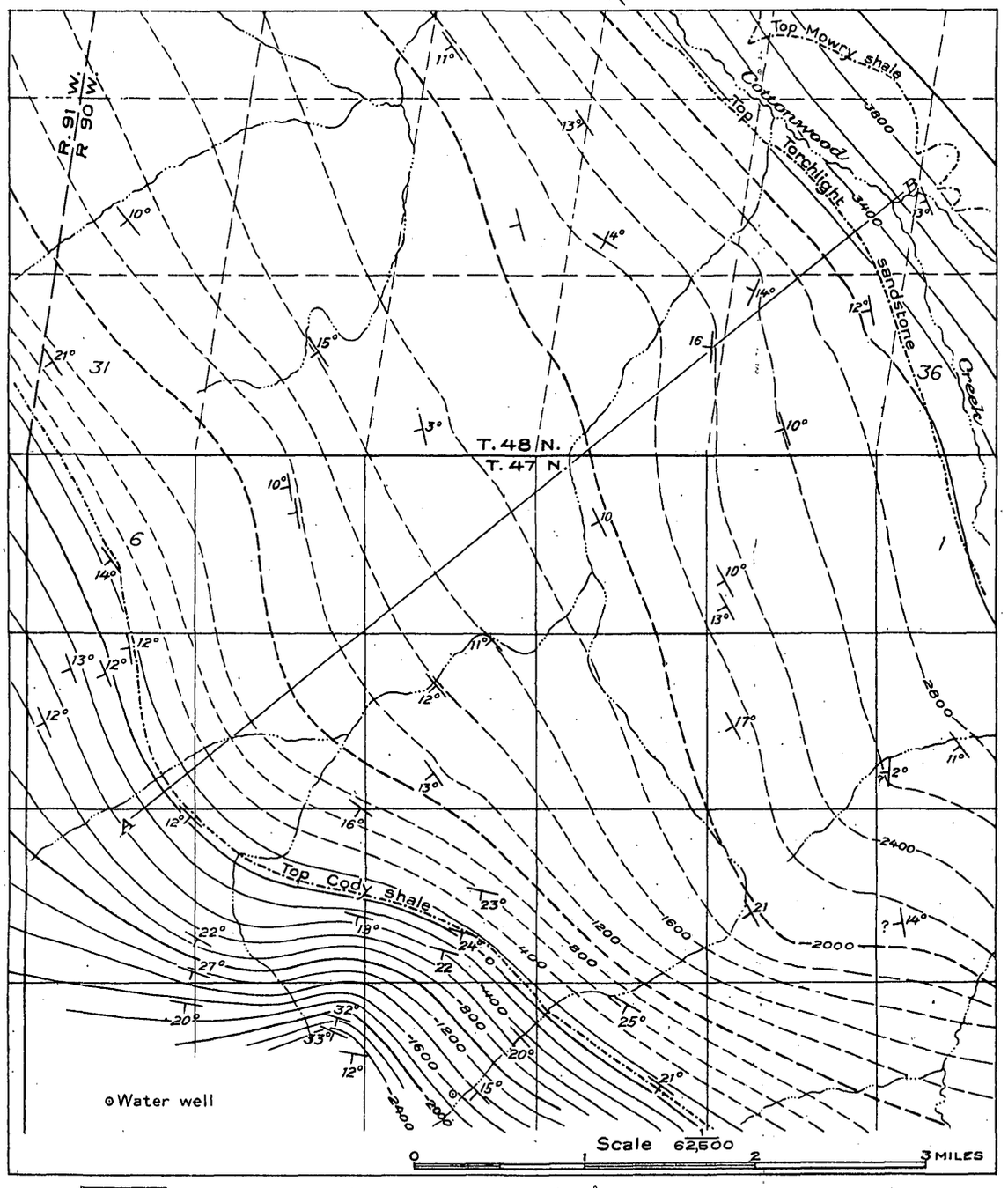
WELL AREA.

By CHARLES T. LUPTON.

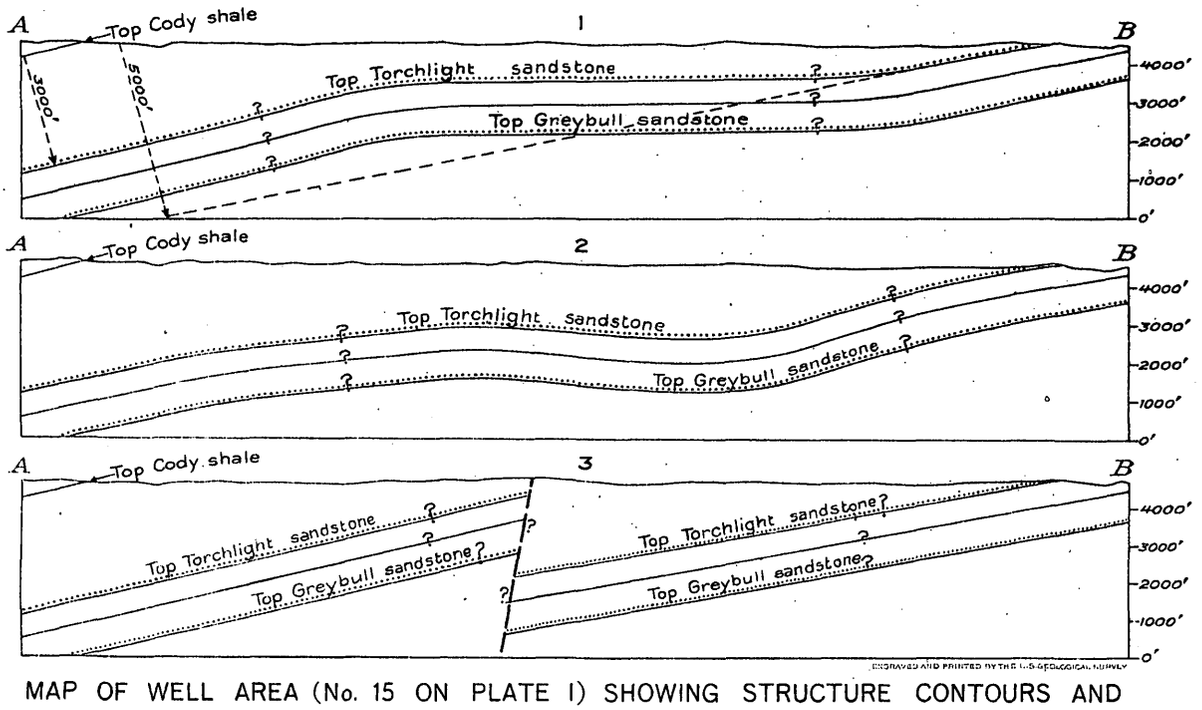
GENERAL FEATURES.

The Well area (No. 15, Pl. I), so named from the fact that it is near a water well drilled on the Worland-Tensleep road, in the central part of sec. 21, T. 47 N., R. 90 W., is about 10 or 12 miles west of Tensleep, 16 or 18 miles east of Worland, and an equal distance southeast of Bonanza. (See Pl. XIII.) A detailed examination of the area was made to determine whether or not it included an anticline or dome which might contain oil or gas, but the information collected is in places so conflicting that this point was not settled. Nevertheless, it seems advisable to call attention to the locality as a possible area for oil or gas and to furnish the reader such information as was obtained.

The area is most easily reached from Worland, on the Chicago, Burlington & Quincy Railroad, 16 or 18 miles to the west, from which a fairly good road extends eastward to Tensleep. By leaving this main road at the well in the central part of sec. 21, T. 47 N., R. 90 W.,



Structure contours (lines of equal altitude) on top of Greybull sand. Numbers show distance above or below sea level. Solid lines represent accurate contours; broken lines, hypothetical contours. Interval 200 feet



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MAP OF WELL AREA (No. 15 ON PLATE I) SHOWING STRUCTURE CONTOURS AND THREE STRUCTURE SECTIONS REPRESENTING DIFFERENT INTERPRETATIONS OF STRUCTURE

The outcrops of sands are mapped as sandstones

By Charles T. Lupton

and traveling north 2 or 3 miles by wagon or automobile, the area is reached. It can also be visited by leaving the railroad at Manderson and following an excellent road along the course of No Wood Creek to the mouth of Cottonwood Creek. Beyond this the road is very poor, and the remaining 6 miles is best traversed on horseback.

The surface of the Well area is comparatively smooth, being cut here and there by shallow stream courses which carry water only during short periods of the year. To the east and northeast is the prominent valley of Cottonwood Creek, bounded on the east by a high ridge which forms the west flank of the No Wood anticline (p. 97). To the west of the comparatively smooth country constituting the Well area a higher ridge, formed by an outcrop of sandstone and shale, trends northwest. The surface altitudes range from about 4,450 feet on Cottonwood Creek, in the northern part of sec. 22, T. 48 N., R. 90 W., to about 4,800 feet in the NW. ¼ NW. ¼ sec. 17, T. 47 N., R. 90 W.

The only water in this region is derived from small seeps which issue at a few places in the bed of Cottonwood Creek and of the well in the central part of sec. 21, T. 47 N., R. 90 W. During the spring, early in summer, and after heavy rains water flows in Cottonwood Creek and its intermittent tributaries. Reservoirs could be made along these streams with but little difficulty to catch and hold the flood waters for drilling and camp use. The shale which forms the surface in this locality is nearly impervious, and the possibility of the water in the reservoirs escaping through the shale is remote. The water in the well above referred to is of poor quality for camp and ranch use, as it is highly alkaline, but it could be used for drilling. This well was drilled to a sand at a depth of a little less than 200 feet and obtained a fairly good flow of water. Water could undoubtedly be obtained from the same sand at many places north and west of its outcrop.

STRUCTURE.

The dips of the beds at the surface are represented on the map (Pl. XIII) by numerous symbols. The dips east of the top of the outcrop of the Torchlight sandstone and west of the base of the Mesaverde formation indicate the attitude of the various strata beneath the surface, including the Greybull sand (the top sandstone of the Cloverly formation), on which the structure contours are drawn, because dips in these localities were determined on beds of sandstone or upon near-by shale beds. The dips in areas of Cody shale between the top of the Torchlight sand (top of Frontier formation) and the base of the Mesaverde formation, however, are not believed to indicate reliably the attitude of the Torchlight and other sands lying directly beneath. This conclusion was forced on the

writer by certain inconsistencies. The Cody shale ranges from 3,000 to 3,300 feet thick at places a few miles from this area both to the northwest and the southeast. These thicknesses, which were determined by calculations based on the dips and the width of outcrop, correspond closely to the thickness of the shale at other places on the east and south sides of the Big Horn Basin. When the same means are used to determine the thickness of the Cody shale in the Well area it is found to be a little less than 5,000 feet (see Pl. XIII), or 1,700 to 2,000 feet thicker than it is a few miles away on either side. The writer has no reason to believe that the Cody shale is any thicker here than elsewhere. As there is no evidence that the shale is thicker here than elsewhere, it is probable either that the surface dips of the Cody shale do not indicate accurately the attitude of the sands beneath the surface, or that the structure is more complicated than it is in most places in Big Horn Basin.

What, then, is the most reasonable interpretation of the surface dips? Three hypothetical cross sections (1, 2, and 3, Pl. XIII) are given to show what the writer believes to be the possible structure of the rocks in this area. These sections are supposed to show the position and dips of the sands according to the various hypotheses.

Hypothetical cross section 1 represents a terrace structure and is consistent with the structure contours shown on the map, but does not correspond to the dips on the shale shown on the map. It is, however, the simplest structure that one can imagine to exist at this locality unless a synocline is present, a supposition which is probably impossible. (See p. 108.) This section corresponds to the structure contours on Plate XIII, which are broken in places to indicate that their positions are uncertain.

Hypothetical cross section 2 shows the beds in the west half of the section to be affected by one upfold. This structure more nearly explains the great thickness of Cody shale than section 1, but it does not agree with the surface dips any better than that section. It assumes one area of northeastward dips, but no such dips have been observed at the surface. If such a structural feature is present, it is probable that it would contain oil or gas in commercial quantities, as there is no other upfold known between it and the depths of the basin to the west.

Hypothetical cross section 3 shows the attitude of the beds beneath the surface if a normal strike fault were present in the area. This interpretation would fit all the dips observed along or in the vicinity, but no surface evidence of such a fault was observed. As faults in shale areas are exceedingly difficult to discover, one may be present here without having been detected. If the structure shown in section 3 is correct, then the presence of oil or gas in the area would probably depend on whether or not the fault has been of such a char-

acter as to bring the oil-bearing sands on the west in contact with shale in the east, thereby probably sealing the cut edge of the sand and rendering it a good receptacle for the storage of oil or gas.

The lowest surface rocks exposed in the northeast corner of the area belong to the Mowry shale, a hard, dark-gray, platy shale, which includes at least two sandstone beds that carry oil of economic importance in the Torchlight dome a few miles east of Basin. Directly overlying the Mowry is the Frontier formation, about 600 feet thick, which is mainly beds of sandstone with thin layers of shale and bentonite. This formation contains oil and gas in the Grass Creek, Elk Basin, Little Buffalo Basin, and Byron fields, and the writer believes it also may carry oil and gas at one or more localities here. Overlying the Frontier formation is the light to dark gray Cody shale, about 3,000 feet thick. Overlying the Cody shale is the Mesaverde formation, consisting mainly of sandstone with thin layers of shale and in some localities a little coal.

Underlying the surface are the lower part of the Mowry shale, the Thermopolis shale, the Cloverly formation, and lower formations. The Thermopolis shale, about 600 feet thick, is largely dark-gray shale, with a bed of sandstone (Muddy sand) about 200 feet above its base. Although this sandstone bed is very persistent throughout the Bighorn Basin, it is not known to be important as an oil or gas reservoir except in the Oregon Basin field. Directly beneath the Thermopolis shale is the Cloverly formation, about 125 feet thick, which consists usually of about 20 feet of sandstone (Greybull sand) at the top, 70 to 100 feet of variegated shale in the middle, and zero to 25 feet of conglomerate at the base. The Greybull sand is a possible reservoir of oil and gas in this locality, as it carries all the oil and gas produced in the Greybull field.

CONCLUSIONS.

Although the writer is unable to point out specifically the crest line of any anticline or dome in the area under consideration, yet he believes that certain parts of the area are more likely to contain oil and gas in commercial quantities than are some of the areas where the exact position of the anticlinal crest line is known. A fault may cross the area in a northwest-southeast direction, in which case the part of the area lying directly west of the fault probably will be as good a reservoir as if an anticline were present, because in the faulting there has been vertical displacement, which may throw sandstone beds against beds of shale, and movement along this fault plane which may seal the sandstone and prevent any oil or gas that may migrate along these beds from escaping to the surface.

If there is no fault through the field, then there may be a structural terrace, as the contours suggest. An accumulation of oil or

gas may be found near the line of change of dip, as in many other fields.

It is possible also that there may be one or more anticlines or domes in this broad area. If these supposed anticlines or domes exist, they certainly would be favorable to the accumulation of oil. From present knowledge, however, such folds can not be located. Certain topographic features suggest the possible locations of one or more of these, which are given below.

If any one desires to test this area, concerning which the evidence is unusually meager, the writer advises drilling the initial well near the center of sec. 4, T. 47 N., R. 90 W. As may be noted on the map, there are no dips shown in this section, which lies opposite the prominent reentrant in the outcrop of the Mesaverde formation to the southwest. A dip of 3° directly north of the section and dips of 11° and 12° directly south are suggestive of terrace structure. Another point at which the writer considers drilling may show the presence of oil is in the E. ½ sec. 33 and W. ½ sec. 34, T. 48 N., R. 90 W., southwest of the prominent bend in the structure contours.

Owing to lack of time to search more carefully for dips in this locality and to the fact that shale dips are not always reliable guides to the structure beneath the surface the entire area was not fully examined. The writer advises anyone who considers drilling in this locality to make a thorough search for eastward and northeastward dips, which would suggest that a favorable structure is present a short distance west of the locality where such dips are noted.

TENSLEEP ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Tensleep anticline (No. 17, Pl. I) is in the northwestern part of T. 46 N., R. 88 W., about 5 miles south of Tensleep post office and about 30 miles slightly south of east of Worland, a town on the Chicago, Burlington & Quincy Railroad. Although it has not been tested, it is believed that this anticline offers favorable area for the accumulation of oil and gas, because it pitches at each end and is the upfold lying nearest the central part of the Big Horn Basin. The position of an anticline with reference to the main basin is very important, as the long dip slope below the innermost minor fold affords a large gathering ground for the oil, whereas anticlines farther up the rim of the basin have had their supply cut off by folds lying below them.

The anticline is most easily accessible from Tensleep, which is connected with the railroad by two fairly good roads. One follows roughly the course of No Wood Creek from Manderson near the

mouth of that stream through Bonanza to Tensleep, a distance of 35 or 37 miles. A mail stage traverses this route daily. The other route is a few miles shorter but is not so good, as it traverses a rougher country. It connects with the railroad at Worland and crosses the badlands in a fairly direct line to Tensleep. From Tensleep a second-class road leading to the coal mine in Bud Kimball Draw, 10 to 12 miles to the southwest, crosses the northern part of the Tensleep anticline.

The crest of the Tensleep anticline (Pl. XIV) coincides with a troughlike depression which is surrounded by a wall of sandstone and shale in places 75 feet high. This wall is encircled by lower walls of sandstone due to the outcropping of the harder overlying beds which dip away from the crest. Badlands are common in places adjacent to stream courses.

The water supply of the anticline is exceedingly meager. There are no perennial streams or springs nearer than No Wood Creek, 5 miles or more to the east. Water for drilling must be brought from that stream, which carries an almost inexhaustible supply of fairly good water the year round. It is, of course, possible to construct reservoirs in the valleys of the intermittent streams to catch and hold the spring run-off and floods following heavy rainstorms. At certain times of the year, particularly in spring and early in summer, water may be found in the intermittent stream courses.

STRUCTURE.

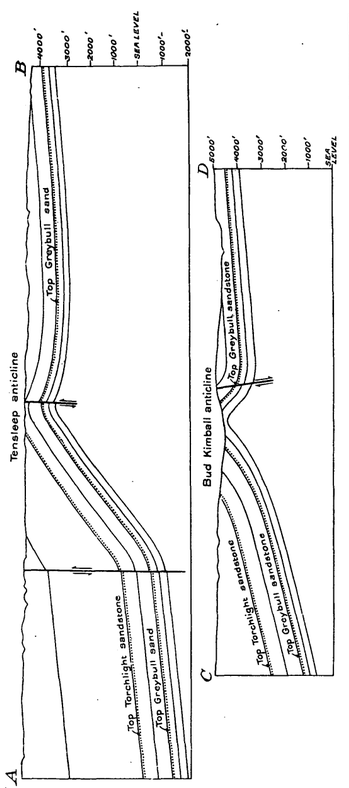
The Tensleep anticline is a northwestward-trending upfold, and, as shown in the cross section (Pl. XIV), the steeper dip is on the southwest side. This is a condition not common in the anticlines and domes along the east side of the Big Horn Basin, where the steep dips usually occur on the east or mountain side. On the southwest limb the dips average about 45° but vary from zero near the crest line to 90° locally at the fault lying about 1½ miles distant. In fact, at one place in the E. ½ sec. 24, T. 46 N., R. 89 E., the strata are overturned and dip 86° toward the east. On the northeast limb the dips are less, averaging about 10° but attaining a maximum of 38° locally in the eastern part of sec. 18, T. 46 N., R. 88 W. This steep dip occurs near a fault and undoubtedly is due to the drag of the beds. The dip of the beds on this limb decreases to zero at the trough of the syncline lying about three-fourths mile from the crest line of the anticline. The beds at the northwest end of the anticline dip 8° NW.; those at the southeast end, near the north end of Bud Kimball anticline, dip less steeply.

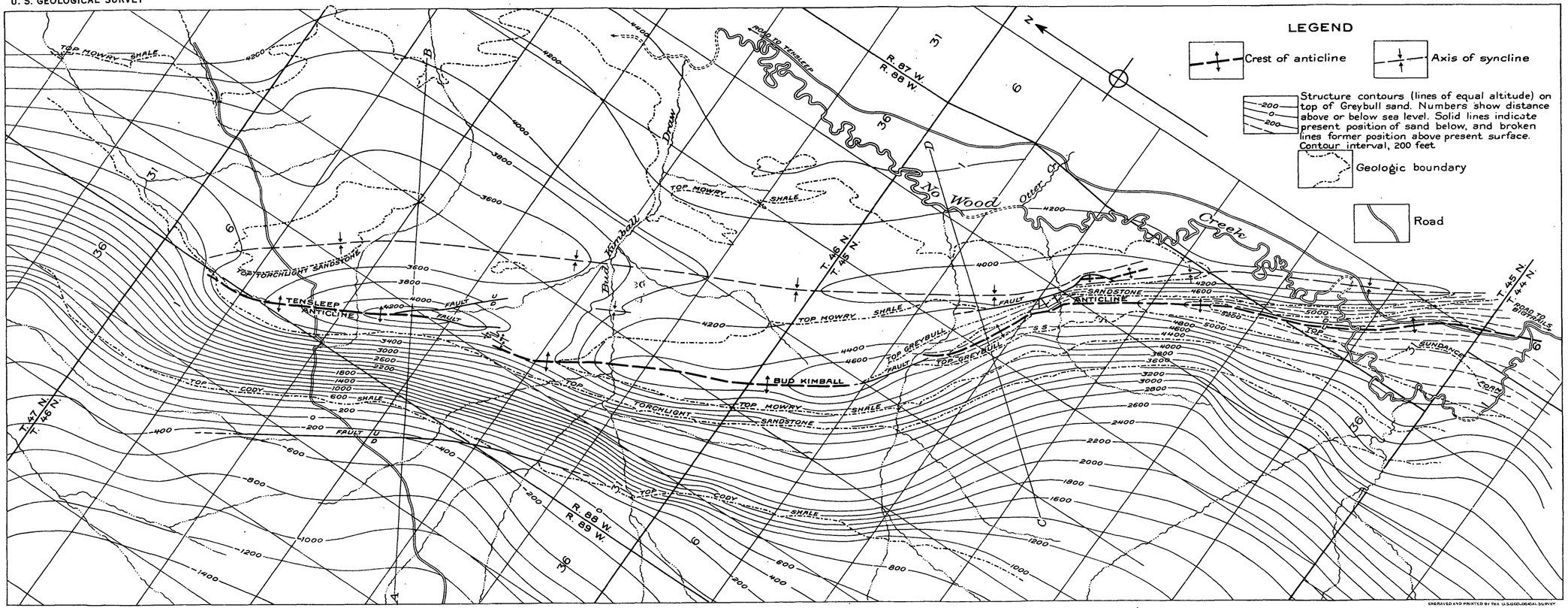
Several strike faults lie nearly parallel to the crest line of the anticline. (See Pl. XIV.) The largest is about 1½ miles southwest of the crest line and is practically parallel to it. The upthrow is about 200 feet and is on the east side of the fault. This fault is about 5 miles long and dies out at the southeast in steeply dipping beds. The other faults are near the southeast end of the anticlines and are small. The largest fault, just east of the crest line of the anticline, raises the east side from 75 or 100 feet above the west.

The structure contours drawn on the Greybull sand, at the top of the Cloverly formation, show the shape and extent of the anticline. From these and from the surface elevations, which vary from about 4,750 feet above sea level at the southeast end of the anticline, near the center of sec. 20, T. 46 N., R. 88 W., to a little more than 4,900 feet in the eastern part of sec. 18 of the same township, the approximate depth to the top of the Greybull sand, or any other sand whose position with relation to the Greybull sand is known, may be determined.

The lowest rocks exposed along the crest of the anticline belong to the Frontier formation, which in this locality is about 600 feet thick and consists of sandstone, sandy shale, shale, and thin beds of bentonite, with sandstone predominating. The lowest sandstone of any considerable thickness in the Frontier is the Peay sand, which yields the gas and some of the oil in the Lamb anticline. The top sandstone, which, in the vicinity of Basin and Greybull, has been named the Torchlight sand, is not so thick as the Peay sand and is characterized by a thin bed of conglomerate near its top. Overlying the Frontier formation is the Cody shale, which is exposed on the west side of the anticline, with two outliers on the east side, one in secs. 6, 7, and 8 and the other in secs. 19 and 20. The shale is about 3,000 feet thick and consists mainly of dark-gray shale, with thin beds of sandstone near the top and one lenticular bed near the base. None of these sandstone beds, however, is known to contain oil or gas in this part of the Big Horn Basin.

There remain buried at the crest of the anticline the Mowry shale, about 175 feet thick, the Thermopolis shale, about 500 feet thick, and the Cloverly formation, about 125 feet thick. The Mowry shale contains in places two oil sands, the Kimball sand above and the Octh Louie sand below. Both of these sands, together with the entire thickness of the Mowry shale, carry oil in the Torchlight dome. As they are only slightly buried in the Tensleep anticline, it is doubtful if they contain any oil. The Thermopolis shale consists of dark soft shale with a sandstone bed (Muddy sand) about 250 feet above its base. This sand is not known to carry oil or gas except in the Oregon Basin. The Greybull sand, the top sandstone of the Cloverly formation, is believed to be the most promising oil sand underlying the anti-





STRUCTURE CONTOUR MAP OF TENSLEEP AND BUD KIMBALL ANTICLINES (Nos. 17 AND 18, RESPECTIVELY, ON PLATE I), AND TWO CROSS SECTIONS

The outcrops of sands are mapped as sandstones

By Charles T. Lupton

Scale 1/62500

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cline, as it is the sand which carries oil and gas in the Greybull field. It is in general about 20 feet thick and in texture ranges from medium to coarse grain. Underlying it is about 80 feet of variegated shale, mainly red in color; and in most places underlying the shale is a bed of sandstone and conglomerate 5 to 25 feet thick.

CONCLUSIONS.

No development work has been done on this anticline, and no oil seeps or gas vents on or adjacent to it are known to the writer. The anticline as a whole is believed to be worthy of careful consideration by oil drillers as a reservoir for oil and gas, as it pitches at both ends and lies adjacent to the deeper part of the great basin.

The Greybull sand is believed to be the best oil sand in the anticline, as it is not exposed at the surface at any place, and any oil that may have accumulated in its pores has had little opportunity to escape. The sandstone beds in the Mowry formation may contain some oil or gas, but are less likely than the Greybull sand to do so, for they are near the surface, particularly at the top of the anticline.

The oil sands, where cut by faults, are believed to have been sealed by shale, preventing the escape of the oil or gas. Particular attention is called to the main fault southwest of the anticline. It has probably penetrated as deep as the Cloverly formation; and if so, any oil or gas that may have migrated up that stratum from the southwest would have entered the sandy beds of the Morrison or Sundance formations on the other side of the fault. The overlying sandstone beds of the Mowry and Frontier formations, however, would probably be sealed by the Thermopolis shale. (See fig. 6, p. 61.) Special attention is called to the possibility that although the Frontier is exposed around Tensleep anticline it may carry oil and gas directly west of this fault. It is not likely that the fault has completely prevented access of oil from the Greybull sand under the Tensleep anticline, because oil and gas may have migrated up the strata around the north end of the fault into the Tensleep anticline.

Of the different anticlines and domes along the east side of the Big Horn Basin southeast from the Torchlight dome that have been described but not tested, the writer considers the Tensleep and the area directly west of the main fault to be among the most favorable.

BUD KIMBALL ANTICLINE.

By Charles T. Lupton.

GENERAL FEATURES.

The Bud Kimball anticline (No. 18, Pl. I), as shown on Plate XIV, lies mainly on the west side of No Wood Creek, 8 to 16 miles south of Tensleep post office and in the southeastern part of the Big Horn Basin.

It is most easily accessible from Tensleep post office, and the routes to the railroad are fully described on pages 112–113. Beyond Tensleep one should follow the River Road to the mouth of Bud Kimball Draw or to the mouth of Otter Creek, 6 or 8 miles farther south, from both of which secondary roads lead westward and give easy access to the entire anticline. Much of the examination, however, must be made on foot or horseback as the surface is exceedingly rough in places. The River Road connecting Tensleep and Bigtrails crosses the southeast end of the anticline in sec. 31, T. 45 N., R. 87 W., near the mouth of Buffalo Creek, a western tributary of No Wood Creek.

The crest of the anticline is marked on the surface by a prominent ridge, in which gaps are cut by No Wood Creek near its southeast end and by several intermittent streams. (See Pl. XIV.) In many places near the heads of streams badlands are common, and in a few places the streams have worn the rocks in such a way as to form pronounced cliffs.

The main water supply is derived from the perennial streams, No Wood and Otter creeks, and from numerous western intermittent tributaries of No Wood Creek, which carry water early in spring, in summer, and after heavy rains. A few small springs issue from the sandstone beds, mainly in the deeper intermittent stream channels on the west limb of the anticline. The greater number occur along Buffalo Creek and its tributaries near the southeast end of the anticline. Their yield is small, but reservoirs below them would probably collect sufficient water for drilling and camp uses. Where there are no springs reservoirs could be made in the valleys of the intermittent streams to catch and hold flood waters. The best water for camp and ranch use, however, is contained in No Wood Creek and its eastern perennial tributaries.

STRUCTURE.

The Bud Kimball anticline is a northward-pitching wrinkle on the west slope of the great upfold of the Big Horn Mountains. It is 12 to 15 miles in length, and, like many of the anticlines on the east and south sides of the Big Horn Basin, is partly unsymmetrical (see Pl. XIV), the mountainward side of its southwest half being much narrower and the beds more steeply inclined than the basinward side. The mountainward limb ranges in width from about one-fourth of a mile a short distance southwest of the mouth of Otto Creek to about a mile directly south of Bud Kimball Draw. The west limb is broad, extending from the crest of the anticline into the depths of the great downfold of the Big Horn Basin. On the mountain flank the dips of the beds range from zero at the crest line of the anticline to about 76° locally. The maximum dip, which is probably due to drag of the beds during faulting, was noted in the W. ½ sec. 30,

T. 45 N., R. 87 W., near a fault which is less than one-fourth mile from the crest line of the upfold. From this point the dips decrease gradually northeastward to zero at the axis of the syncline. Near the north end of the west limb the dips of the beds range from zero at the crest line to about 65° locally a short distance south of Bud Kimball Draw about 1½ miles west of the crest and near the southeast end of the prominent fault shown on Plate XIV. This high dip, which is also probably due to drag, is on the southwest slope at the southeast end of the anticline, about a mile north of the mouth of Buffalo Creek in the SW. ¼ sec. 30, T. 45 N., R. 87 W., and within one-fourth of a mile of the crest line of the anticline. The north end of the anticline pitches slightly into a shallow sag separating it from the Tensleep anticline. At the south end the anticline does not pitch south but pitches slightly and uniformly northwest, hence the outcrops of the beds of rock do not close around the end of the upfold but connect with beds outcropping along the west limb of the Big Horn Mountains.

Many small faults are present along this anticline. That to the west of the northwest end is described on page 114. In addition to the minor faults some of greater magnitude parallel the crest of the anticline near its middle. (See Pl. XIV.) The throw in places is as much as 200 feet. The downthrow of the easternmost fault is on the east side, and that of the westernmost, near the crest of the anticline almost directly west of the mouth of Otter Creek, is on the west and amounts to 100 feet or more.

The structure contours drawn on the top of the Greybull sand (top of the Cloverly formation) show the shape and extent of the anticline. From these and from the surface altitudes, which vary from about 4,575 feet on the river near the mouth of Otter Creek in sec. 12, T. 45 N., R. 88 W., to as much as 5,220 feet near the north end of the anticline in sec. 4, of the same township, the approximate depth from the surface to the sand on which the structure contours are drawn or to any other sands whose relative positions are known may be determined. (See p. 39.)

The lowest surface rocks exposed in the Bud Kimball anticline belong to the Chugwater formation ("Red Beds"), about 1,000 feet thick, which consists mainly of red sandstone but includes a small quantity of shale and a thick gypsum bed near the top. This formation is exposed only near the southeast end of the anticline, mainly south and east of No Wood Creek. Directly overlying the Chugwater formation is the Sundance formation, about 250 feet thick, consisting of sandstone and shale with small amounts of limestone, most of which has a slightly greenish tint. Overlying the Sundance is the Morrison formation, about 250 feet thick, consisting of variegated shale and sandstone, the shale in most places predominating. Directly overlying the Morrison is the Cloverly formation, the top

sand of which (the Greybull sand) is the bed on which the structure contours are drawn. This formation is about 125 feet thick and consists, in addition to the Greybull sand, which is about 20 feet thick, of 75 or 80 feet of reddish shale directly underlying the Greybull, and of 20 to 25 feet of gray to white conglomeratic sandstone at the base. Directly overlying the Cloverly is the Thermopolis shale, 500 to 600 feet thick, consisting of a dark-gray to blue shale with a rather persistent bed of sandstone (Muddy sand) near its middle. This sand is not known to contain commercially valuable oil or gas except in the Oregon Basin, though it does carry these substances in small quantities wherever it has been penetrated by the drill. Directly overlying the Thermopolis is the Mowry shale, 175 to 200 feet in thickness. It consists of a hard dark-gray platy shale with intervening beds of shaly sandstone, which in some localities are recognized as sands and which carry oil and gas. This formation produces practically all the oil and gas obtained in the Torchlight dome near Basin. Overlying the Mowry is the Frontier formation, 600 feet or more in thickness, containing three or four prominent beds of sandstone. Two of these, one at the top and the other near the base, have been designated as the Torchlight and Peay sands, respectively. In this anticline, however, it is impossible to differentiate these beds with certainty. Overlying the Frontier is the Cody shale, which, owing to the wearing away of the formations by streams, is present only on the west flank of the anticline. It is at least 3,000 feet thick and contains thin beds of sandstone near its top and in places a bed of sandstone near its base. Where present this formation makes an excellent cover for the Frontier formation and where the structure is favorable, it would probably retain any oil or gas that may have accumulated.

The rocks beneath the surface along the axis of the anticline belong to the lower part of the Chugwater formation, the Embar formation, about 200 feet thick, the Tensleep sandstone, about 400 feet thick, and the Amsden formation, possibly a little thinner. The Amsden rests directly upon the Madison limestone, the top part of which may possibly carry oil and gas in commercial quantities, but this is rather doubtful, as the limestone is so dense in most places as to prevent the accumulation of oil or gas in its pores.

CONCLUSIONS.

No drilling has been done on this anticline, and no seeps of oil or vents of gas are known at any place along or near its crest. As the anticline plunges gradually northwestward and as all the strata from the Cody down to and including the upper part of the Chugwater formation are exposed along its crest, it seems safe to predict that

neither oil nor gas in commercial quantities will be found in these formations. It is also doubtful if the Embar can serve as a reservoir for oil or gas, because it consists mainly of thin sandstone and shale along the southeast side of the Big Horn Basin. The top of the Madison limestone, which is exposed a few miles to the east and southeast, is an equally poor reservoir because of its compact character.

MAHOGANY BUTTE ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Mahogany Butte anticline (No. 19, Pl. I) is a deeply eroded upfold, the western part of which is in the area represented on Plate XV. All rocks known to carry oil or gas at any place in Wyoming are exposed along the valley of No Wood Creek near the top of the anticline. This fact and the proximity to the Big Horn Mountains make the anticline one of doubtful value as an oil or gas reservoir except at its west end in the east part of T. 43 N., R. 89 W., where there is a flattening of the dips.

The anticline lies mainly in T. 43 N., Rs. 88 and 89 W., west of No Wood Creek. It is in the southeastern part of the Big Horn Basin and on the south side of the deep part of the basin.

The nearest railroad town is Lucerne, on the Chicago, Burlington & Quincy Railroad, 40 miles west. From this place a good road follows the valley of Kirby Creek and a second-class road leads up the valley of Lake Creek to its head, thence over the divide across the upper drainage of No Water Creek and on the east to this anticline and the settlements along No Wood Creek. A stage road connects Bigtrails, a post office a few miles northeast of Mahogany Butte, with Manderson, a small town on the Chicago, Burlington & Quincy Railroad at the mouth of No Wood Creek about 55 miles to the northwest. The latter route, although longer, is probably the most advisable unless one desires to follow the less frequented road from Lucerne and thus see along the route other anticlines described in this report.

The greater part of the Mahogany Butte anticline lies west of the deep valley of No Wood Creek, and the surface near by contains many rugged hills 1,000 to 1,200 feet high. Farther from the stream the valleys are shallower and the hills less rugged. Mahogany Butte, a conical mass of Madison limestone and overlying formations, is the most conspicuous topographic feature of the locality. The surface of the anticline varies in elevation from about 6,430 feet above sea level at the top of Mahogany Butte (Pl. X, *B*, p. 98) to about 5,150 feet at the northwest end of the anticline near Buffalo Spring Creek in sec. 15, T. 43 N., R. 89 W.

Water may be obtained from No Wood Creek, a perennial stream that crosses the anticline, and from springs mainly along the outcrop of sandstone beds on the north side of the upfold. Intermittent streams and reservoirs that could be made in the shallow valleys would provide an additional supply. As drilling is most likely to be done at some distance from No Wood Creek rather than close to that stream, water is best procured from the springs, the valley of No Wood Creek being too deep to make pumping practicable.

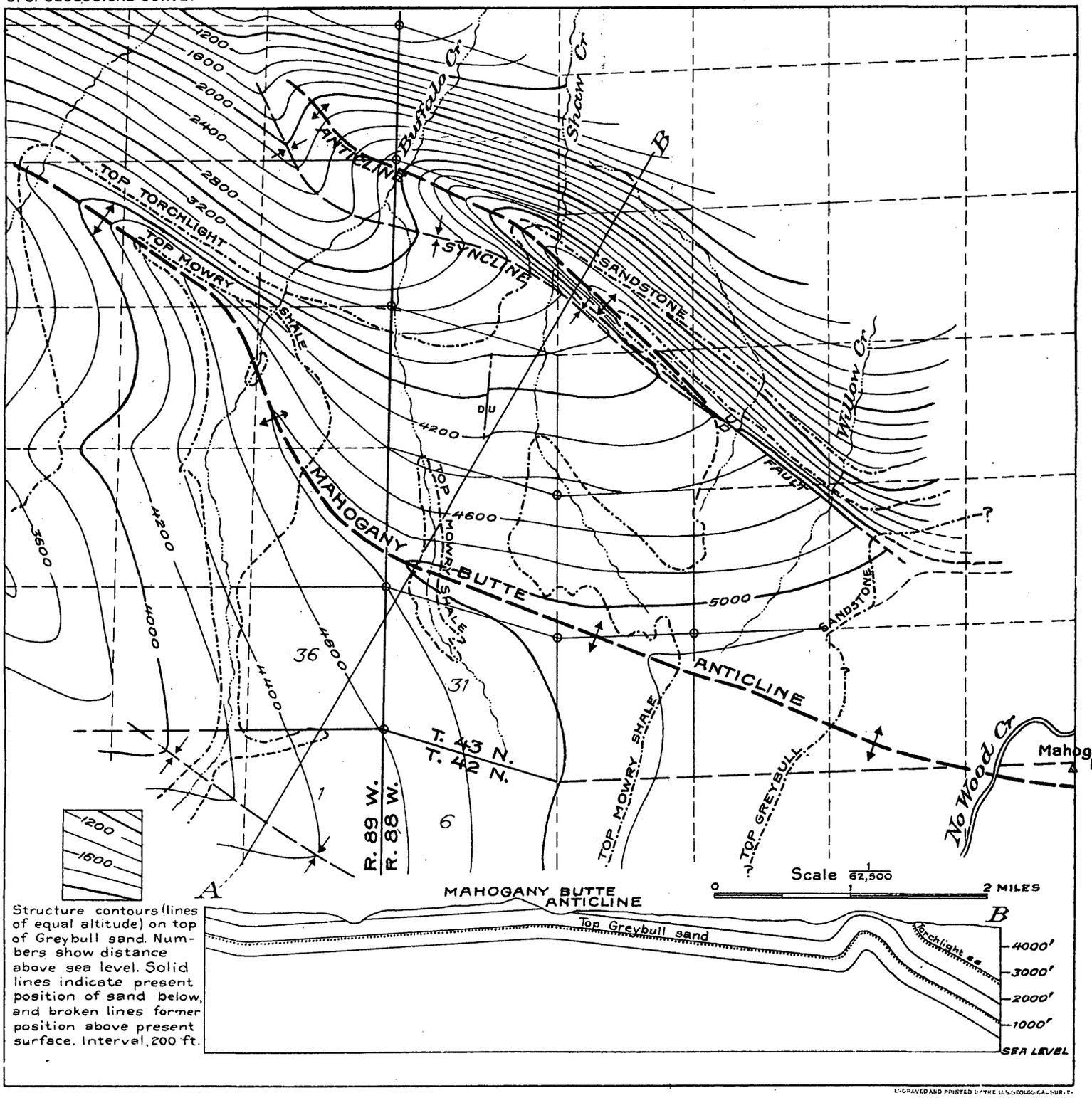
STRUCTURE.

The Mahogany Butte anticline (Pl. XV) is an unsymmetrical upfold about 15 miles long and 8 to 10 miles wide. Its highest point is near Mahogany Butte at the east edge of the area. It trends in general northwest-southeast, but in secs. 23–25, T. 43 N., R. 89 W., it trends more nearly north. The steepest dips are on the northeast limb, where a maximum of 54° just west of Buffalo Creek in the SE. ¼ sec. 14, T. 43 N., R. 89 W., was measured. The beds near the crest dip very gently but become rapidly steeper one-fourth to one-half a mile away, particularly at the northwest end. Directly east of No Wood Creek the anticline rises abruptly at the butte, the top of the Madison limestone being several hundred feet above the river level. Immediately east of the top of Mahogany Butte the anticline slopes gently to the southeast. Directly west of No Wood Creek the anticline is probably nearly level, but 7 or 8 miles west of the river it pitches rapidly to the northwest.

Where the strata begin to dip more strongly toward the northwest oil and possibly gas may have accumulated in the rocks. On the northeast limb of the anticline there is a small parallel upfold in secs. 17, 18, 20, and 21, T. 43 N., R. 88 W., and secs. 12 and 13, T. 43 N., R. 89 W., but it probably contains no oil, as it pitches northwest and is broken by a fault about 2 miles in length, the throw of which is in places 300 to 400 feet.

Structure contours drawn on the Greybull sand show the shape of the anticline. From these and from the surface elevations the approximate depth to the Greybull sand or to any other sand whose relation to the Greybull is known may be determined. (See p. 39.)

The lowest rocks exposed at the east end of the part of the anticline lying west of No Wood Creek belong to the Chugwater formation. Overlying it are the Sundance and Morrison formations, which are not known to carry oil in this region. Overlying the Morrison is the Cloverly formation, about 125 feet thick, the uppermost sandstone of which (the Greybull sand) may serve as a reservoir for oil or gas, as it is the oil and gas bearing sand of the Greybull field. Above the Cloverly is the Thermopolis shale, having a thickness of



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STRUCTURE CONTOUR MAP OF THE GREATER PART OF MAHOGANY BUTTE ANTICLINE (No. 19 ON PLATE I) AND CROSS SECTION

The outcrops of sands are mapped as sandstones

By Charles T. Lupton

about 500 feet and bearing near its middle a sand that, although not productive of oil in the Big Horn Basin, has been named the Muddy sand. The Frontier formation carries oil and gas in the Grass Creek and Little Buffalo fields, and the Mowry shale bears these substances in the Torchlight dome, but it is doubtful if these beds contain them here. If a hole were drilled in the northern part of sec. 15, T. 43 N., R. 89 W., on Buffalo Springs Creek, it would penetrate the following beds in order to reach the Greybull sand, which, as stated above, is the most promising oil sand in the anticline, although the Mowry may contain small quantities of oil or gas:

Rocks below the surface and above the Greybull sand in sec. 15, T. 43 N., R. 89 W.

	Feet.
Frontier formation, sandstone and shale, sandstone predominating	600±
Mowry shale, bluish gray, hard, platy shale, with two or more sandstone beds	200+
Thermopolis shale, dark shale with sandstone bed about 250 feet above base (Muddy sand)	500+

CONCLUSIONS.

No drilling has been done on the Mahogany Butte anticline. The north limb is faulted, but faults do not always produce unfavorable conditions for the accumulation of oil and gas. That part of the structure east of No Wood Creek seems to be of no value, as the limestone (Embar), which in places carries oil, is well exposed on three sides of Mahogany Butte. West of No Wood Creek for 4 or 5 miles oil or gas may be found in the Embar limestone, but this is doubtful, as any oil or gas that was originally in this limestone probably would have migrated through the strata up the rise to the northeast and have escaped at the surface. If a well is to be drilled on this anticline the writer would recommend some point near the crest line in sec. 15, T. 43 N., R. 89 W., where the beds seem to flatten, forming a structural terrace. A 1,200 to 1,400 foot hole probably would penetrate the Greybull sand at this place.

LYSITE MOUNTAIN ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Lysite Mountain anticline (No. 20, Pl. I) trends northwest-southeast in the central part of T. 42 N., R. 90 W., at the southeast end of the Black Mountain anticline (p. 123). It is so named because its southeast end pitches under Lysite Mountain, where it is obscured by Tertiary rocks, which overlie it and which are not

folded in conformity with it. (See Pl. XVII, p. 126.) No drilling has been done on this anticline, but an oil seep near its crest line in sec. 21 and the shape of the anticline suggest that it may contain oil and gas.

The nearest railroad point is Lucerne, on the Chicago, Burlington & Quincy Railroad near Big Horn River, about 27 miles to the west. From this place a good road follows the valley of Kirby Creek to the mouth of Lake Creek, thence up that stream by means of a second-class road to its head, and thence over the divide a few miles to the northwest end of the anticline.

The surface near the anticline is characterized by canyons cut into the sandstone beds by the streams tributary to No Water Creek. Its entire surface is rugged, ranging from hilly to mountainous.

Water for drilling and for camp use is abundant in springs and small ponds along the north front of Lysite Mountain. It is less abundant, however, at the northwest end of the anticline than along the southeast two-thirds of it. This water is of excellent quality and is better than any found in the springs farther from the mountain front.

STRUCTURE.

The Lysite Mountain anticline is about 4 miles long, and its southeast end is covered by the rocks that form the top of Lysite Mountain. (See Pl. XVII.) Its northeast limb slopes regularly into a small syncline with an average dip of about 30° but its southwest limb is steeper, the beds averaging 45° or more and reaching a maximum dip of 72° locally near the fault. The width of the southwest limb is generally less than half a mile, and that of the northeast flank is several miles. The section shown on Plate XVII cuts the fold obliquely and does not show its true shape. The anticline is broken by a fault which crosses the crest obliquely near the middle and offsets it about one-fourth mile. The downthrow is on the southwest side and amounts to about 100 feet. The shape of the southeast end of the anticline is unknown, as it is covered unconformably by rocks of Tertiary age.

The surface rocks of the Lysite Mountain anticline belong to the Mowry shale, about 250 feet thick, and to the Frontier formation, about 600 feet thick. The Mowry contains hard, platy dark-gray shale with numerous fish scales, and the Frontier is mainly beds of sandstone with interbedded shale and sandy shale. The oil seep in sec. 21 is in one of the lower beds of the Frontier formation and may be interpreted in two possible ways: It may indicate that oil in larger or smaller quantities occurs in the anticline and that some of it has migrated through the rocks to the surface; or it may mean that a small quantity of oil is being formed in the rocks beneath and is reaching the surface as fast as it is formed.

The formation directly underlying the Mowry is the Thermopolis shale, which is about 400 feet thick in this part of the Big Horn Basin. Near the middle of this shale there is a persistent bed of sandstone known in other parts of the region as the Muddy sand. It is not known to contain oil or gas in commercial quantities, although in places it contains traces of these substances. Directly underlying the Thermopolis shale is the Cloverly formation, the top sandstone of which—the Greybull sand—is the reservoir in which oil and gas occur in the Greybull field, and is believed to be that in which oil and gas are most likely to be found in the Lysite Mountain anticline.

CONCLUSIONS.

It is difficult to determine the value of this anticline as a possible reservoir for oil or gas. Its value depends largely on whether the southeast end of the anticline pitches southeast or whether it rises and merges with the north flank of the great upfold lying to the south, and this can not be determined because the south end of the anticline is concealed by horizontal Tertiary beds. Should any one decide to test it the most favorable point at which to drill is probably near the central part of sec. 21, T. 42 N., R. 90 W., as this point is near the crest line of the anticline and also near water for drilling and camp use.

BLACK MOUNTAIN ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Black Mountain anticline (No. 21, Pl. I), mainly in the southeastern part of T. 43 N., R. 91 W., is a northwestward-trending fold near the south edge of the Bighorn Basin. It has not been tested for oil or gas, but both its shape (Pl. XVI, *A*) and the absence of known anticlines between it and the deeper part of the Big Horn Basin suggest that it may contain oil or gas.

Lucerne, about 25 miles to the west, on the Chicago, Burlington & Quincy Railroad, is the nearest railroad point. From it a good road leads up Kirby Creek to the mouth of Lake Creek, where it connects with a second-class road that follows the valley of Lake Creek to its head, crosses the divide into the drainage of Mud Creek, and follows along the south side of the Black Mountain anticline.

The principal surface feature of the anticline is a prominent ridge known as Black Mountain (Pl. XVI, *A*), the northwest end of which is cut by Mud Creek. In places the south limb is carved into badlands; elsewhere there are nearly impassable cliffs, and Black Mountain can be ascended from the south at a few places only. The north side is more gentle and is more easily ascended, but it is deeply

eroded by streams tributary to No Water Creek. The top of Black Mountain nearly coincides with the crest line of the anticline. Its surface ranges in altitude from about 6,170 feet in sec. 6, T. 42 N., R. 90 W., to about 4,875 feet along Mud Creek near the crest line in sec. 27, T. 43 N., R. 91 W. From these altitudes and from the structure contours (Pl. XVII, p. 126) the approximate depth and thickness of the rocks that must be penetrated by the drill to reach the possible oil-bearing sands may be determined. (See p. 39.)

The water supply is meager. The only perennial spring is one at Shoemaker's ranch in the SW. ¼ sec. 36, T. 43 N., R. 91 W., and it flows barely enough for ranch use and can not be depended on to furnish water for drilling. Water from a number of good springs which flow into natural ponds a few miles to the south along the north front of Lysite Mountain could be piped down the slope to the south side of Black Mountain. Reservoirs to catch and hold the flood waters of Mud Creek could be made and probably would be the most economic means of obtaining water for drilling. Water for camp use must be hauled or piped from the springs or ponds to the south.

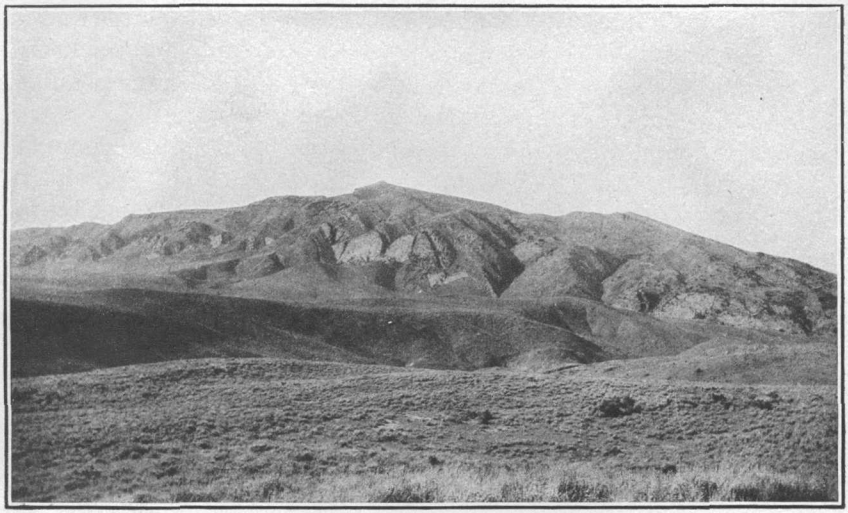
STRUCTURE.

The Black Mountain anticline is about 5 miles long and is unsymmetrical (Pl. XVII, p. 126), the dips on the south side being much steeper than those on the north side, and the south limb is consequently much narrower than the north. The south limb is, in fact, less than half a mile in width, and the north limb several miles, extending from the crest line of Black Mountain anticline probably to the deeper part of the great syncline of the Big Horn Basin. The dip of the beds on the north limb ranges from 25° at the steepest place to 8° at points 6 to 7 miles to the northeast.

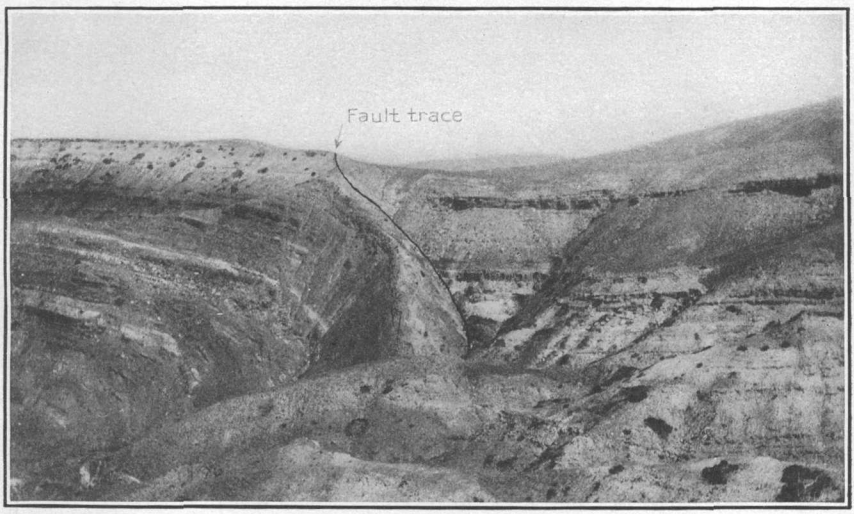
Structure contours drawn on the Greybull sand, the top sandstone of the Cloverly formation, show in general the shape of the anticline. From these contours and from the surface elevations given above the thickness of strata the drill must penetrate to reach the Greybull sand or any other bed whose position with relation to the Greybull sand is known may be closely determined. (See p. 39.)

The Black Mountain anticline is nearly parallel to the near-by Lysite Mountain anticline to the southeast and the Lake Creek anticline to the northwest. Its northwest end is within one-half mile of the Lake Creek anticline, from which it is separated by a narrow steep-sided syncline.

The most prominent fault or break in the rocks is in sec. 5, T. 42 N., R. 90 W., at the southeast end of the anticline. It is parallel to the crest line of the anticline and has a downthrow of about 150 feet on the south side. It does not form an outlet for any oil or gas below, as no oil seeps or gas vents are present in or near it.



A. BLACK MOUNTAIN ANTICLINE, LOOKING NORTHWEST.



B. FAULT TRACE AT EAST END OF RED SPRING ANTICLINE, NEAR THERMOPOLIS.

The surface rocks of Black Mountain are the Mowry shale, a hard dark-gray platy shale about 200 feet thick, and the Frontier formation, 500 to 600 feet thick, which is mainly of sandstone and sandy shale. The Frontier is overlain by the Cody shale, about 3,000 feet thick. The lowest beds exposed along the crest of the anticline belong to the upper part of the Mowry shale, which is underlain by the Thermopolis shale, about 400 feet in thickness, with a persistent bed of sandstone near the middle. Directly underlying the Thermopolis shale is the Cloverly formation, the top sandstone of which—the Greybull sand—carries oil and gas in the Greybull field and may do so in the Black Mountain anticline.

CONCLUSIONS.

The Black Mountain anticline appears to be favorable for the accumulation of oil and gas, but it has not been drilled and so far as known has no oil seeps nor springs. From conditions in other areas it seems probable that the best place to drill lies along the north flank near the crest of the anticline, because any oil that it may contain probably has migrated or is migrating up the long slope from the bottom of the basin and is likely to find lodgment before it reaches the crest of the upfold. Hence the writer recommends that a well be drilled a short distance north of the crest line in the south and highest part of sec. 36, T. 43 N., R. 91 W. The Greybull sand at this place will probably be reached at a depth of about 1,300 feet. Considerable difficulty will undoubtedly be experienced in bringing drilling machinery, as the place is on a high rugged ridge.

LAKE CREEK ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Lake Creek anticline (No. 22, Pl. I) is in the southern part of the Big Horn Basin, mainly north of Lake Creek in T. 43 N., Rs. 91 and 92 W., T. 44 N., R. 92 W., and T. 42 N., R. 91 W. It has not been tested for oil and gas, but its shape and relation to the deeper part of the great basin suggest that it may contain these substances. (See Pl. XVII.)

Lucerne, on Big Horn River, on the Chicago, Burlington & Quincy Railroad, about 20 miles to the west, is the railroad point from which this anticline can be visited most easily. From this place the route lies over a good road up the valley of Kirby Creek as far as the mouth of Lake Creek and from that point over a second-class road which extends the entire length of the anticline, lying for the most part within one-fourth of a mile of its crest line.

The anticline coincides with a ridge, which is cut in a number of places by small streams. Badlands are common in the shale on the north side, and on the south side the surface is broken by many cliffs formed by the wearing away of the sandstone beds by Lake Creek. The ridge ranges from 200 to 400 feet above the surrounding country, and the cliffs along Lake Creek are in many places impassable.

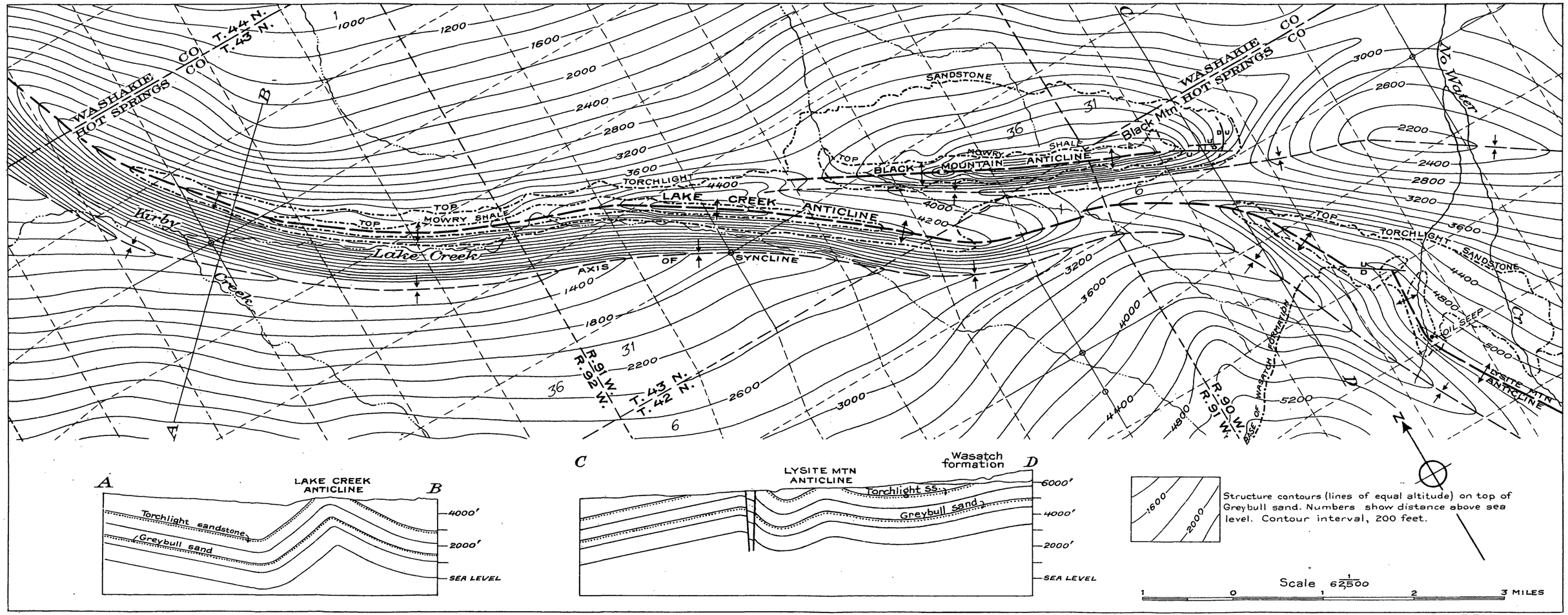
Water for drilling and domestic use is scarce, as Lake Creek is an intermittent stream and the few springs are somewhat alkaline and have a small flow. The best spring known on or near the anticline is at the K I S ranch in the SW. ¼ sec. 13, T. 43 N., R. 92 W. Another spring of smaller flow is at the Auterbach ranch, in the NE. ¼ sec. 33, T. 43 N., R. 91 W. The amount of water furnished by these and poorer springs is not sufficient for drilling and camp use, and water for these purposes would have to be stored in reservoirs at times when Lake Creek carries water or be hauled or piped from springs or ponds along the north front of Lysite Mountain, 4 to 10 miles to the south. Water will undoubtedly be found in drilling in the sandstone beds outcropping along the anticline but will probably be in small quantities.

STRUCTURE.

The Lake Creek anticline, which trends northwest-southeast, is about 9 miles long and the steepest limb is on the southwest side. (See Pl. XVII.) The average dip on this side is about 50° near the crest line, but in the SW. ¼ sec. 28, T. 43 N., R. 91 W., a maximum local dip of 69° was observed. The north side of the anticline is broad, and the northeastward dip probably extends from the crest line to the bottom of the great syncline of the Big Horn Basin, except at the southeast end, where it is interrupted by the Black Mountain anticline. Here the north side is less than one-fourth of a mile wide, about the same as the width of the south side. The maximum dip noted on the north near the K I S ranch, within one-fourth of a mile of the crest, is 25°. From this point the dips gradually decrease toward the northeast.

The shape and extent of the Lake Creek anticline are shown by the structure contours drawn on the Greybull sand and by the cross section (Pl. XVII). The surface elevations range from about 4,535 feet on Lake Creek near the center of sec. 9, T. 43 N., R. 92 W., to about 5,375 feet near the center of sec. 34, T. 43 N., R. 91 W. From these and from the structure contours the approximate depth to the Greybull sand at any point shown on the map can be ascertained. (See p. 39.)

The oldest rocks exposed on the surface of the anticline belong to the Frontier formation, which for the most part is sandstone with smaller amounts of sandy and clay shale. The formation is about



STRUCTURE CONTOUR MAP OF LYSITE MOUNTAIN, BLACK MOUNTAIN, AND LAKE CREEK ANTICLINES (Nos. 20, 21, AND 22, RESPECTIVELY, ON PLATE I) AND TWO STRUCTURE SECTIONS

The outcrops of sands are mapped as sandstones

By Charles T. Lupton

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

600 feet thick and includes the rocks from which issue the springs of the anticline. The Frontier formation is overlain by about 3,000 feet of the Cody shale, which fringes the Lake Creek anticline. Directly underlying the Frontier formation is the Mowry shale, about 200 feet thick, which contains one or two sandstone beds that may serve as reservoirs for oil and gas, as they do in the Torchlight dome. The formation is characterized by great numbers of fish scales and by hard dark-gray platy shale which constitutes the greater part of the formation. Underlying the Mowry shale is the Thermopolis shale, which is about 400 feet thick in this part of the Big Horn Basin, and which includes one bed of sandstone near the middle known as the Muddy sand. Although this sandstone is remarkably persistent, it is not known to carry oil or gas in commercial quantities at any place in the Big Horn Basin except in the Oregon Basin, where the gas is thought to come from the Muddy sand. Directly underlying the Thermopolis shale is the Cloverly formation, the top sandstone of which—the Greybull sand, on which the structure contours are drawn—is believed to be the most promising reservoir for oil and gas in the anticline.

CONCLUSIONS.

The Lake Creek anticline is a sharp flexure, and therefore is not an ideal fold to serve as a reservoir for the accumulation of oil and gas, but some of the sands that are productive in other parts of the Big Horn Basin are below the surface here, and, as the anticline pitches at both ends, it is possible that they may be found to contain oil or gas. Two of these sands (Kimball and Octh Louie) are in the Mowry shale, but the bed that is most likely to be productive is the Greybull sand, which lies 1,000 to 1,200 feet below the surface along the anticline and is known to be one of the most important sands of Big Horn Basin, being the one from which oil and gas are obtained in the Greybull field.

It is believed that the most favorable part of the anticline is the north limb, where the structure is broader and the rocks dip less steeply than they do on the south limb. The writer therefore suggests that the best place for a test well is on the highest part of the anticline, north of Lake Creek, in secs. 28 and 29, T. 43 N., R. 91 W. Water for drilling and camp use can be obtained at Auterbach's spring in this vicinity.

WILDHORSE BUTTE ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Wildhorse Butte anticline (No. 23, Pl. I) lies on a high ridge mainly in the northeastern part of T. 42 N., R. 93 W., south and southeast of Wildhorse Butte. (See Pl. XIX, p. 134.) It is a small

northward-pitching wrinkle on the north flank of Bridger Mountain, and hence is probably of little value as a reservoir for oil and gas. It is accessible with difficulty, as no wagon road leads to any part of it. Thermopolis, about 11 miles to the west, is the nearest railroad station. A second-class road extending east several miles from that town is the easiest route, but the last few miles must necessarily be made on foot or horseback.

The surface of the anticline is characterized by a shallow trough-like depression in the rocks, which widens and deepens toward the southeast, where it merges with the valley of Buffalo Creek on the north flank of Bridger Mountain. Hogback ridges lie parallel to the crest line of the anticline and form the sides of the surface depression. The rocks of the upfold are cut by streams which have worn comparatively deep channels, mainly parallel to the crest line of the anticline and about one-fourth mile southwest of it.

Water for ranch and camp use and for drilling is scarce but may be obtained from springs in the valleys, either to the north or the south. As it is doubtful if drilling will be done on this anticline the question of water for such purposes is of little importance.

STRUCTURE.

The Wildhorse Butte anticline is an unsymmetrical upfold about 3 miles long, with its broad limb on the northeast, a condition that is characteristic of most anticlines along the south side of the Big Horn Basin. (See Pl. XIX.) The dips on the southwest limb are steepest at the north end, where they range from zero at the crest line to as much as 49° near Wildhorse Butte, 200 to 300 feet distant, beyond which they decrease southeastward to 36° in a distance of 2½ miles. Southwestward from the line of steepest dips the beds gradually flatten to zero at the trough of the syncline one-fourth of a mile to a mile distant. To the north the dips range from zero at the crest line of the anticline to a maximum of 36° about one-fourth of a mile away, beyond which they gradually flatten to the axis of the syncline or downfold. The steep dips on the south side necessarily make that limb much narrower than the northern, which is about 2 miles wide.

The lowest rocks exposed in the anticline belong to the Chugwater formation, which contains about 1,100 feet of red sandstone and shale, with a thick bed of gypsum near the top. Overlying these beds, on the limbs of the anticline, are the Sundance, Morrison, and Cloverly formations, Thermopolis and Mowry shales, and Frontier formation. Underlying the Chugwater formation and not exposed are the Embar, Tensleep, and Amsden formations and Madison limestone.

Structure contours on the top of the Greybull sand show the shape of the anticline. From these and from the surface elevations, which range from about 5,000 to 6,000 feet, the depth to the Embar limestone or any other bed whose relation to the Embar is known may be determined.

CONCLUSIONS.

The beds that outcrop in the northwest part of the Wildhorse Butte anticline are eroded at the southeast end, and as it pitches northwest throughout its length it is very doubtful if oil or gas in commercial quantities would have been retained if ever present in any of the sands. The writer advises against the expenditure of money in drilling in this anticline.

BLUE SPRING ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Blue Spring anticline (No. 24, Pl. I), situated mainly in the southeastern part of T. 43 N., R. 93 W., and the southwestern part of T. 43 N., R. 92 W., is about 4 miles long and trends in general northwestward. (See Pl. XIX, p. 134.) It may contain oil and gas, but it has not been tested.

The nearest railroad points to this anticline are Lucerne, about 10 miles to the northwest, and Thermopolis, about 12 miles to the west, both on Big Horn River. Lucerne is the more convenient point of approach. A good road extends from Thermopolis north 6 or 7 miles to Lucerne and thence eastward up Kirby Creek. From this road, at a point about 3 miles west of the mouth of Lake Creek, a second-class road extends southward to the highest part of the anticline.

A depression, in places 200 to 300 feet deep, coincides with the crest of the anticline and is locally bounded by inward-facing walls of shale and sandstone cut by canyons. In places, however, the depression is not conspicuous. The limbs of the anticline are for the most part marked by steep slopes of sandstone. The surface is hilly, and badlands are present where streams have worn into the shale.

Water is plentiful near this anticline and the quality is good. The best springs issue from the beds of sandstone that are upturned around the flanks of the fold. They are naturally more abundant in the principal valleys in secs. 24 and 25, T. 43 N., R. 93 W., and in secs. 29, 32, and 33, T. 43 N., R. 92 W., than elsewhere. Water also flows in the upper course of the main valleys at the west end of

the anticline throughout the greater part of the year, and abundant supplies for drilling and camp purposes are present or near at hand in all parts of the anticline.

STRUCTURE.

The Blue Spring anticline has the general shape of a reversed letter S. Its length is about 4 miles and the south limb is very much narrower than the north, for the former is about half a mile and the latter is as much as 5 miles in width. The south limb is steeper than the north, its maximum dips being about 20°, whereas those of the north limb reach a maximum of only 12°, in the southern part of sec. 19, T. 43 N., R. 92 W. (See Pl. XX.)

The anticline is closely associated with a larger upfold farther west, known as Red Spring anticline. The two upfolds do not connect directly, but their north limbs merge into the general dip toward the central part of the Big Horn Basin. The only faults known in or adjacent to this anticline are one of small throw mainly in sec. 30, T. 43 N., R. 92 W., on the north flank of the Blue Spring anticline and another at the east end of the Red Spring anticline, about a mile west of the upfold here described. (See Pl. XVI, *B*, p. 124.)

The surface rocks of the Blue Spring anticline belong to the Thermopolis shale, Mowry shale, and Frontier formation. Only the lower part of the Thermopolis shale is below the surface, the upper part as well as all of the Mowry shale and Frontier formation being visible in outcrop in the anticline. The Thermopolis shale is about 400 feet thick and near the middle contains a thin but persistent bed of sandstone known as the Muddy sand, which, however, is not known to contain oil and gas in commercial amounts in any part of the Big Horn Basin except in the Oregon Basin. The Mowry shale, directly overlying the Thermopolis, is 200 to 300 feet thick and consists mainly of hard dark-gray platy shale with layers of sandstone interbedded, all containing fish scales in great abundance.

The formation underlying the Thermopolis shale can not be seen in the anticline but can be studied in the Red Spring anticline and in other parts of the Big Horn Basin. The uppermost formation is the Cloverly, about 125 feet thick. Its upper bed of sandstone, the Greybull sand, which carries oil and gas in the Greybull field, is believed to be the most probable reservoir of oil and gas in this anticline. It is about 20 feet thick and is underlain by variegated beds of shale and sandy shale. Directly underlying this shale and forming the base of the formation is a conglomeratic sandstone about 30 feet thick.

The structure contours drawn on the top of the Greybull sand and the cross section (Pl. XIX) show the shape of the anticline and its

relation to the adjacent upfolds. From the structure contours and the surface elevations the depth to the different sands may be approximately determined. (See p. 39.) In the Blue Spring anticline the surface elevations range from about 4,680 feet in the N. ½ sec. 24, T. 43 N., R. 93 W., to about 5,390 feet in the NE. ¼ sec. 31, T. 43 N., R. 92 W.

CONCLUSIONS.

The Blue Spring anticline has not been drilled, and no seeps of oil or asphaltum are known in or adjacent to it. Although the west half of the anticline is nearly level, it is believed to be a possible reservoir of oil and gas. In the writer's opinion the most favorable places for drilling are along the crest on the upland in the northern part of sec. 31, T. 43 N., R. 92 W. Water for drilling would have to be hauled 1 or 2 miles and fuel would have to be brought from the coal mines near Big Horn River in the vicinity of Gebo and Crosby. The Greybull sand at this place is probably not more than 350 feet below the surface.

ZIMMERMAN BUTTE ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

In a small area south and west of Zimmerman Butte, north of Kirby Creek and from 6 to 10 miles east of Big Horn River, there is a small anticline (No. 25, Pl. I) which is here called the Zimmerman Butte anticline. (See Pl. XVIII.) The observed fold has a length of only about 2 miles, but it possibly extends 4 or 5 miles farther northwest and may contain oil or gas. The bedrock in the doubtful area is shale, in which dips are exceedingly difficult to detect, and it was impracticable to obtain sufficient data to determine whether or not the anticline is present here, and, if present, whether it probably contains oil or gas.

This area is easy of access, as it lies directly north of the well-traveled road connecting Thermopolis and Lucerne with Lost Cabin and Casper. The road follows the west side of Big Horn River from Thermopolis to Lucerne, where it crosses the river and ascends Kirby Creek along the south side of the Zimmerman Butte anticline. The greater part of the area can be traversed by vehicles.

The area is bounded on the south by the valley of Kirby Creek and on the north by prominent sandstone cliffs. The highest part of these cliffs, in the NE. ¼ sec. 25, T. 44 N., R. 93 W., is known as Zimmerman Butte. The area lies between Kirby Creek valley and Zimmerman Butte and has for the most part a smooth surface, here and there broken by badlands along the streams.

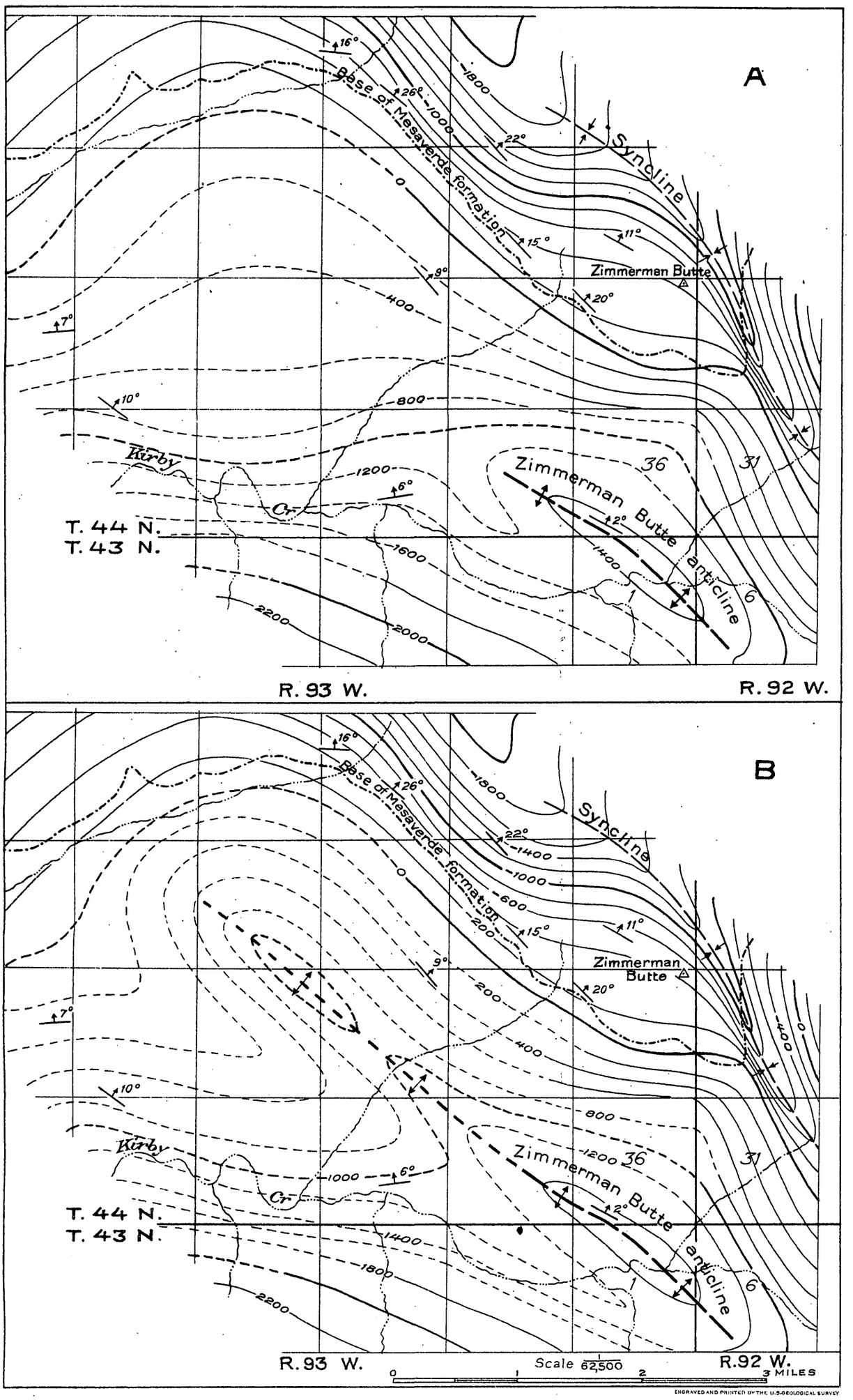
The available water supply is from Kirby Creek and a few seeps that issue at points along its course. Throughout the dry season the supply is extremely meager, and water for drilling and camp purposes must be hauled from Big Horn River several miles to the west or from springs along the north limbs of Blue and Red Spring anticlines, about the same distance to the south. Reservoirs could be made with little difficulty in the stream courses and water caught and held for use during the dry season.

STRUCTURE.

The small but well-defined anticline along Kirby Creek near the southeast corner of T. 44 N., R. 93 W. (Pl. XVIII), was followed northwest as far as the SE. ¼ sec. 35, T. 44 N., R. 93 W., but beyond that no dips were obtained, owing to the flatness of the surface and the absence of exposures of the shale. The continuation of the anticline to the northwest is therefore uncertain. The presence of a linear anticline or dome farther to the northwest is suggested by the incurving escarpment of the Mesaverde through secs. 23, 22, 15, 16, 17, 18, and 19, T. 44 N., R. 93 W., but the dips noted in the shale south of this escarpment are not so located as to make it possible to determine whether the anticline observed near the southeast corner of the township continues to the northwest, as suggested on Plate XVIII, *B*, whether a separate upfold lies to the northwest, or whether the rocks gradually dip from sec. 33 to and beyond sec. 16, T. 44 N., R. 93 W., as shown on Plate XVIII, *A*.

The hypothetical structure contours on Plate XVIII, *A*, suggest a general dip of the rocks from south to north from a point a mile or more south of Kirby Creek to the outcrop of the Mesaverde rocks 3 miles or more to the north. Along the north flank of Red Spring anticline, a few miles south of Kirby Creek, the top sandstone of the Frontier dips 8°–20° N. At Kirby Creek the Cody shale dips 6° N., and 3 or 4 miles farther north, at the base of the Mesaverde sandstone, the beds dip as much as 26° N. These dips suggest the presence of what is known as a "structural terrace," which in some of the eastern fields would be considered favorable for the accumulation of oil and gas; in Wyoming, however, such structural features have not been tested by the drill and are not known to contain oil and gas in commercial quantities.

In the writer's opinion Plate XVIII, *B*, which suggests the northwestward prolongation of the known anticline, represents the structure more accurately than Plate XVIII, *A*. The principal reason for so thinking is that the crest line of the anticline parallels the northwest-southeast trend of the anticlines along the south flank of the Big Horn Basin. Attention is called to the fact that still other interpretations of the structure in this locality may be made.



1000 — Structure contours (lines of equal altitude) on top of Greybull sand. Numbers show altitude above or depth below sea level. Solid lines represent accurate contours; broken lines, hypothetical contours. Interval, 200 feet

STRUCTURE CONTOUR MAPS A AND B, SHOWING TWO INTERPRETATIONS OF ZIMMERMAN BUTTE ANTICLINE (No. 25 ON PLATE I)

Map A shows a possible structural terrace in the western half of the area, and map B shows a possible anticline at the same locality

By Charles T. Lupton

The surface rocks of this area belong to the Cody shale, which in this locality is about 3,000 feet thick. The rocks beneath the Cody shale down to and including the Cloverly formation, on the top of which the structure contours are drawn, are the Frontier formation, about 600 feet thick; the Mowry shale, about 200 feet thick; the Thermopolis shale, about 400 feet thick; and the Cloverly formation, about 125 feet thick. The Frontier formation, which consists mainly of sandstones interbedded with thin layers of sandy shale and shale, is the formation in which oil and gas occur in the Grass Creek, Elk Basin, Byron, and Little Buffalo Basin fields. The Mowry shale is a dark-gray, slaty, hard shale, about 200 feet thick, with two or more sandy beds, which in the Torchlight dome carry oil and gas. Under the Mowry is the Thermopolis shale, about 400 feet thick, which contains a rather persistent bed of sandstone (Muddy sand) near its middle. The top sand of the Cloverly formation—the Greybull sand—is about 20 feet thick and yields all the oil and gas in the Greybull field. Underlying the Greybull sand there is about 80 feet of variegated sandy shale and shale, mainly red in color, and underlying them is a conglomerate sandstone in places about 25 feet thick.

CONCLUSIONS.

No drilling has been done in the locality. Although dips do not positively show the presence of an anticline in the area west of Zimmerman Butte (a northwest projection of the Zimmerman Butte anticline), the probability is strong that one exists and that it may serve as a reservoir for oil and gas. If no well-defined anticline or dome is present there is without question a lowering of the dips or flattening of the beds, which constitutes a structural terrace that in some localities is favorable for the accumulation of oil and gas. Hence the writer recommends that the small anticline, shown on both maps of Plate XVIII, near the southeast corner of the township, the S. ½ sec. 21, the N. ½ sec. 28, T. 44 N., R. 93 W., and parts of the adjacent sections along its crest projected to the northwest are territory worthy of careful investigation by the driller.

RED SPRING ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Red Spring anticline (No. 26, Pl. I), in the southern part of the Big Horn Basin in the southwestern part of T. 43 N., R. 93 W., has not been tested for oil and gas, but a small seep of heavy oil in the NW. ¼ sec. 29 of the same township suggests that in places it contains small amounts of that material. As the lowest bed of rock

known to carry oil at any place in Wyoming is exposed in the middle of the anticline, it is exceedingly doubtful if oil or gas will ever be found in commercial quantities.

The anticline is most easily accessible from Thermopolis, on the southwest, or from Lucerne, on the northwest, both on the Chicago, Burlington & Quincy Railroad. In a direct line it is about 7 miles distant from each, but by road it is several miles nearer to Thermopolis, from which a good wagon road, following Big Horn River and Kirby Creek, connects about 6 miles east of the Big Horn with a second-class road leading south about 5 miles to the heart of the west end of the anticline.

The surface of the anticline is characterized by a basin-like depression surrounded by an inward-facing wall of sandstone and shale, in places 300 to 400 feet high. (See Pl. XIX.) On the north flank of the anticline other walls of similar material, less conspicuous, however, lie farther out and form a series of corrugations as far as 2 miles from the crest line; on the south flank the walls are less prominent and occupy a narrower belt. The streams have cut deep canyons, which form easy routes into the basin.

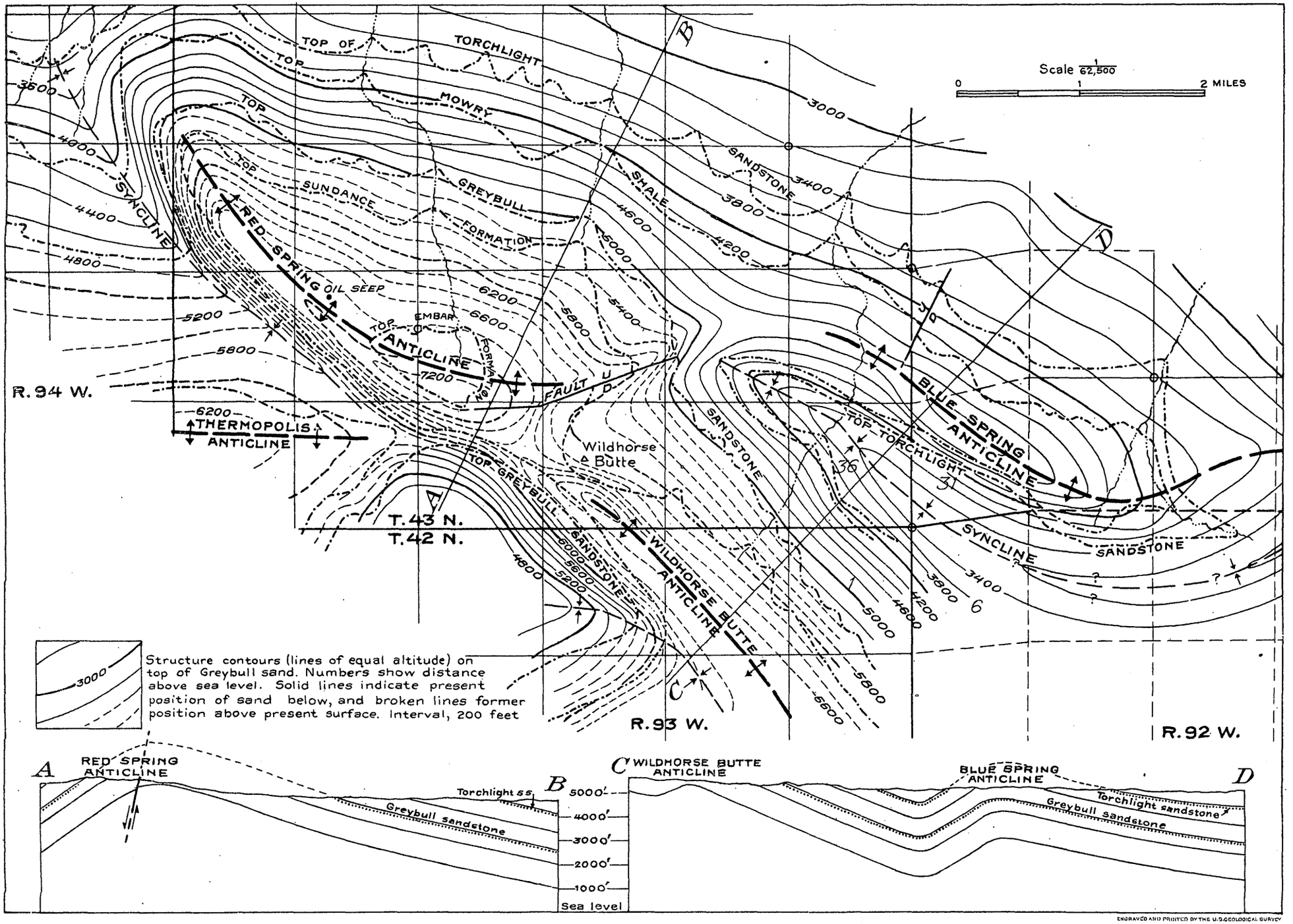
Water is scarce near the Red Spring anticline. The entire supply comes from a few alkaline and gypsiferous springs of small flow that issue mainly from the north flank of the upfold. The best water comes from the outermost walls of sandstone. Water for ranch and domestic uses and for drilling during the dry months could be caught during the flood season and stored in reservoirs.

STRUCTURE.

The Red Spring anticline is an unsymmetrical curved upfold about 4 miles long, concave to the northeast. (See Pl. XIX.) On the south limb the dips average about 45° and range from zero at the crest trace to as much as 60° locally half a mile to the south, in the NE. ¼ sec. 33, T. 43 N., R. 93 W. On the north limb they are much less steep, reaching a maximum of 30° at a point somewhat less than a mile from the crest line in the NE. ¼ sec. 28, T. 43 N., R. 93 W., and thence decreasing northward to about 6° near Kirby Creek. The south limb of the anticline dips more steeply than the north and is therefore much narrower. The dips are less at the ends of the anticline than on the north and south limbs. The structure contours drawn on the top of the Greybull sand show the shape of the upfold.

One fault southeast of the crest line of the anticline (see Pl. XVI, *B*, p. 124) has a downthrow of about 150 feet on the south side. It is about 1½ miles long, lying nearly parallel to and not more than one-fourth mile from the crest line at any place.

The lowest rocks exposed in the anticline are beds of limestone that belong to the Embar formation, the upper part of which is charac-



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STRUCTURE CONTOUR MAP OF WILDHORSE BUTTE, BLUE SPRING, AND RED SPRING ANTICLINES (Nos. 23, 24, AND 26, RESPECTIVELY, ON PLATE I) AND TWO CROSS SECTIONS

The outcrops of sands are mapped as sandstones

Note.—The crest line of the Red Spring anticline on the surface does not conform to the structure contours in the central part of the anticline, because the axial plane is not vertical, and as shown on cross section A-B the crest trace of the Greybull sand if restored would lie farther to the southwest.

By Charles T. Lupton

terized by a bed of fairly pure gypsum. Directly overlying the Embar is the Chugwater formation, about 900 feet thick, which contains red sandstone and sandy shale with a thick bed of gypsum near the top. The seep of heavy oil in the NW. ¼ sec. 29, T. 43 N., R. 93 W., is near the base of this formation.

The surface rocks in the center of the Red Spring anticline are limestone beds of the Embar formation. Underlying these beds, which are about 100 feet thick, are beds of variegated sandstone, shale, and limestone of the Tensleep and Amsden formations, 300 or 400 feet thick. Directly underlying the Amsden formation is a bed of massive limestone (Madison), 900 to 1,000 feet thick, the upper part of which may contain oil if it is not too dense, as it is overlain in most places by an impervious bed of shale which would serve as a cap and would prevent the escape of any oil or gas caught under it. Underlying the Madison limestone there is 900 to 1,800 feet of limestone, shale, sandstone, and conglomerate, at the base of which the granite is exposed in the Big Horn Mountains.

CONCLUSIONS.

It is doubtful if this anticline contains oil and gas, for the lowest rocks (Embar formation) exposed in the upfold are the lowest rocks that are known to contain oil in the Rocky Mountain region, and any oil that may have been contained in them has had opportunity to escape.

The possibility of obtaining oil from the upper part of the Madison limestone, which lies 500 or 600 feet below the surface in the heart of the Red Spring anticline, is also questionable, as oil in commercial quantities is not known to occur in this formation in any part of the region. The presence of the seep in the NW. ¼ sec. 29, T. 43 N., R. 93 W., may mean that whatever oil had collected under this anticline has reached the surface, or it may mean that some bed farther down the flank of the anticline has caught and held oil because of a decrease in the dips.

The writer would not advise the expenditure of much money in testing the Red Spring anticline, as it is very doubtful from the obtainable data that it offers a reservoir for oil or gas in commercial quantities.

THERMOPOLIS ANTICLINE.

By CHARLES T. LUPTON.

The Thermopolis anticline (No. 27, Pl. I) lies in the southern part of the Big Horn Basin and is cut near its center by Big Horn River. It was not examined in detail and hence is not separately mapped in this report. (See, however, Pl. XXI, p. 146.) The town

of Thermopolis and the hot springs (now included in a State reservation) are situated on its south flank, where the beds dip more steeply than they do on its north flank.

The anticline is about 25 miles long and is narrower east of the river, where it trends nerly east and west, than it is west of that stream, where it trends more nearly northwest and southeast.

The lowest rocks exposed in the crest of the anticline belong to the Embar formation, so that the lowest rocks known to carry oil in commercial quantities in Wyoming or adjacent States are exposed. This condition alone suggests that this anticline contains no oil or gas.

One well (No. 6, Pl. XXI) was drilled a few years ago near the crest in the NW. ¼ sec. 32, T. 43 N., R. 94 W. Little information regarding it is available. It was begun in the Chugwater formation and may have penetrated the Embar but found no oil in commercial quantity.

In the writer's opinion the Thermopolis anticline is of doubtful value as a reservoir for oil and gas. This judgment is based on the fact that the Embar, the lowest known oil-bearing formation in Wyoming, is exposed at the surface west of Big Horn River at the crest of the anticline, and also on the fact that the crest of the anticline is faulted. This fault is not sealed everywhere, for it permits the water of the hot springs to reach the surface. Any oil formerly contained in the rocks cut by the fault has had the same means of escape.

LUCERNE ANTICLINE (INCLUDING THE GEBO DOME).

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Lucerne anticline (No. 28, Pl. I) is situated mainly in the valley of Big Horn River in T. 43 N., R. 94 W., and T. 44 N., Rs. 94 and 95 W. A small part of the anticline lies east of Big Horn River and the remainder west of that stream near the towns of Lucerne and Gebo. Only the northwest part of this anticline, locally called the Gebo dome, is believed to contain oil or gas in commercial amounts.

The Lucerne anticline may be very easily reached from Lucerne, on the Chicago, Burlington & Quincy Railroad. The entire upfold can be examined with ease, as the surface of the greater part of it is smooth or rolling and good roads are plentiful.

The surface features near the anticline are the broad valley of Big Horn River, where the bedrock is covered by a veneer of alluvium and terrace gravel, and the more hilly southeast and northwest ends, where the bedrock is well exposed. The surface elevations vary from about 4,300 feet near Big Horn River to 5,200 feet in the northeast corner of sec. 12, T. 44 N., R. 96 W.

The principal water supply of this locality is from Big Horn River. During the spring months and after rainstorms water flows in the intermittent streams shown on Plate XXI (p. 146), but it is not found throughout the year except locally in small springs. Owl Creek carries water for the greater part of the year, but during the summer months most of its water is appropriated for irrigation. Hence water for drilling and for camp and ranch purposes must be obtained from Big Horn River, or from reservoirs built near the stream courses to catch and hold the flood waters, or from shallow wells in the alluvium and gravel near Big Horn River.

STRUCTURE.

The Lucerne anticline is a broad northwestward-plunging wrinkle in the rocks on the south rim of the Big Horn Basin. (See Pl. XXI.) A sag in the anticline near Lucerne makes the northwest half of the upfold, the Gebo dome, apparently a good reservoir for oil and gas. The anticline is about 13 miles long, and, like most of the anticlines along the south side of the Big Horn Basin, has steep dips on the southwest and more gentle dips on the northeast, and consequently has a narrow south limb and a broad north limb. The dip on the south limb increases from zero at the crest line to 35° in the northeast corner of sec. 21, T. 44 N., R. 95 W., beyond which it gradually decreases toward the trough of a syncline which lies one-fourth to three-fourths of a mile southwest of the crest line of the anticline. The dip on the north limb ranges from zero near the crest line to as much as 32° at a point 1½ miles to the northeast, about half a mile north of the coal-mining camp of Gebo, beyond which for about 9 miles it gradually decreases, reaching zero at the axis of the syncline just south of the Neiber anticline. The dips at the northwest and southeast ends of the anticline are very gentle. Exposures are poor directly west and northwest of Lucerne, and it is impossible to state with certainty whether or not the upfold mapped as the Lucerne anticline is continuous. Dips measured in secs. 23–26, T. 44 N., R. 95 W., show definitely that there is a shallow saddle or depression (which cuts off the Gebo dome) along the crest of the anticline. At the northwest end, near the southeast corner of sec. 8, T. 44 N., R. 95 W., the strata dip perceptibly to the northwest. The dips at the southeast end of the Gebo dome range from 2° to 7° in secs. 25 and 26, T. 44 N., R. 95 W.

The structure contours are drawn on the top of the Greybull sand at intervals of 200 feet. These contours show the general shape and size of the anticline and its relation to the Sand Draw anticline which lies to the northwest. From these and from the surface elevations (p. 136) the depths to the Greybull and other sands may be determined. (See p. 39.)

The lowest surface rocks exposed in the Lucerne anticline belong to the Morrison formation, which is exposed only at the southeast end of the anticline in secs. 16 and 22, T. 43 N., R. 94 W. It consists of variegated sandstone and shale and is about 300 feet thick. Overlying it is the Cloverly formation, about 125 feet thick, with a gray to white conglomeratic sandstone bed at its base overlain by variegated sandy shale, which in turn is overlain by a sandstone bed (the Greybull sand) about 20 feet thick that is known to carry oil and gas in the Greybull field. The Cloverly formation is overlain by the dark and in places fossiliferous Thermopolis shale, in this locality about 400 feet thick, which has near its middle a persistent bed of sandstone (Muddy sand), which, however, is not known to carry oil or gas in this general region except in the Oregon Basin. The Thermopolis shale is overlain by the Mowry shale, about 250 feet thick, which consists of hard, dark-gray, platy shale, with one or two beds of sandstone and a few thin beds of bentonite. This formation carries the oil and gas found in the Torchlight dome, near Basin. Overlying the Mowry is the Frontier formation, about 600 feet thick, which contains several beds of sandstone and minor quantities of shale and sandy shale. This formation carries the oil and gas in the Grass Creek, Little Buffalo Basin, and Elk Basin fields. The Frontier formation is overlain by the Cody shale, about 3,000 feet thick in this part of the basin, which contains thin beds of fossiliferous sandstone near the top and one or two very thin beds of sandstone near the base. The Cody forms the surface rock of the greater part of the Gebo dome at the northwest end of the Lucerne anticline. It is overlain by the Mesaverde formation, which is mainly sandstone and sandy shale, with beds of coal near its base.

DEVELOPMENT.

The anticline is untested with the exception of a well (No. 5, Pl. XXI) drilled about 2,500 feet deep by the Ohio Oil Co. in the NE. ¼ NW. ¼ sec. 16, T. 44 N., R. 95 W., about 1½ miles west of Gebo. This well is reported to have penetrated the upper sands of the Frontier formation at a depth of about 2,000 feet and to have failed to find oil or gas of economic importance. The well is near the crest line of the anticline but is not at the highest part of the Gebo dome, which is about 2 miles farther southeast. The entire area of the anticline is withdrawn from entry by the Government, and it is doubtful if it will be thoroughly tested until a law has been passed by Congress enabling the various companies to lease the land on which to drill.

CONCLUSIONS.

Only the part of the Lucerne anticline included in what is known as the Gebo dome is believed to contain oil or gas. This judgment is based on the fact that the anticline plunges from its southeast end to a point a mile or more northwest of Lucerne, or to the saddle separating the southeast end of the anticline from the Gebo dome. Any oil or gas contained in this southeast half of the anticline has had an easy means of escape through the sandstone beds to the surface, where beds as old as the upper part of the Morrison formation outcrop. If another hole is drilled on the Gebo dome, the writer advises that the best location appears to be near the crest line of the dome near Coal Draw in the W. ½ sec. 23, T. 44 N., R. 95 W. This dome is ideally situated for drilling, as fuel is plentiful at the Gebo coal mines near by, and water occurs in seeps along Coal Draw and may be stored in reservoirs along the intermittent streams near the southeast end of the dome.

NEIBER ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Neiber anticline (No. 29, Pl. I) in the southern part of the Big Horn Basin has its greatest development on the east side of Big Horn River (Pl. XX) but crosses that stream about a mile above the mouth of Gooseberry Creek and extends westward for 6 to 7 miles. This anticline is one of those folds nearest the deeper part of the Big Horn Basin and should, if other conditions are favorable, carry oil and gas in commercial quantities. The sands which contain oil and gas in the Grass Creek, Little Buffalo Basin, Torchlight, Greybull, and Byron fields are too deeply buried, 7,500 feet or more below the surface, in the Neiber anticline to be reached by the average drilling rig, but other sands lie within 3,000 or 3,500 feet of the surface and may contain oil or gas. None of them, however, were penetrated by the only well drilled, although a little gas was reported from several horizons.

This anticline is easily accessible, as it is crossed near its middle by the Chicago, Burlington & Quincy Railroad and also by a good wagon and automobile road connecting Worland and Thermopolis. Much of the part lying west of the river can be traversed with wagon or automobile, but the part east of the river can be examined in detail only on foot or horseback, as the surface, especially within 3 miles of the river, is very rough. Neiber, a post office about 2 miles north of the axis of the anticline, is the nearest railroad station at which all passenger trains stop. Hotel and livery accommodations are much

better at Worland, about 10 miles farther northeast, or at Kirby, an equal distance to the southwest, than they are at Neiber.

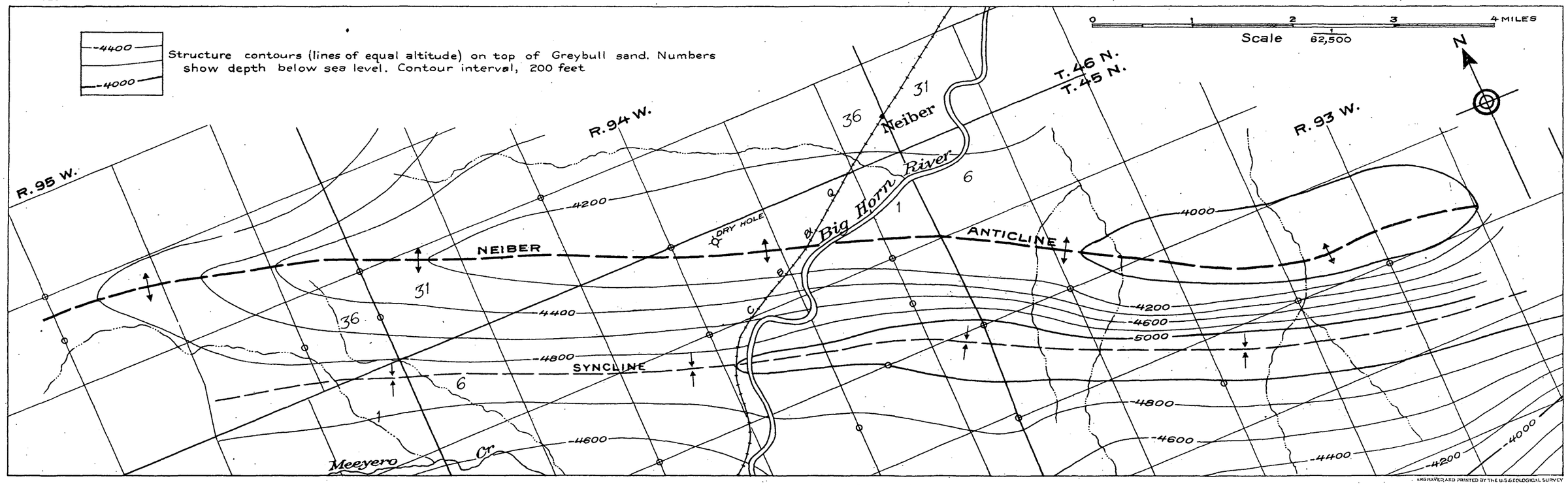
As this anticline is crossed by the broad valley of Big Horn River, which in places is more than 2 miles wide, the surface in the middle part is relatively smooth. West of the river flood plain the surface consists in part of the remnants of gravel-capped terraces, cut by intermittent streams which flow parallel to the crest line of the fold; near the heads of some of these streams badlands are developed. Immediately east of the river the surface is exceedingly rough, for it is sharply dissected by numerous streams, but at the east end it is much smoother than that just described and more nearly resembles the country lying west of the river.

The main water supply is derived from Big Horn River, which carries an almost inexhaustible quantity of excellent water throughout the year. Gooseberry Creek, a few miles north of the anticline, and Meeyero Creek, an equal distance south, also contain water along their courses or in pools throughout the greater part of the year but are usually considered intermittent streams. The intermittent streams carry water only in spring, early in summer, and after heavy rainstorms. No perennial streams except Big Horn River are known at any place near the anticline. Reservoirs in which flood waters could be impounded could be made with little difficulty at many places, particularly along the courses of some of the intermittent streams.

STRUCTURE.

The Neiber anticline is an unsymmetrical upfold about 15 miles long trending northwest. The north limb is much broader than the south and constitutes an extensive gathering ground for any oil or gas that may have originated in the deeper parts of the Bighorn Basin. The dips on the narrow south limb are much steeper than those on the north limb. They range from zero at the crest line to as much as 21° near the trough of the syncline in sec. 21, T. 45 N., R. 93 W. The maximum dip on the north limb is believed to be 8°, which was noted near the northeast corner of sec. 9, T. 45 N., R. 93 W., about a mile northeast of the crest line. From here the dip gradually decreases to the central part of the Big Horn Basin. Other dips show that the anticline pitches slightly at each end.

The lowest surface rocks belong to what is thought to be the lower part of the Fort Union formation. The total thickness of the formation, which consists mainly of sandstone interbedded with sandy shale and clay, has not been determined in this locality, but is believed to be about 1,500 feet. Unconformably overlying the Fort Union is the Wasatch formation, which is largely variegated sandstone, clay, and shale, and here and there beds of conglomerate, and which outcrops along the synclinal axis east of Big Horn River.



STRUCTURE CONTOUR MAP OF NEIBER ANTICLINE (No. 29 ON PLATE I)

By Charles T. Lupton

The rocks through which the drill will pass on the crest of the anticline near Big Horn River consist first of 800 feet or more of the lower part of the Fort Union formation. Directly underlying these is the Lance formation, about 1,800 feet thick, which is similar to the overlying Fort Union and consists of yellowish-gray sandstone interbedded with shale. Underlying the Lance is the Meeteetse formation, about 350 feet thick, which is believed to correspond to the Lewis shale of southern Wyoming and to the Bearpaw shale of central Montana. Below the Meeteetse is the Mesaverde formation, about 1,200 feet thick, consisting of massive sandstone and sandy shale with coal beds near the base which are mined at Gebo and Crosby on the west side of Big Horn River, a few miles southwest of Kirby. The top sandstone of this formation, being overlain by the impervious Meeteetse shale, may possibly contain oil. Directly underlying the Mesaverde is the Cody shale, about 3,000 feet thick, and underlying it is the Frontier and other formations.

The structure contours drawn on the top of the Greybull sand, or top sandstone of the Cloverly formation, in which the oil and gas are found in the Greybull field, together with the surface elevations, which range from about 4,100 feet near the center of sec. 1, T. 45 N., R. 94 W., to about 4,700 feet near the center of sec. 16, T. 45 N., R. 93 W., enable the depth from the surface to the Greybull sand or to any other sand whose position with relation to the Greybull is known to be determined. (See p. 39.)

DEVELOPMENT.

A well (Pl. XX), drilled with a standard rig in the NE. ¼ NW. ¼ sec. 3, T. 45 N., R. 94 W., by the Tanberg Oil Co., of Thermopolis, Wyo., was begun in May or June, 1915, and by the last of July had reached a depth of about 900 feet. A little gas is reported to have been encountered at a depth of about 600 feet. Drilling was continued to about 2,000 feet, but according to the latest reports no oil or gas had been obtained in commercial quantities. Much water was encountered at a depth of about 1,000 feet. The mouth of the well is about 4,340 feet above sea level. A generalized log of this well follows:

Log of well drilled in the NE. ¼ NW. ¼ sec. 3, T. 45 N., R. 94 W., near Neiber, Wyo.

	Thickness.	Depth.
	Feet.	*Feet.*
Sandstone and shale; about 8 feet of coal at the base	750	750
Shale and sandstone; large water-bearing sand near base	250	1,000
Sandstone and shale	150	1,150
Shale	750	1,900
Hard shells, brown sandstone, hard white sandstone, and black shale. (Bottom of hole, Mar. 23, 1916)	100	2,000

CONCLUSIONS.

As the sands of the Frontier formation, which carry oil and gas in the Grass Creek and Little Buffalo basins, are 7,500 to 8,000 feet below the surface at the point where the crest line of the Neiber anticline crosses Big Horn River, they must be eliminated from the list of possible oil sands at present available. The next higher sand of possible value is at the base of the Mesaverde formation, 4,200 to 4,700 feet below the surface; and its value is questionable, for it is not covered by an impervious cap of shale, a necessary condition for the retention of oil or gas in areas where the sands are saturated with water, as they are in places in the Big Horn Basin. Near the top of the Mesaverde, about 1,200 feet above the base, a sand of suitable texture and density is overlain by a bed of shale (Meeteetse) about 350 feet thick, which serves as an impervious cap. This sand lies at a depth of probably not more than 3,000 feet. If it does not contain oil or gas in commercial quantities, it is doubtful if the underlying sandstone beds of the Mesaverde are sufficiently promising to warrant further drilling operations. The writer therefore advises against deeper drilling until such a time as drilling rigs are perfected to penetrate a depth of 7,000 or 8,000 feet without difficulty. At that time the sands of the Frontier formation may here be found to carry oil and gas.

The well in the NE. ¼ NW. ¼ sec. 3, T. 45 N., R. 94 W. (Pl. XX), is fairly well located to test the western half of the anticline but was not drilled deep enough to penetrate the top sandstone of the Mesaverde formation, which lies 1,000 or 1,200 feet deeper.

If the eastern part of the anticline is tested the writer advises drilling 800 to 1,200 feet north of the crest, approximately in the SW. ¼ NW. ¼ sec. 15, T. 45 N., R. 93 W., where the top sandstone of the Mesaverde can be penetrated at a depth of about 3,500 feet.

SAND DRAW ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Sand Draw anticline (No. 30, Pl. I), an untested small upfold on the north flank of the larger Thermopolis anticline, is situated mainly in the southern part of T. 45 N., R. 96 W., about 10 miles west of Kirby and 16 miles northwest of Thermopolis. It lies mainly in the drainage basin of Sand Draw, which joins Big Horn River near Kirby.

This anticline is most easily reached from Kirby, a town on the Chicago, Burlington & Quincy Railroad directly west of Big Horn River. From this place a good road, over which much of the freight

to the Grass Creek oil field has been hauled, follows in general the course of Sand Draw and crosses the northwest end of the anticline. Parts of the anticline, however, can be reached only on foot or on horseback.

The surface of the anticline is characterized by the valley of Sand Draw, which crosses the anticline transversely and in places is narrow and canyon-like.

The surface is rough and hilly near the tributaries of Sand Draw. The altitude of the surface ranges from about 4,840 feet in the NE. ¼ sec. 20, T. 45 N., R. 96 W., to about 5,225 feet in the SW. ¼ sec. 34 of the same township.

The water supply near the anticline is meager and obtained wholly from Cottonwood and Grass creeks and Sand Draw, all of which are intermittent streams that carry water only in spring, early in summer, and after rainstorms, and from a few alkaline springs along these streams which supply small quantities of water in the dry season. A little water for camp use can be obtained from the Zimmerman spring, on the Thermopolis-Grass Creek road in sec. 23, T. 44 N., R. 96 W., about 3 miles south of the southeast end of the anticline.

STRUCTURE.

The Sand Draw anticline is a northwestward-pitching unsymmetrical upfold about 4½ miles long with its narrow flank on the southwest side. The comparative narrowness of the southwest limb is due mainly to the greater steepness of its dip, which ranges from nearly zero at the crest line to as much as 18° near the center of sec. 33, T. 45 N., R. 96 W. On the northeast limb the dip reaches a maximum of 14° at a point about a mile from the axis, beyond which it gradually decreases to zero in the synclinal trough south of Neiber anticline. The dip at the southeast end of the anticline is slight. One dip of 4° S. in the northern part of sec. 11, T. 44 N., R. 96 W., suggests that the anticline pitches slightly at its southeast end.

The lowest surface rocks belong to the upper part of the Cody shale, about 2,800 feet thick, which is exposed at the extreme southeast end of the upfold at the reentrant in the cliff line in secs. 1, 2, and 3, T. 44 N., R. 96 W. (See Pl. XXI, p. 146.) Overlying the Cody shale is the Mesaverde formation, about 1,200 feet thick, consisting mainly of sandstone with minor amounts of sandy shale, shale, and coal beds (mined at Gebo and Crosby, a few miles to the east). Resting on the Mesaverde formation is the Meeteetse formation, about 350 feet thick and largely shale. Above the Meeteetse lies a mass of sandstone and shale, sandstone predominating, about 3,000 feet thick, which includes the Lance and Fort Union formations. Probably little more than half of these formations lies beneath the surface at the northwest end of the anticline near Cottonwood Creek.

The rocks directly beneath the surface at the southeast end of the anticline belong to the Cody shale. A deep well here would pass through about 2,000 feet of this shale before reaching the underlying sandstone beds (of the Frontier formation) that carry oil and gas in the Grass Creek and Little Buffalo Basin fields. This predominantly sandy formation is about 600 feet thick and contains thin layers of sandy shale, shale, and bentonite. Below the Frontier is the Mowry, a hard, gray, platy shale 200 to 300 feet thick, which contains one or more sandstone beds that carry oil and gas in the Torchlight dome, near Basin. Underlying the Mowry is the dark-gray Thermopolis shale, about 400 feet thick, containing near its middle in most places a bed of sandstone (the Muddy sand), which is not known to contain oil or gas in the Big Horn Basin except in the Oregon Basin. Underlying the Thermopolis shale is the Cloverly formation, about 125 feet thick, which consists of an upper sandstone (the Greybull sand, which carries oil and gas in the Greybull field) about 20 feet thick, a middle variegated shale about 80 feet thick, and a lower conglomeratic sandstone about 25 feet thick.

The structure contours drawn on the top of the Greybull sand and the cross section (see Pl. XXI, p. 146) show the shape and size of the anticline. With these contours and surface elevations known, the approximate depth of the Greybull sand may be determined. (See p. 39.)

CONCLUSIONS.

The Sand Draw anticline has not been drilled, and no seeps of oil or vents of gas on it are known. The part of the anticline that should be first prospected is the domelike expansion at the southeast end, where the Frontier formation can be reached with the least drilling; secs. 2 and 11, T. 44 N., R. 96 W., are recommended. The top of the Frontier formation, the oil and gas bearer in the Grass Creek and Little Buffalo Basin fields, is about 2,000 feet beneath the surface; and the Greybull sand, the oil and gas bearer in the Greybull field, is about 1,200 feet deeper.

WAUGH ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Waugh anticline (No. 31, Pl. I) is in T. 44 N., Rs. 96 and 97 W., and T. 45 N., R. 97 W., about 25 miles northwest of Thermopolis and about an equal distance west of Kirby, both on the Chicago, Burlington & Quincy Railroad. It can be most easily reached from Thermopolis along the well-traveled road leading to the Grass Creek

oil field, which lies 15 miles farther northwest. This main road lies within 1¼ miles north of the crest line of the Waugh anticline at almost every point. As the surface is comparatively smooth, many second-class roads lead from the main road, making nearly all parts of the anticline easily accessible.

The area adjacent to this anticline is for the most part smooth, but its west end is trenched by the valley of Cottonwood Creek and here and there at other places by shallow valleys. On its southwest side prominent cliffs of sandstone show interbedded shale and one or more beds of coal. These cliffs are rugged, but the possible oil-bearing part of the anticline lies in the smooth lower country nearer the crest.

The water supply is derived from Cottonwood Creek, which is intermittent except for small flows of water from seeps that occur here and there along its course. Reservoirs to catch and hold the flood waters along the beds of the intermittent streams can be easily made in the soft impervious shale which forms the surface rock of the greater part of the anticline.

STRUCTURE.

The Waugh anticline is a northwestward-pitching wrinkle on the north flank of the larger Thermopolis anticline, which is about 25 miles long and in places is 10 miles wide. The Waugh anticline is unsymmetrical, the southwest limb being narrower than the northeast. (See Pl. XXI.) The dips on the southwest limb attain a maximum of 53° in the NW. ¼ NW. ¼ sec. 3, T. 44 N., R. 97 W., and those on the northeast limb a maximum of 24° near the center of sec. 35, T. 45 N., R. 97 W., about one-fourth of a mile from the crest line. From here northeastward the dips decrease gradually to the trough of the syncline, which parallels the anticline about 4 miles northeast. The beds at the northwest end of the anticline dip as much as 10° NW., indicating that the anticline pitches sharply. At the southeast end the beds in the lower part of the Cody shale dip slightly southeast, suggesting that the anticline pitches in that direction for a short distance, but this slight dip probably has not affected the underlying sandstone beds (Frontier formation) which carry oil in some parts of the Big Horn Basin. If it has not, the anticline is not promising as an oil or gas reservoir, for any oil that may have accumulated along the crest would have a free avenue of escape toward the southeast.

The surface rocks of the Waugh anticline belong to the lower part of the dark-gray Cody shale, which is about 2,500 feet thick and contains thin sandstone beds near its top and base.

Beneath the surface are the lower part of the Cody shale, Frontier formation, consisting mainly of sandstone with thin layers of shale

and bentonite about 500 to 600 feet thick; the Mowry shale, about 175 feet thick; the Thermopolis shale, about 400 feet thick, and other formations. The Frontier formation is the most important, as it carries the oil and gas found in the Grass Creek and Little Buffalo fields, 10 and 25 miles, respectively, to the northwest.

Four wells have been drilled on this anticline, but only two of them have reached the Frontier formation. The log of the Levi No. 3 well (No. 3, Pl. XXI) is given to show the character and thickness of the beds down to and including the upper part of the Frontier formation.

Log of Levi No. 3 well, in the NE. ¼ NE. ¼ sec. 2, T. 44 N., R. 97 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Shale	1,370	1,370
Sand, water bearing	12	1,382
Shale, tough	45	1,427
Shale	60	1,487
Sand and slate, hard	8	1,495
Shale, tough	30	1,525
Shale	130	1,655
Shale, tough	35	1,690
Sand, hard	4	1,694
Sand (showing trace of oil)	2	1,696
Slate	10	1,706
Lime, blue	17	1,723
Sand	7	1,730

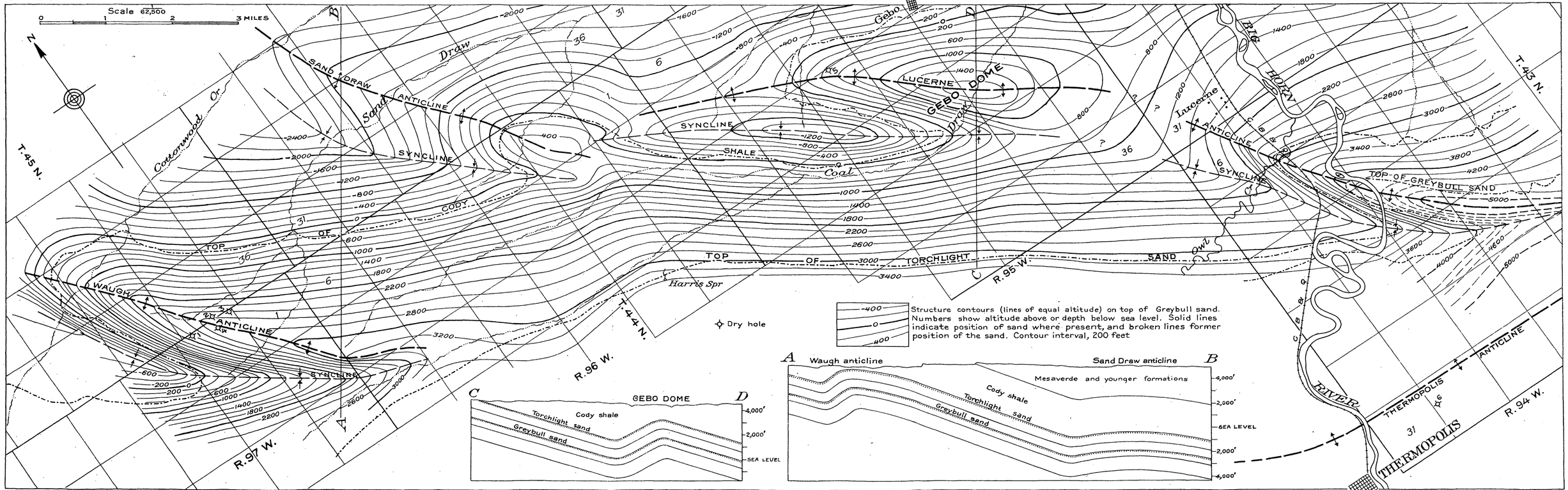
This well was drilled by Levi & Son from February to May, 1915. The surface elevation of its mouth is about 5,050 feet.

The structure contours drawn on the top of the Greybull sand, supplemented by the cross section (see Pl. XXI), show the shape and extent of the anticline. With these and the surface elevations, which range from about 4,900 feet above sea level in the SE. ¼ sec. 23, T. 45 N., R. 97 W., to about 5,400 feet in the NE. ¼ sec. 3, T. 44 N., R. 97 W., the approximate depth to the top of the Greybull sand or any other sand whose position with relation to the top of that sand is known may be determined.

Faults are not known in any part of the anticline, but they may be present and undetected, as it is exceedingly difficult to detect them in the Cody shale.

DEVELOPMENT.

Of the four wells drilled by Levi & Son on this anticline the Levi No. 1 (No. 1, Pl. XXI) in the NE. ¼ NW. ¼ sec. 2, T. 44 N., R. 97 W., was drilled (from August to December, 1914) to a depth of 880 feet, all of it in black shale. No trace of oil or gas was found. The elevation of its mouth is about 5,025 feet. The Levi No. 2 (No. 2, Pl. XXI) in the SW. ¼ SE. ¼ sec. 35, T. 45 N., R. 97 W., was drilled (December, 1914, to January, 1915) to a depth of only 200 feet in the shale. The



STRUCTURE CONTOUR MAP OF THERMOPOLIS, LUCERNE (INCLUDING GEBO DOME), SAND DRAW, AND WAUGH ANTICLINES (Nos. 27, 28, 30, AND 31, RESPECTIVELY, ON PLATE 1) AND TWO STRATIGRAPHIC SECTIONS

The outcrops of sands are mapped as sandstones

By Charles T. Lupton

elevation of its mouth is about 5,075 feet. A log and other information regarding the Levi No. 3 well is given above. The Levi No. 4 well (No. 4, Pl. XXI) in the NW. ¼ NE. ¼ sec. 2, T. 44 N., R. 97 W., penetrated to a depth of 1,272 feet. It entered the top of the Frontier formation at a depth of 1,035 feet and found, at 1,150 feet, an oil sand with a fair showing of oil, below which was water. The well was stopped after drilling about 70 feet into the underlying shale.

CONCLUSIONS.

As two of the wells described have penetrated the Frontier formation without finding more than showings of oil and gas it seems doubtful if this anticline is an important oil and gas reservoir. The highest part of the upfold, in which oil and gas are most likely to be found, is about 2 miles southeast of the wells near the point where the strata dip slightly to the southeast. Any further drilling should be done somewhere near the crest line, preferably in the SW. ¼ sec. 7, T. 44 N., R. 96 W. Possibly the change of dips (p. 145) does not affect the underlying sandstones, and unless it does it is almost certain that no oil or gas in commercial quantities will be found in the Waugh anticline.

COTTONWOOD ANTICLINE.

By D. F. Hewett.

GENERAL FEATURES.

The Cottonwood anticline (No. 32, Pl. I) crosses the valley of Cottonwood Creek about 23 miles northwest of Thermopolis. Its highest part is well shown by conspicuous outcrops of sandstone in the east half of T. 44 N., R. 98 W., but it extends eastward and northward beyond the limits of this township. It has been tested near the crest by three wells, but as none has yielded oil or gas the anticline is not regarded as favorable for exploration. It may be reached from Thermopolis by the road up Owl Creek to Rothwell and thence north of Cottonwood Creek; or from Kirby up the Sand Draw road to Waugh's ranch and thence southwest along Cottonwood Creek.

The crest of the anticline is marked by a number of concentric ridges surrounded by a broad plain that is trenched by a few streams and interrupted here and there by low ridges and gravel-covered terraces. North of the anticline this plain has a width of about 4 miles and is bounded by a rugged escarpment, which, in T. 45 N., R. 98 W., is an almost unbroken and impassable wall 200 to 450 feet high.

There are no perennial streams in the vicinity of the anticline. Cottonwood Creek, whose course cuts across the anticline, derives

its supply from snow fields that lie among the outlying ridges of the Shoshone Mountains; but water does not flow on the surface in this region between the middle of August and the later part of November in years of average rainfall. The flow of Cottonwood Creek near Kemp's ranch, in sec. 17, T. 44 N., R. 98 W., early in August, 1913, was estimated at 25 gallons a minute. The ranches along the valley derive their water supply from wells dug in the wash near the stream. Several stream courses, such as that of Wagonhound Creek, contain a few pools of highly alkaline water that are used only by stock on the near-by range.

In comparison with much of the region on the west side of the Big Horn Basin, vegetation is sparsely distributed near the valley of Cottonwood Creek and is limited to grasses, sagebrush, and a few pines which occur along outcrops of sandstone. Alfalfa and oats are grown by irrigation along the lower part of the valley of Cottonwood Creek.

STRUCTURE.

Erosion has cut deeper into the crest of this anticline than into most of those on the west side of the Big Horn Basin, and all of the sandstone beds of the Frontier formation are well exposed along a series of roughly elliptical parallel ridges. Four fairly persistent sandstones correspond closely to the beds reported in the wells of the Grass Creek Basin. The Frontier sandstones dip 10° NE. on the flat limb of the anticline, and the basal Mesaverde sandstone, which outcrops nearly 3 miles to the northeast, dips 12° NE. These relations indicate a thickness of 2,950 feet for the Cody shale—a formation that is only 1,900 feet thick on the southwest or steep limb of the anticline and 2,450 feet in the Grass Creek Basin. It is therefore assumed that the beds along the flat north limb (concealed by the valley wash) dip locally less than 10° and that there is a pronounced structural terrace on that limb. The form of the escarpment of Mesaverde sandstones farther west is also such as would be produced by a structural terrace.

In making the structure contours of Cottonwood anticline on the Waugh coal bed the thickness of Cody shale has been assumed to be 2,050 feet, and the distance from the base of the Mesaverde to the Waugh coal bed 50 feet. On the flat northeast limb of the anticline the contours are therefore about 2,100 feet higher than the top of the Torchlight (?) sand. On the steep southwest limb, the difference in elevation is slightly greater because the dips are so much greater than on the northeast limb.

The beds that would show the form of Cottonwood anticline west of the highest sandstone of the Frontier formation are concealed by the gravel which covers Wagonhound Bench, and the structure

contours of the area north of Cottonwood Creek are adjusted, therefore, to the few outcrops on the southeast end of the Wagonhound anticline.

On the southwest limb of the Cottonwood anticline, the beds of Frontier sandstone attain a maximum dip of 72°, whereas the overlying Mesaverde sandstone dips 44° to an extensive syncline.

The crest of the anticline is broken by a number of nearly vertical faults, which offset the beds of Frontier sandstone. The stratigraphic displacement of most of these is small and it is scarcely probable that they extend far into the overlying Cody shale.

DEVELOPMENT.

When field work was concluded in this region in September, 1913, one well near the crest of the anticline, in the NW. ¼ SE. ¼ sec. 14, T. 44 N., R. 98 W., had been completed and a new well 100 feet to the southeast had reached a depth of 850 feet. In 1916 this well was abandoned and a third had been drilled to an unknown depth near the southeast corner of sec. 14. The first two wells started in the upper part of the Thermopolis shale and passed through the Cloverly and Morrison formations into the upper part of the Sundance formation, and it is reported that no oil or gas was found. It is also reported that it was necessary to haul water for drilling purposes throughout the period of operations.

CONCLUSIONS.

As all the Frontier sandstones outcrop and as two wells have failed to show the presence of water, oil, or gas on the crest of this anticline, it is regarded unfavorable territory for further exploration. In view of this conclusion, the prospects for oil or gas on a structural terrace in the sandstones of the Frontier formation on the north limb of the anticline in secs. 34, 35, and 36, T. 45 N., R. 98 W., and secs. 5 and 6, T. 44 N., T. 97 W., are not particularly favorable.

WAGONHOUND ANTICLINE.

By D. F. Hewett.

GENERAL FEATURES.

Fair exposures of Cody shales in sec. 6, T. 44 N., R. 98 W., show the end of a narrow anticline (No. 33, Pl. I) which pitches southeast, although no exposures under the lowest Mesaverde sandstone have been found farther northwest, which indicates closely the position of the crest. There is little doubt, however, that there is a well-defined crest which is not continuous with that of the Cottonwood anticline farther southeast.

The anticline is exposed in a small basin that contains numerous irregular flat-topped ridges which were once continuous with Wagon-

hound Bench, an extensive gravel-covered terrace that lies north of Cottonwood Creek. The basin is bounded on the west and north by a steep, rugged escarpment of Mesaverde sandstone. Wagonhound Creek and its several tributaries, which are dry during the summer and fall months, rise in a rough region that lies west of the escarpment. By cleaning out Wagonhound Spring sufficient water was obtained to supply boilers and a camp while several wells were being drilled on the anticline.

The anticline may be reached by an old road that leads from lower Wagonhound Bench to Wagonhound Spring in the northwest corner of sec. 36, T. 45 N., R. 99 W., or by a new road that leaves Cottonwood Creek near Kemp's ranch.

During 1915 and 1916 three wells were drilled near the crest of the anticline, two of which passed through the productive sandstones of the Frontier formation. Only traces of oil and gas were found in these wells. It is not thought that the anticline offers an encouraging area for the discovery of oil and gas in commercial quantities.

STRUCTURE.

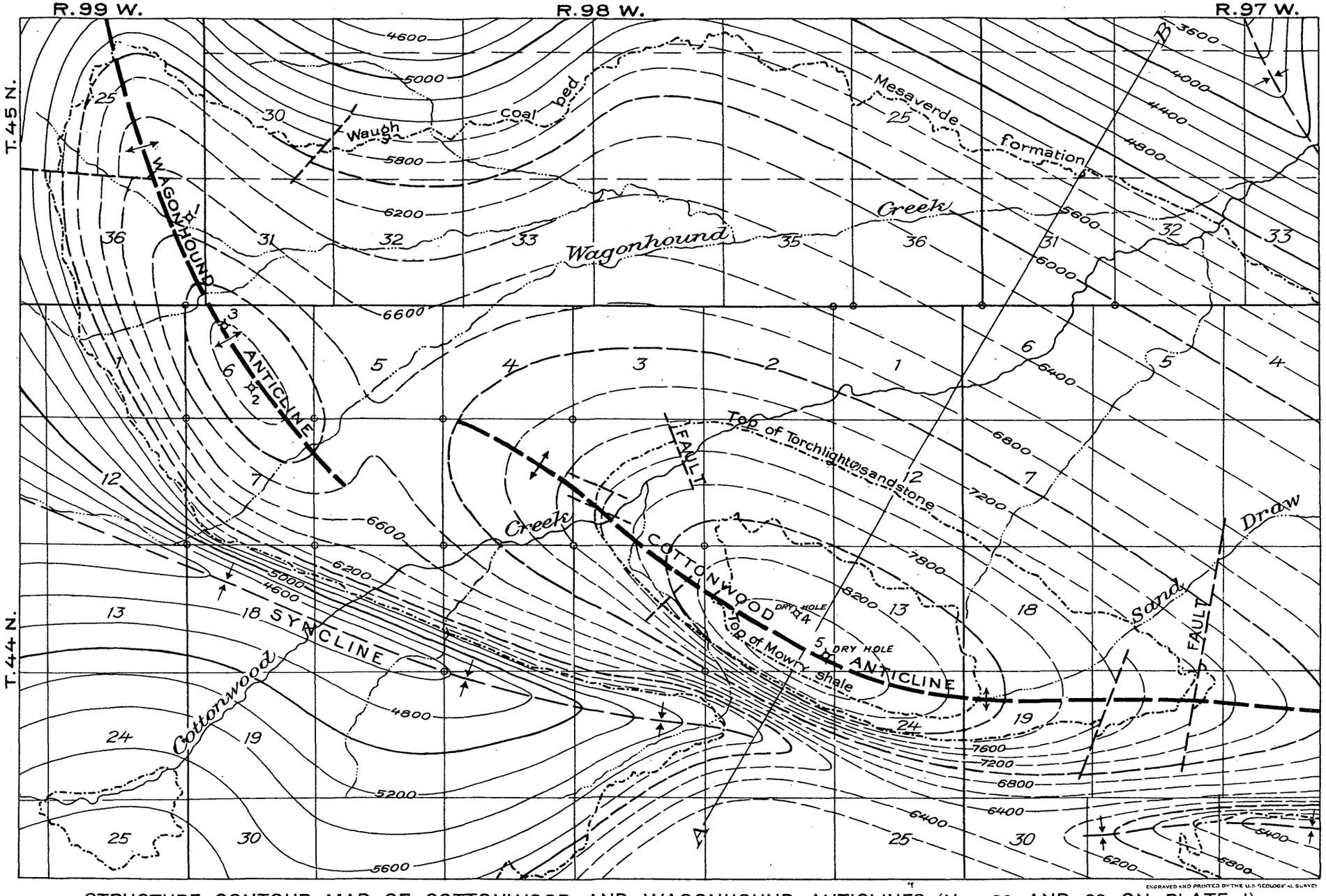
The outcrops of Cody shale on the basis of which structure contours are drawn are limited to a small area along a shallow ravine near well No. 2, in the S. ½ sec. 5, T. 44 N., R. 98 W. (See Pl. XXII.) These outcrops show clearly the east end of a narrow anticline which plunges southeast in the general direction of the Cottonwood anticline. No outcrops could be found in any of the ravines west and north of this well under the sandstone at the base of the Mesaverde formation.

About 1,000 feet northeast of well No. 2 thin sandy layers in the dark-gray Cody shale dip 12° NE., whereas the massive beds of Mesaverde sandstone which limit the basin 2 miles north dip 14°. On the south limb outcrops of Cody shale dip 18° SW., whereas the lowest sandstone of the Mesaverde formation dips from 24° to 36°. In order to calculate the thickness of Cody shale, both the observations of dip of the beds and the logs of the wells have been considered. These data show that the Cody shale southwest from well No. 2 is about 2,300 feet thick and about 2,450 feet near well No. 1. The distance from the Waugh coal bed to the base of the Mesaverde formation is 135 feet.

The anticline disappears in a region of complicated structure along Prospect Creek, 3 miles northwest of Wagonhound Spring.

DEVELOPMENT.

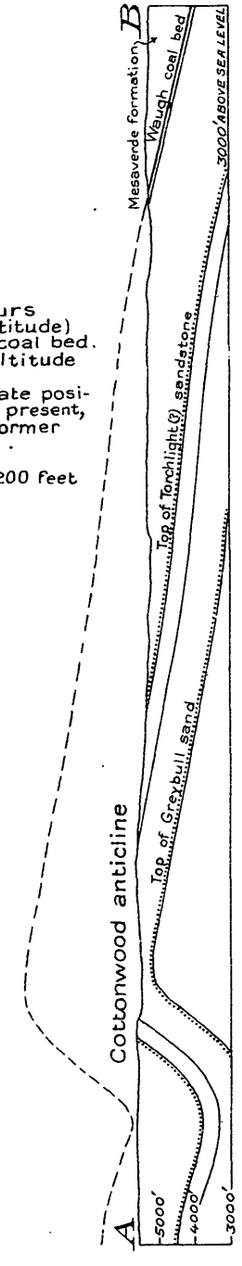
Three wells have been drilled close to the crest line of the anticline—No. 1, 1,833 feet; No. 2, 1,300 feet; and No. 3, 680 feet deep. The results obtained in drilling these wells are submitted by Mr. C. S. Sollars. The log of well No. 1 is given herewith.



Structure contours (lines of equal altitude) on top of Waugh coal bed. Numbers show altitude above sea level. Solid lines indicate position of bed where present, and broken lines, former coal bed.

Contour interval 200 feet

Dry hole



STRUCTURE CONTOUR MAP OF COTTONWOOD AND WAGONHOUND ANTICLINES (Nos. 32 AND 33 ON PLATE I) AND ONE CROSS SECTION

The outcrops of sands are mapped as sandstones

By D. F. Hewett

Scale 1/62,500

0 1 2 3 4 Miles

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

Log of well No. 1, Wagonhound anticline, NE. ¼ sec. 36, T. 45 N., R. 99 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Cody shale:		
Shale, gray and brown	1,505	1,505
Frontier formation:		
Sandstone, dark	23	1,528
Shale	18	1,546
Sandstone; a little gas at 1,562 feet	60	1,606
Shale, black	64	1,670
Sandstone, coarse, with water	20	1,690
Shale, black; a little oil and gas	35	1,725
Sandstone with shale	5	1,730
Sandstone, gray; water	24	1,754
Shale, gray	5	1,759
Sandstone	16	1,775
Shale, with bentonite	12	1,787
Sandstone, oil	8	1,795
Shale, with bentonite	7	1,802
Sandstone, water	12	1,814
Shale, with bentonite	7	1,821
"Lime" rock	2	1,823
Sandstone, oil	10	1,833

It is reported that the flow of water from this well was temporarily too great to determine the amount of oil that could be produced Well No. 2, in the S. ½ sec. 6, T. 44 N., R. 98 W., struck a sandstone with a show of oil at 475 feet and was continued to 1,300 feet but did not strike appreciable quantities of oil or gas in deeper sands. As the uppermost bed of sandstone was reported to be underlain by 320 feet of shale, it may not be the top of the Frontier, for both along the Cottonwood anticline, 5 miles southeast, and the Grass Creek anticline, 10 miles north, this zone of the Frontier contains several beds of sandstone. Well No. 3 was drilled to 680 feet without striking any beds of sandstone.

CONCLUSIONS.

Wells Nos. 2 and 3 are well placed to test the highest part of the anticline, but the first yielded traces of oil only, and the second has not penetrated the sands of the Frontier formation. The records of wells Nos. 1 and 2 and the size of the anticline, as well as its relation to the Cottonwood anticline, where the most productive sands outcrop, and to the structural depression of the Big Horn Basin, however, hold out little encouragement for finding important quantities of oil and gas on the structure.

GRASS CREEK ANTICLINE.

By D. F. Hewett.

GENERAL FEATURES.

The Grass Creek anticline (No. 34, Pl. I) has been extensively explored by drilling in the Grass Creek Basin and has been shown to contain one of the best oil fields in Wyoming. It lies about 28 miles

northwest of Thermopolis and may be reached from Worland by the Gooseberry Creek road to the north end of the basin, from Kirby by the road up Sand Draw and Cottonwood Creek, and from Thermopolis by the old Cody stage road as far as the crossing of Grass Creek. Worland, Kirby, and Thermopolis are towns on the Chicago, Burlington & Quincy Railroad. Most of the heavy freight is brought into the basin through Kirby.

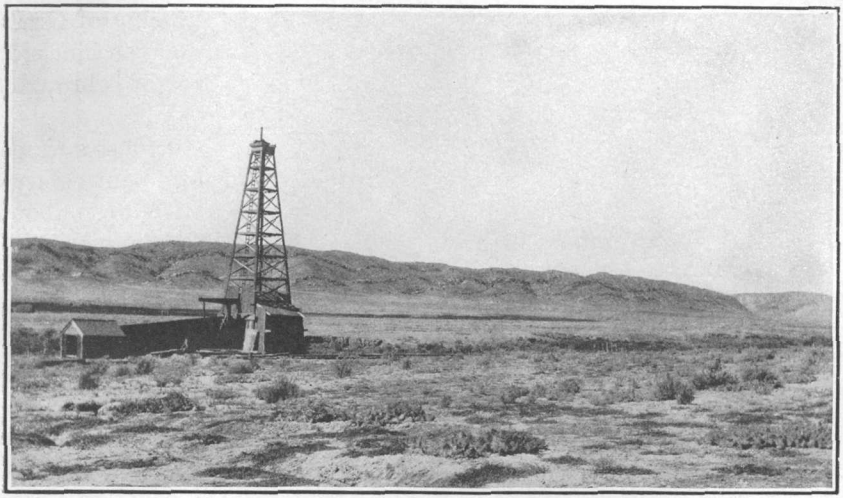
The Grass Creek Basin is one of the best examples of those surface basins that are almost completely surrounded by prominent escarpments or rim rocks. The rim of the basin forms a rude ellipse about 7 miles long and 3 miles wide at the widest part. Although the rim (see Pl. XXIII, *A*) forms a nearly impassable wall 400 feet high on the northeast side of the basin, it is cut by several narrow notches on the north, west, and south, through each of which a road passes. The basin is drained by two streams, Canyon Coulee, which flows north and east to Gooseberry Creek, and Grass Creek, which flows east to Cottonwood Creek. The part of the basin drained by Canyon Coulee contains numerous low knobs and ridges and is sparsely covered with grass and sagebrush, but the slopes adjacent to Grass Creek are almost flat and, by the aid of water drawn by ditches from Grass Creek, several large tracts are cultivated and yield abundant crops of alfalfa and oats. The two drainage areas are separated by a low but conspicuous gravel-covered ridge which is part of a terrace that was once extensive.

For most of the year Grass Creek, which rises among the high ridges of the Shoshone Mountains, carries a surface flow that during the early summer months is used for irrigation. Water suitable for drinking may be found by digging shallow holes near the stream channel. The surface flow at Littlejohn's ranch after the irrigation season in September, 1913, a year of abnormal rainfall, was estimated at 40 gallons a minute. Several ranches depend entirely upon water from wells, which is used in spite of the excessive alkali content. The main fork of Canyon Coulee at the northwest end of the basin is dotted with pools of highly alkaline water, which are used only by cattle.

STRUCTURE.

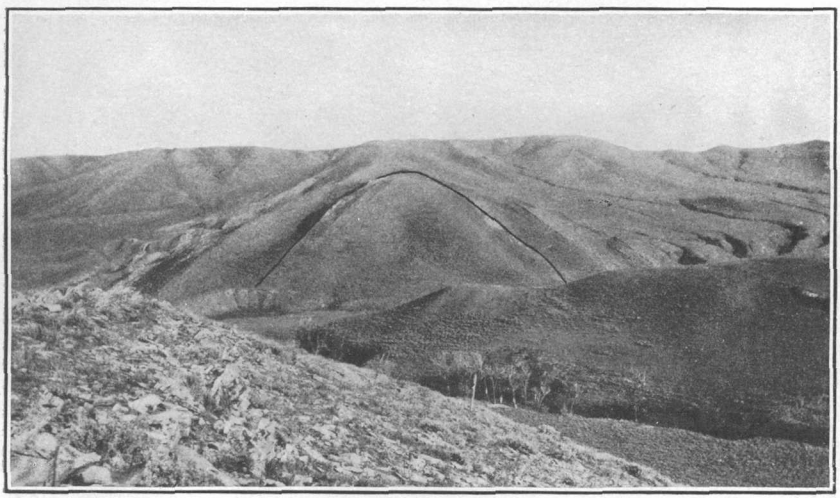
The shape and size of the Grass Creek anticline is shown on the map (Pl. XXIV, p. 160) by a cross section and by structure contours drawn at intervals of 200 feet on the lowest coal bed, the Dickie (Mesaverde formation), which appears to be continuous around the basin.

Well and surface data show the thickness of the Cody shale to be 2,450 feet; and as the sandstone underlying the lowest Mesaverde coal bed is about 60 feet thick the approximate elevation above sea level of the top of the upper Frontier sandstone at any point may be found



A. STANDARD DRILLING RIG IN GRASS CREEK OIL FIELD.

View westward toward the gap through which Grass Creek enters the basin. The character of the topography and vegetation is well represented.



B. CROSS SECTION OF NORTHWEST END OF SPRING CREEK ANTICLINE.

The heavy line indicates the outcrop of a folded bed in the Frontier formation.

by deducting the sum of these two figures (2,510 feet) from the elevation of the coal bed shown by the contours.

The Grass Creek Basin is carved in the soft Cody shale, and the surrounding rim rock is formed by the massive sandstone beds at the base of the overlying Mesaverde formation. The interpretation of the part of the anticline lying beyond the rim rock is based on the dip and strike of beds that overlie the Cody shale; and that of the part lying within the rim rock is based chiefly on data gathered from the logs of wells. The sandstones of the Frontier formation which yield the oil in this anticline do not outcrop but are struck in wells at a minimum depth of 365 feet in the east side of sec. 13, T. 47 N., R. 99 W.

The contours show a relatively simple but sharp anticline broken by a few faults. The fold, as shown by the cross section (Pl. XXIV), is unsymmetrical, with a steep limb on the southwest side and a very gently dipping limb on the northeast side. The dips on the northeast side increase from zero at the crest line to a maximum of 34° on the outcrop of beds of the Meeteetse formation 4 miles distant. The rim rock of Mesaverde sandstone dips from 12° to 24° (average 15°) along the northeast limb. On the southwest side the beds descend sharply into the adjacent syncline and dip from 50° to 60° across a wide belt. The anticline is limited on the northwest by a short syncline, west of which is the Little Grass Creek dome.

Although outcrops indicate that the only crest of the Grass Creek anticline lies in the W. ½ sec. 18 and the NW. ¼ sec. 19, T. 46 N., R. 98 W., where it is well marked by the logs of the wells, the logs also show a smaller but fairly defined crest farther southeast in sec. 29, T. 46 N., R. 98 W. The fault of 146 feet shown in the SE. ¼ sec. 19, T. 46 N., R. 98 W., is based on the correlation of two near-by well logs.

In the Grass Creek Basin, according to the logs of 44 wells that are available, only one (No. 22), in the NW. ¼ sec. 19, has penetrated the rocks below the Frontier formation. This well, which is near the crest line of the anticline, extends to the persistent sandstone in the Thermopolis formation, where it struck gas under great pressure. This sandstone occurs in the same part of the Thermopolis shale as the sandstones which yielded considerable gas in well No. 2 in the Oregon Basin and which yielded gas with some oil in the well on the Shoshone anticline.

So far as can be inferred from well logs the Frontier formation is 450 to 500 feet thick and contains several beds of sandstone. A tentative correlation of the logs of wells within an area about 1½ miles wide by about 6 miles long indicates that four of the sandstone beds are persistent, and it is the local practice to refer to these from the

highest to the lowest, respectively, as the "water" sand, and the "first," "second," and "third" oil sands. Although such a correlation is useful to the driller it disregards the uncertainties that attend recognition of the exact character of the rocks passed through and assumes that the beds are essentially parallel and persistent—a condition that probably does not exist. The maximum range in thickness of the four sands is 15 to 75 feet, but in most of the wells they are reported to be 20 to 30 feet in thickness. In the northern part of the basin, where the logs may be correlated with greatest assurance, the thickness of beds between the "water" sand and the "first" oil sand is about 190 feet; between the "first" and "second" oil sands about 90 feet, and between the "second" and "third" oil sands, about 90 feet. Locally there are other beds of sandstone, in some of which small quantities of oil and gas have been found.

In the southern part of the basin only a few wells explore more than the upper 300 feet of the Frontier formation, so that it is not known that the lowest sand is persistent. In this part of the basin, the zone including the "first" and "second" oil sands contains three sands, each of which, within the proved territory, contains some oil. Bentonite occurs in the Frontier formation in the Grass Creek Basin, and in some wells as many as eight beds of it have been struck. It causes much trouble in drilling, on account of its tendency to absorb water and greatly increase in volume.

Log of well (No. 12) in the NW. ¼ sec. 18, T. 46 N., R. 98 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Cody shale:		
Shale	540	540
Frontier formation:		
Sandstone, little water	25	565
Shale, hard, blue	75	640
Bentonite	30	670
Shale, blue	10	680
Shale, with bentonite	30	710
Shale, blue	25	735
"Cap rock"	6	741
Sandstone, hard, with oil	14	755
Bentonite and sandy shale	30	785
Shale, blue	15	800
Sandstone	5	805
Bentonite	21	826
Shale, blue	10	836
Bentonite	5	841
Shale, blue	7	848
Sandstone, with oil	17	865
Bentonite	10	875
Shale, blue	10	885
Bentonite	20	905
Shale, blue	30	935
Bentonite	10	945
Shale, blue	16	961
Sandstone, gas and oil	35	996
Mowry shale:		
Shale, blue	51	1,047

DEVELOPMENT.

Although it is locally reported that shallow wells were drilled during the summer of 1913, the first discovery of oil was made in June, 1914, in well No. 17 of the Valentine interests. There was considerable activity during 1914, and as the result of an examination of the field during August of that year Hintze [1] located 23 wells and gives the records of 16. On August 1, 1915, 55 wells had been completed, and in the preparation of this report the records of 44 were available. During October, 1916, the field was revisited by one of the authors and 193 wells had been completed. Of these, 129 were producing on October 15, and 22 had struck water in the productive sands. Most of the remaining 42 wells had struck small flows of oil that did not pay to pump, but information concerning some is lacking. The logs of most of the existing wells are known, but it has not been deemed advisable to delay the publication of this report until all of the information to be obtained from them has been incorporated. There is in process of preparation a more complete report on the Grass Creek oil field, which will be published later.

In drilling, both stationary and portable rigs have been used. For generating power, coal from near-by mines was first used, but recently it has been displaced by oil and gas from a number of the wells, notably No. 22 in the NW. ¼ sec. 19, T. 46 N., R. 98 W. The cost of drilling ranges from $2 to $3 a foot. The standard type of drilling rig is shown in Plate XXIII, *A* (p. 152).

Except in a few wells in the southeastern part of the basin the uppermost Frontier sandstone has yielded a little water and is locally known as the "water" sand. In several wells it contained small pockets of gas, and in one well, No. 61, in NE. ¼ sec. 29, it yielded several barrels of oil when pumped. Small and unimportant quantities of oil and gas are locally found in the stray sands between the top sand and the "first" oil sand, but the most important oil-bearing sands occur in the zone 100 to 150 feet thick, the top of which is 90 to 180 feet below the uppermost sand. Locally, as many as three oil-bearing sands are found in this zone. In three wells oil from these sands has flowed at the surface, but ordinarily it rises only several hundred feet and must be pumped. Oil flowed from one well in the SW. ¼ NE. ¼ sec. 29, T. 46 N., R. 98 W., for three weeks after the well was "shot." Gushers, such as have been found in a part of the Salt Creek field, have not yet been found in the Grass Creek Basin. The maximum yield a day of the sands of this zone has not been established, because until the fall of 1915

[1] Hintze, F. F., jr., Grass Creek oil and gas field, Wyo.: Wyoming Geol. Survey Bull. 11, 1915.

there were no facilities for shipment or storage of oil, and most of the wells were capped.

It is the practice in the field to shoot the pay sands with from 60 to 250 quarts of nitroglycerine when the well is completed. Under these circumstances the production of the good wells during the first 24 hours ranges from 150 to 400 barrels. The production during the second 24 hours is less, and although the system of pumping now in use by the companies that operate in the field does not permit them to record the daily production of each well, it is known that the average production from groups of 15 to 20 wells on some of the central tracts soon declines to 50 to 75 barrels per well a day. The lowest sand of the Frontier formation has been penetrated by only a few of the wells, most of which are in the northern part of the basin, and although it contains oil its probable yield has not been determined.

Up to October, 1916, production was confined to the land lying south of the north boundary of secs. 19 and 20, T. 46 N., R. 98 W., where most of the surface of the basin was covered by agricultural entries. It is apparent, therefore, that although wells have shown the presence of oil in a large area adjacent to the crest and north of the line referred to, the possible yield of the sands in this area is not known. The production of the district rose rapidly during the summer of 1916, owing to a great increase in the number of wells. It is estimated that the weekly production during October, 1916, was about 45,000 barrels.

Water has been struck in a number of wells along both limbs. The water commonly has a mildly alkaline taste, but none that is appreciably salty or sulphurous has yet been found. In most instances when the water is struck it rises from 10 to 50 feet in the well. More rarely it has risen about 200 feet, and in one well on the northeast limb it rose 900 feet, or within 200 feet of the surface. In that part of the field that has been most thoroughly explored the horizontal distance between wells that yield oil and those that yield water is not great. It therefore appears that in the productive sands a fairly defined surface of demarcation exists between oil and water.

Oil is pumped from groups of 5 to 20 producing wells by power supplied from centrally located plants. The oil is received in a settling tank which serves to separate any sediment and water that may have been raised during pumping and then flows to storage tanks. From these storage tanks oil is drawn directly by 3-inch pipes into the 6-inch pipe line which transports it to Chatham, on the Chicago, Burlington & Quincy Railroad. This pipe line was constructed early in 1915, and in a distance of 27 miles has a fall of about 1,500 feet, so that the oil flows freely without pumping.

The following analysis of a sample of oil from well No. 35, in the NW. ¼ sec. 20, was made at the laboratory of the Bureau of Mines.

The oil is from the zone that includes the "first" and "second" oil sands of the Frontier formation.

Analysis of oil from well No. 35, in the NW. ¼ sec. 20, T. 46 N., R. 98 W.

Began to boil at 80°.

	Per cent.
Gasoline:	
80°–100°	3
100°–125°	9
125°–150°	10
	22
Kerosene:	
150°–175°	8
175°–200°	4
200°–225°	6
225°–250°	8
250°–275°	8
275°–300°	8
	42
Residuum	36
Specific gravity at 60° F.:	
Crude oil (41° Baumé)	0.8187
Gasoline (55.9° Baumé)	.7530
Kerosene (41.3° Baumé)	.8175
Residuum (33.7° Baumé)	.8553

CONCLUSIONS.

The areal limits of the productive territory in the Grass Creek field, or the limits beyond which the sands contain water instead of oil, appear to be fairly indicated by the wells that have been drilled, although little is known concerning the possibility of finding oil in commercial quantities in the sandstones of the Thermopolis and lower formations. In the portion of the field north of the north boundary of secs. 29 and 30, T. 46 N., R. 98 W., the productive area in the Frontier sandstones appears to be roughly inclosed by the 7,200-foot contour on the lowest Mesaverde coal, and by the closely corresponding 4,700-foot contour that might be drawn on the uppermost sandstone of the Frontier formation. In the southeastern part of the field the limit is less clearly defined but appears to be inclosed by a lower contour on the Mesaverde coal, approximately the 6,700-foot, and by the equivalent 4,200-foot contour on the top of the uppermost sandstone of the Frontier formation. Several factors might account for this apparent difference in the level of the lower limit of oil, but the subject will not be discussed in this report. The gas, oil, and water in the middle zone of the Frontier formation appear to be arranged in the pervious beds in roughly horizontal zones, the gas lying close to the crest traces of the folded Frontier sandstones and being under-

lain successively by the oil and the water in accordance with the simplest conception of the anticlinal theory.

The present development of the Grass Creek field shows better prospects for the production of oil than any of the explored fields of the Big Horn Basin, although possibly not better than those of the Salt Creek fields, where wells of the gusher type are not uncommon and many wells have yielded considerable quantities of oil by natural flow for periods as long as five years. Exploration to date has shown the possible yield of pervious sands of the Frontier formation, but it is not improbable that here, as at Salt Creek and other fields in the eastern slope of the Rocky Mountains, important quantities of oil may be found in lenses of sand in the thick shale or in fissures.

ENOS CREEK ANTICLINE.

By D. F. HEWETT.

A small but well-developed fold (No. 35, Pl. I) is exposed along the valley of Enos Creek, in the southwestern part of T. 46 N., R. 100 W., about 6 miles above the Dickie ranch on Gooseberry Creek. It is most easily accessible, however, from the Grass Creek Basin, the central part of which is 7 miles due east and which is 28 miles northwest of Thermopolis. Enos Creek is a small perennial stream which rises among the timbered hills along the eastern edge of the Shoshone Mountains and flows in a deep, narrow valley to its junction with Gooseberry Creek. There are no ranches along the stream, and the adjacent region is devoted to grazing.

During 1916 a well was drilled near the crest line and at 2,400 feet struck water in the Torchlight (?) sand. On account of the position of the anticline with reference to the border belt of anticlines, the prospect for finding oil or gas in this anticline is not good.

The anticline is marked by good exposures of the lower sandstone beds of the Mesaverde formation and the underlying shaly sandstone of the Cody shale. Erosion has produced a small basin along the crest of the anticline, and the lowest coal bed of the Mesaverde formation may be traced around the adjacent slopes and ridges. On the northeast side of the anticline, the beds of the formations successively higher than the Mesaverde dip uniformly at about 10° to the syncline which bounds the Grass Creek anticline on the southwest. The Mesaverde coal beds attain a maximum dip of 28° west along the west side of the anticline. The structure contours in figure 10 are based upon a traverse of the lowest coal bed, and show a small anticline that trends northwest, the highest part of which is situated where the crest line crosses Enos Creek. This reconnaissance did not permit the determination of the extent of the anticline northwest and southeast of the outcrops of the Mesaverde coal bed.

From April to October, 1916, a well was drilled near the west line of sec. 25, T. 46 N., R. 100 W., by the Grass Creek Oil Co. The top of the well has an approximate elevation of 6,440 feet, and at 2,400 feet the top of a bed of sandstone which is probably the uppermost bed of the Frontier formation was struck. This bed yielded a strong flow of water, which rose 1,000 feet in the well. At 2,436 feet tools were lost and drilling was temporarily discontinued.

The Enos Creek anticline is similar in size and structural relations to the Gooseberry anticline, situated about 7 miles north, which was also recently drilled to the upper Frontier sand and yielded water. As both of these anticlines are separated from the main structural

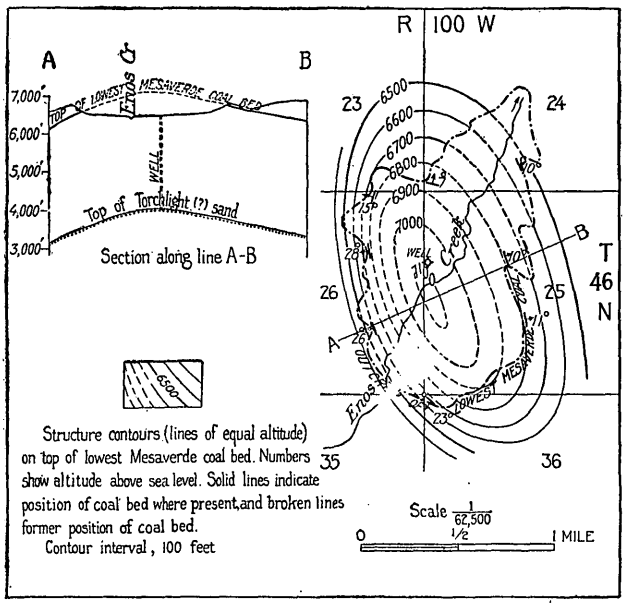


FIGURE 10.—Structure-contour map and cross section of the Enos Creek anticline (No. 35, Pl. I).

depression of the Big Horn Basin by other extensive prominent anticlines, they are not regarded as favorable reservoirs for important accumulations of oil and gas.

LITTLE GRASS CREEK DOME.

By D. F. HEWETT.

The Little Grass Creek dome (No. 36, Pl. I) is in the northeast part of T. 46 N., R. 99 W., adjacent to the northwest part of the Grass Creek anticline, from which it is separated by a short but pronounced syncline. The crest of the dome coincides with a nearly circular basin, about 1½ miles in diameter, that is almost surrounded by a rugged escarpment of sandstone beds of the Mesaverde formation. The western part of the basin is drained northward by a tributary of Gooseberry Creek and the eastern part by the principal fork

of Canyon Coulee. There are no perennial streams in the basin, but Gooseberry Creek, half a mile north, flows on the surface most of the year. The basin is accessible by roads from the Grass Creek basin on the east and from Gooseberry Creek on the north.

One well near the crest is reported to have penetrated the upper half of the Frontier formation and to have encountered water in the sands. Another well on the east side of the dome is too shallow to have reached any of the Frontier sands. The dome appears to offer little prospect for the discovery of oil and gas in commercial quantities.

As shown by structure contours on the lowest coal bed (Dickie) of the Mesaverde formation, the dome is almost circular but merges westward with a flat anticline that can be traced a few miles farther. (See Pl. XXIV.) The dips of the escarpment away from the crest of the dome are low, ranging from 7° to 12°, but the higher beds south of the rim dip as much as 34° S. The contours near the crest of the dome are based on the dip of outcropping beds. The low syncline that separates the dome from the Grass Creek anticline does not persist far north of the limits of the area shown on Plate XXIV and disappears southward near an extensive syncline. The low syncline would tend to divert to the crest of the Grass Creek anticline any oil or gas that was rising from the deeper part of the Big Horn Basin in the area east of the synclinal trough, but it would not prevent the movement to the Little Grass Creek dome of oil or gas from the area west of the trough.

If the thickness of the Cody shale is assumed as 2,450 feet, as at Grass Creek, the top of the uppermost Frontier sand lies about 1,800 feet below the surface on the crest of the dome in the NW. ¼ sec. 11, T. 46 N., R. 99 W. If the section of the Frontier formation is similar to that at Grass Creek the first oil sand would be struck 2,020 feet below the surface.

The Great Dome Oil Co. drilled a well reported to be about 2,100 feet deep on the E. ½ sec. 10, T. 46 N., R. 99 W., but struck water in the upper Frontier sands. The log of this well has not been obtained. It is situated a short distance south of the crest line of the anticline and if important amounts of gas or oil were present in the dome, they should have been struck by the well. Failure to find either of the substances near the crest of the dome must be regarded as satisfactory proof that the lower parts of the dome are not favorable areas for exploration. The well in the E. ½ sec. 11, T. 46 N., R. 99 W., is reported to be shallow and not deep enough to strike any of the Frontier sands.

The Little Grass Creek dome lies between the Grass Creek anticline on the southeast, in which oil has been struck by many wells, and the East Buffalo anticline on the northwest, on which two wells have

R.99 W. R.98 W.

T.47 N. T.46 N.

Dickie Ranch

Gooseberry Cr.

Little Grass Creek dome

FAULT

Canyon Coulee

Dickie coal bed

Mesaverde formation

Grass Creek Syncline

Syncline Coal

Littlejohn Ranch

Grass Creek

FAULT

FAULT

anticline

Draw

Wasatch formation

Structure contours (lines of equal altitude) on top of Dickie coal bed. Numbers show distance above sea level. Solid lines indicate present position of bed below, and broken lines former position above present surface. Contour interval, 200 feet.

o Drilling

● Oil well

◊ Hole; no data

✧ Dry hole

B

5000'

4000'

3000 FEET ABOVE SEA LEVEL

Mesaverde formation

Dickie coal bed

Sand

Top Torchlight (?) sand

Greybull sand

Top

Grass Creek anticline

A

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

STRUCTURE CONTOUR MAP OF GRASS CREEK ANTICLINE AND LITTLE GRASS CREEK DOME (Nos. 34 AND 36, RESPECTIVELY, ON PLATE I) AND ONE CROSS SECTION

The outcrops of sands are mapped as sandstones

By D. F. Hewett

Scale 6 1/2,500

1 0 1 2 3 MILES

yielded gas. As the syncline between Little Grass Creek dome and the Grass Creek anticline disappears a short distance north of Gooseberry Creek, it probably does not prevent the migration of oil or gas from the deeper part of the Big Horn Basin to the crest of the dome. The area from which these materials would tend to migrate to the crest is much smaller than that tributary to the Grass Creek anticline or the East Buffalo anticline, and is probably too small to permit important accumulations to be made.

EAST AND WEST BUFFALO ANTICLINES.

By D. F. Hewett.

GENERAL FEATURES.

The crests of the East and West Buffalo anticlines (No. 37, Pl. I) are indicated by a few outcrops of the Cody shale in the large elliptical depression known as the Little Buffalo Basin, 34 miles southeast of Cody and 6 miles southeast of Meeteetse. Only two roads enter the basin: one from the west connects with a road along Iron Creek and Greybull River from Meeteetse, 10 miles distant; the other, entering through a notch in the east rim, joins the Meeteetse-Thermopolis road 10 miles southeast of Meeteetse. Freight may be brought into the basin most readily by the western route.

The basin is drained by Little Buffalo Creek, an intermittent stream that rises in some seeps outside the western rim and flows east and southeast to its junction with Gooseberry Creek. During the summer the stream bed contains a few pools of highly alkaline water in sec. 3, T. 47 N., R. 100 W., and sec. 5, T. 47 N., R. 99 W. The nearest water of fair quality is that of Gooseberry Creek on the south, but Greybull River, 5 miles to the northwest, offers a more dependable supply.

The Little Buffalo Basin is one of the most conspicuous of the surface basins west of Big Horn River. The rim of Mesaverde sandstone forms a rugged escarpment 200 to 600 feet high, and, except for two narrow notches cut by Little Buffalo Creek, completely encircles the flat basin. No roads and only a few trails cross the escarpment. The floor of the Little Buffalo Basin is made up largely of flat-topped low ridges which are remnants of a plain that once covered the entire basin.

STRUCTURE.

Two anticlines are indicated by the exposures of the Cody shale within the basin. Their positions and forms, as shown by structure contours on the second coal bed of the Mesaverde formation (Pl. XXV), are determined partly by observations of the writer and

by the logs of wells that have been drilled since the field work was completed in 1912, and partly by the recorded observations of Hintze[1] in connection with the field work in 1914. The only beds by which the structure of the central part of the basin may be determined are some sporadic outcrops of thin sandstone that are exposed in several dry ravines. In contrast with many other basins west of Big Horn River, where two or more anticlines or domes occur near one another, curves or offsets that correspond to the form of the anticlines are lacking in the bounding rim of Mesaverde sandstones, on the northeast side of the basin. There is a well-marked offset in the southwest rim, however.

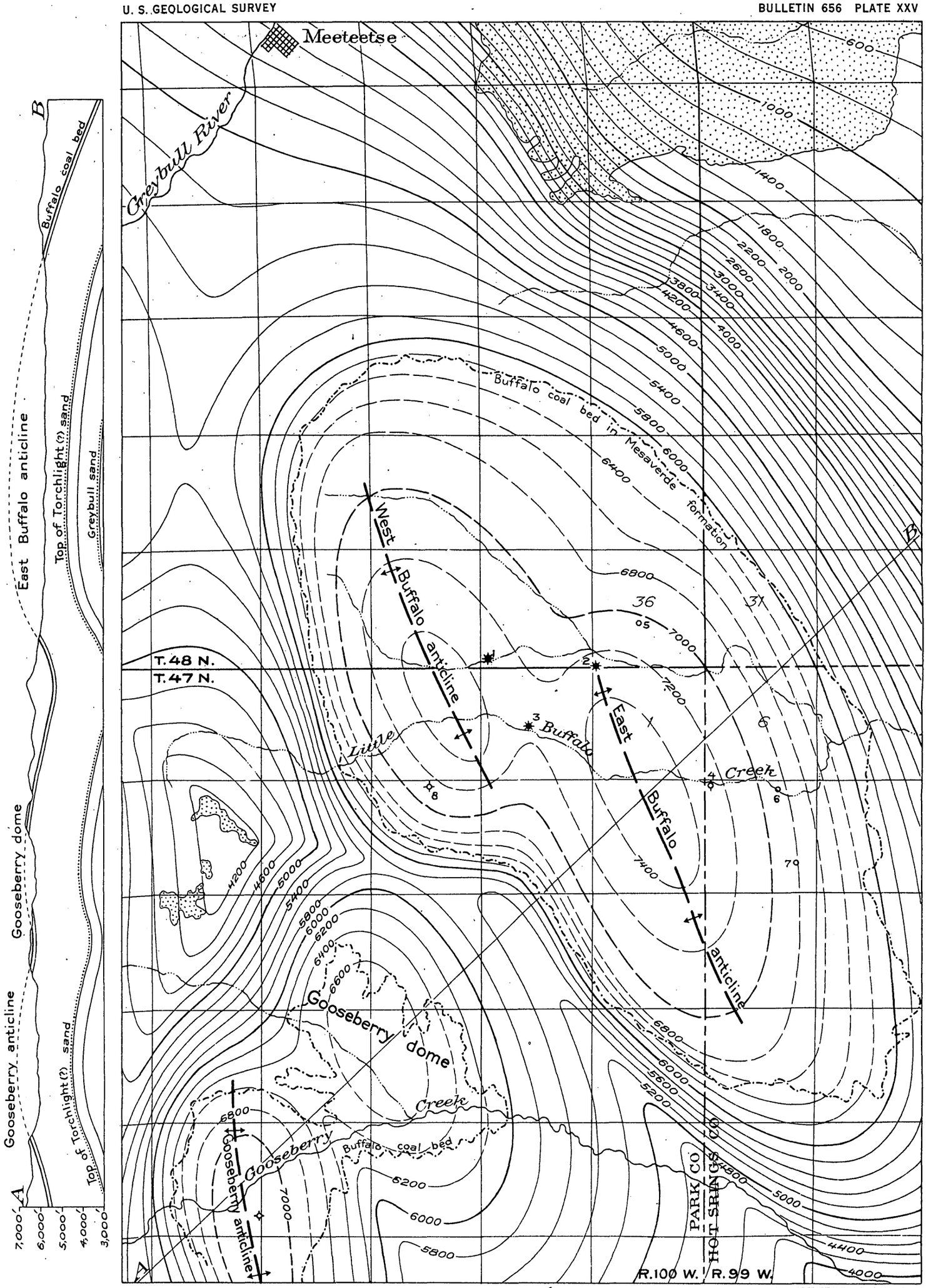
The East and West Buffalo anticlines are among those that lie nearest the deeper central part of the Big Horn Basin. The beds rise gradually from the center of the Big Horn Basin to the outcrop of the Fort Union formation, northeast of Little Buffalo Basin, where the dip changes abruptly from 10° to 35°. From this point southwest the dips along the outcrops of the successively lower formations decrease gradually from 35° to the crest line of the East Buffalo anticline. Southwest of the crest line the dip of the beds increases abruptly to 28° as they descend to the deep syncline that crosses Gooseberry Creek. A shallow syncline separates the East Buffalo anticline from the West Buffalo anticline but does not extend beyond the rim of the basin on the northeast or southwest. The form of the West Buffalo anticline is poorly shown by outcrops of the Cody shale, but the Mesaverde sandstones attain a maximum dip of 36° near the gap through which Little Buffalo Creek flows in sec. 4, T. 47 N., R. 100 W. West of the rim of the basin the dips decrease gradually toward a syncline that extends northwest from Iron Creek.

No faults have been recognized in the outcropping beds in the Little Buffalo Basin, but on account of the steep dips on the southwest limbs of the anticlines small faults may occur in the Frontier sandstones, which are 1,200 feet or more below the surface on the crests of the anticlines.

The thickness of the Cody shale in the Little Buffalo Basin is 2,600 feet, and of the part of the Mesaverde formation below the second coal bed 140 feet, so that the elevation above sea level of the upper Frontier sandstone may be found approximately at any point by deducting the sum of these two figures (2,740 feet) from the elevation of the coal beds as indicated by the structure contours.

The character of the lower part of the Cody shale and the upper part of the Frontier formation are shown in the following log of well No. 3:

[1] Hintze, F. F., jr., The Little Buffalo oil and gas field, Wyo.: Wyoming Geol. Survey Bull. 11, 1915.



Scale 1/62,500

1 0 1 2 3 Miles

o Drilling

✱ Gas well

◊ Hole; no data

⟡ Dry hole

5000 Structure contours (lines of equal altitude) on top of Buffalo coal bed. Number shows elevation above sea level. Solid lines indicate position of coal bed where present, and broken lines former position of coal bed. Contour interval, 200 feet

Wasatch formation

STRUCTURE CONTOUR MAP OF EAST AND WEST BUFFALO ANTICLINES IN LITTLE BUFFALO BASIN, AND GOOSEBERRY DOME AND ANTICLINE (Nos. 37 AND 38, RESPECTIVELY, ON PLATE I) AND CROSS SECTION

By D. F. Hewett

Log of well No. 3 of Ohio Oil Co., West Buffalo anticline NE. ¼ SW. ¼ sec. 2, T. 47 N., R. 100 W.

	Thickness.	Distance.
	Feet.	*Feet.*
Sand and soil	20	20
Soil and gravel	20	40
Cody shale:		
Shale, black and brown	440	480
Sand, greenish	25	505
Shale, brown, sandy, with shells	715	1,220
Sand, black	15	1,235
Shale, black and brown	230	1,465
Frontier formation:		
Sand, hole filled with water	10	1,475
Sand, no water	20	1,495
Sand, water	15	1,510
Sand, no water	30	1,540
Shale, dark	148	1,688
Sand	14	1,702
Shale	28	1,730
Sand, gas	32	1,762
Shale and sand	5	1,767
Sand, much gas	25	1,792

DEVELOPMENT.

In July, 1915, four wells on the anticlines had been completed to depths ranging from 1,680 to 1,792 feet. All were started and completed during the summer of 1914. In October, 1916, another well (No. 8) had been completed and three more were being drilled. The logs of two wells are available—No. 3 through the courtesy of Mr. M. D. Woolery, of the Ohio Oil Co., and No. 2 through Mr. W. L. Walker, representing W. L. Valentine. In addition, Hintze reports the log of the well No. 1 of the Midwest Oil Co. Three of these wells, which are situated (Pl. XXV) on the limbs rather than close to the crest lines of the anticline, struck the top or Torchlight (?) sand of the Frontier formation at 1,370 to 1,465 feet from the surface and penetrated its upper 300 feet. The sand would have been found at a depth of about 1,100 feet if the well had been located in the NE. ¼ NW. ¼ sec. 12, T. 47 N., R. 100 W., on the East Buffalo anticline and at a depth of about 1,270 feet in the SW. ¼ NE. ¼ sec. 3, T. 47 N., R. 100 W., on the West Buffalo anticline.

The sections of the Frontier formation are very similar in the three wells. The Torchlight (?) sand is reported as a single bed 62 feet thick in well No. 1 and as four and six separate beds with similar aggregate thicknesses in the other two wells. Water under pressure is reported from this sandstone in each well, so that in this respect the conditions appear to be similar to those in Grass Creek anticline. Oil was not found in any of the wells, but several beds of sandstone, forming a group 105 feet thick, 145 to 155 feet below the base of the upper sand yields gas, locally under great pressure. The

possible yield of well No. 2 has been estimated, according to Hintze,[1] at 30,000,000 cubic feet per day, but all of the wells are now capped and produce several gallons of gasoline a day. The gas is used in the drillers' camps in the basin. Well No. 8 is reported to have struck water under pressure in the upper sands of the Frontier formation. The lower sands of the Frontier and the deeper formations have not been drilled.

CONCLUSIONS.

On account of discovery of gas under great pressure in wells near the crest of the Little Buffalo anticlines the lower or outer zones of the structures offer favorable sites for exploration for oil. The zone lying between the 6,800 and 7,200 foot structure contours on the north, northeast, and east limbs may be regarded as roughly outlining the area within which oil may be found. Further drilling near the crest of the anticlines should be discouraged until the outer zone has been explored. As few of the wells in the entire Big Horn Basin yield a natural flow of oil for more than a few hours after the productive sands are reached, it is desirable to retain as much gas pressure in the beds as possible.

GOOSEBERRY DOME AND ANTICLINE.

By D. F. Hewett.

The Gooseberry dome and anticline (No. 38, Pl. I) lie southwest of the East Buffalo anticline, in T. 47 N., R. 100 W., Park County, about 12 miles south of Meeteetse and 42 miles northwest of Thermopolis. The crests of both domes coincide with highly irregular surface basins that are surrounded by rugged escarpments of the lower sandstones of the Mesaverde formation. The western or upper basin contains a broad, flat tract about 100 acres in extent, part of which is under cultivation, at Dorr's (originally Renner's) ranch, on Gooseberry Creek. The eastern or lower basin contains no arable land.

Gooseberry Creek carries water on the surface throughout the year in this region, and in spite of its high alkali content is used for drinking at ranches.

On the Gooseberry dome the sandstones of the Mesaverde formation dip 7° to 11° toward a deep syncline on the east and 15° to 32° toward the west. The Gooseberry dome is separated from the Gooseberry anticline by a shallow syncline, which pitches southeast into an area that has not been examined. From this syncline the beds rise at 12° to 16° to the summit of the Gooseberry anticline and then dip 20° to 27° to a deep syncline on the west. The southern end of

[1] Hintze, F. F., jr., Little Buffalo oil and gas field, Wyo.: Wyoming Geol. Survey Bull. 11, p. 88, 1915.

this anticline is covered by sandstone and gravel of the Wasatch formation.

Between September, 1915, and June, 1916, a well was drilled in the SE. ¼ SE. ¼ sec. 29 to a depth of 2,550 feet. A log of this well shows the first sand, Torchlight (?), dry at 1,725 to 1,740 feet, and other sands at 2,002 to 2,032 and 2,070 to 2,110 feet. It is reported that a flow of fresh water was struck at 2,032 feet and that the water rose to the surface. A smaller flow of brackish water, which also rose to the surface, was struck at 2,070 feet. It is also reported that when drilling in the lowest sand the bit became covered with a dark asphaltic material, but none of the common evidences of oil were observed. The casing was placed to 2,272 feet.

It is apparent that if the first sand struck at 1,725 feet be regarded as the top of the Frontier formation, the well penetrated the entire formation but did not reach the "Muddy sand" in the Thermopolis shale. As this well was placed close to the crest line of the anticline and neither oil nor gas in appreciable quantity was struck, there is little prospect that other wells on this structure will find important quantities of these substances.

The Gooseberry dome is a structure similar in extent to the Gooseberry anticline but less pronounced. The dome is separated from the anticline by a low syncline, and though there is a possibility that it may contain oil or gas, if these substances were present in considerable amounts it would appear that more than traces would have been struck in the well on the anticline. The dome is therefore not regarded as a very favorable area for exploration.

In the event that a well may be drilled on the dome, it may be stated that from the depth at which the Torchlight (?) sand was struck on the anticline it has been calculated that the Cody shale is 2,500 to 2,525 feet thick, and that on the crest of this dome this sand would be struck at 2,080 feet. A well that was much shallower than this could not be expected to reach the Torchlight sand.

SUNSHINE AND SOUTH SUNSHINE ANTICLINES.

By D. F. Hewett.

GENERAL FEATURES.

The Sunshine anticline (No. 40, Pl. I) is a narrow fold that crosses Wood River, a tributary of Greybull River, a mile northeast of Sunshine post office, in sec. 21, T. 47 N., R. 101 W. Sunshine is 15 miles southwest of Meeteetse, which, next to Cody, is the largest settlement on the west side of the Big Horn Basin. Meeteetse is 38 miles south of Cody and 59 miles southwest of Basin, both of which are on the Chicago, Burlington & Quincy Railroad. A stage makes the trip

between Sunshine and Meeteetse three times a week. Except for the disadvantage of great distance from the railroad, the Sunshine anticline possesses several natural advantages that facilitate exploration. Wood River carries an abundant supply of good water throughout the year, and the ranches along this stream and Greybull River furnish a supply of wild hay, alfalfa, oats, and produce. Lumber is available from sawmills on the tributaries of Wood River 10 miles above Sunshine.

In the vicinity of Sunshine Wood River flows in an alluvial valley 2,000 to 3,000 feet wide, most of which is cultivated by the aid of water drawn from the river by ditches. The valley is bounded on both sides by abrupt slopes of extensive residual areas of flat gravel-covered terraces that rise 200 feet above the river. Several small but prominent flat-topped ridges, also covered with gravel, rise about 300 feet above the lower terraces. These terraces lie between roughly parallel prominent escarpments of Mesaverde sandstones (Pl. XXXI, *B*, p. 183), which may be regarded as limiting a higher and broader valley than the alluvial valley in which Wood River flows.

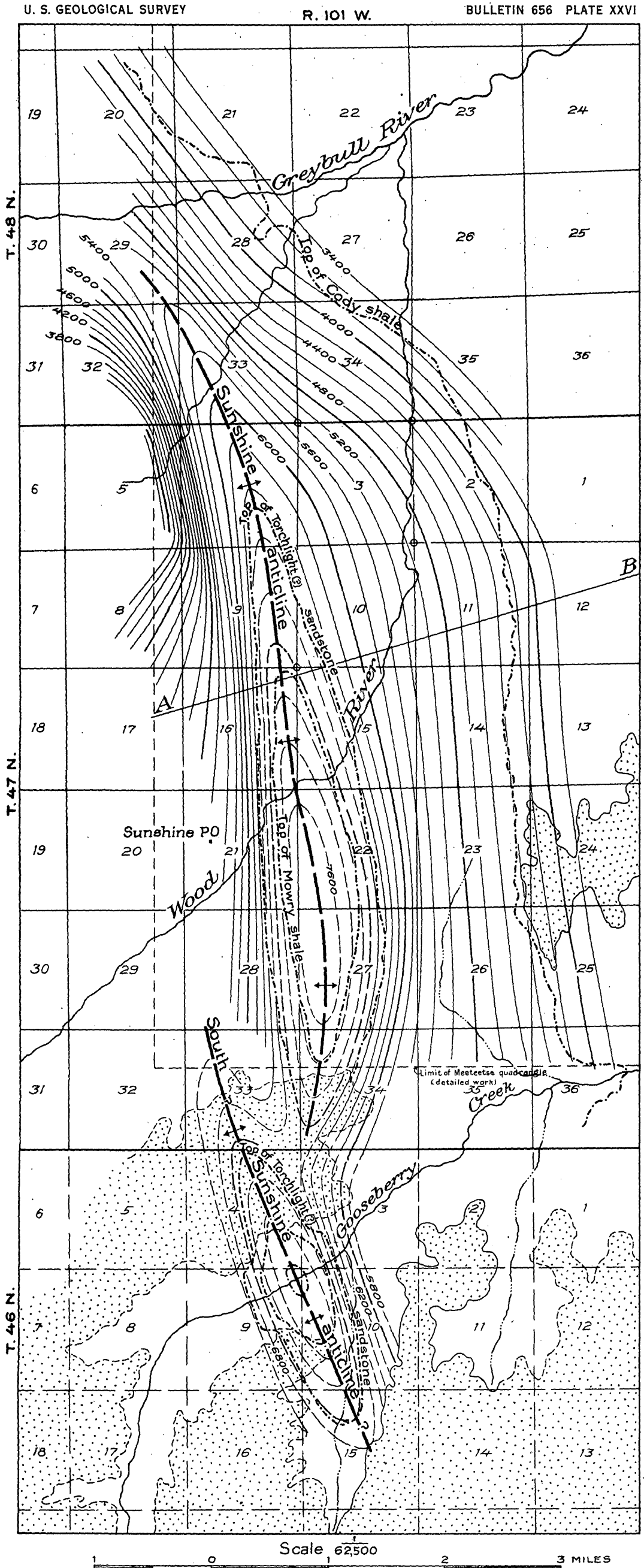
STRUCTURE.

Although the Mowry shale and upper part of the Thermopolis shale are exposed where Wood River crosses the anticline, outcrops are largely covered by alluvium of the river valley. The form of the anticline is shown by outcrops of Frontier sandstones which dip from 22° to 38° E. along the east limb and 30° to 46° W. along the west limb. The Frontier formation, which is well exposed, is 496 feet thick on the west side of the anticline and contains four beds of sandstone, and is 540 feet thick on the east side of the anticline and contains six beds of sandstone, two of which correspond to one thick bed on the west side.

The Cody shale is poorly exposed along the limbs of the anticline, but the sandstones of the Mesaverde formation, which outcrop along the escarpments, dip from 9° to 20° E. on the east limb and 30° to 55° W. on the west limb.

The structure contours (Pl. XXVI) are drawn on the top of the Torchlight (?) sand and show a simple but narrow unfaulted anticline. The unsymmetrical nature of the fold is shown by the steeper dip of the western limb and must here, as in similar anticlines, be taken into consideration in drilling. In those anticlines where the successively lower beds have similar forms the crest line or highest part of one bed does not lie vertically above that of a lower bed. (See p. 36 and fig. 2, p. 35.) The crest line of the Torchlight (?) sand in the Sunshine anticline is 400 feet west of the crest of the sandstone near the base of the Thermopolis shale.

No faults were observed along the beds that outline the anticline.



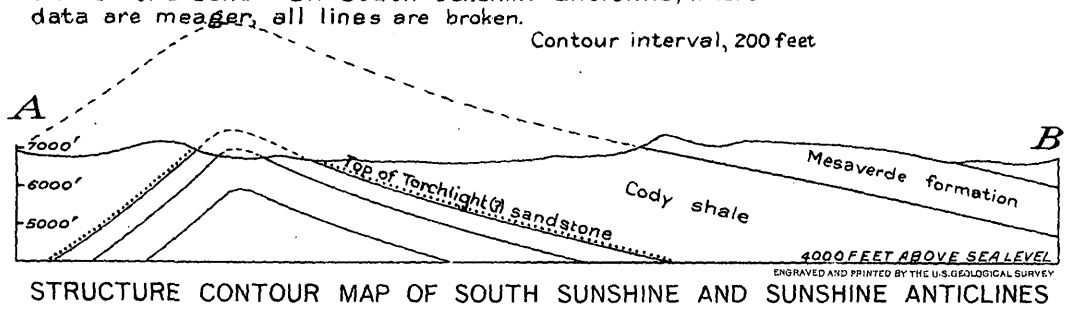
Scale 1/62,500

1 0 1 2 3 MILES

Structure contours (lines of equal altitude) on top of Torchlight(?) sand. Numbers show altitude above sea level. Solid lines indicate position of sand where present, and broken lines former position of the sand. On South Sunshine anticline, where data are meager, all lines are broken.

Wasatch formation and volcanic tuffs

Contour interval, 200 feet



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STRUCTURE CONTOUR MAP OF SOUTH SUNSHINE AND SUNSHINE ANTICLINES (Nos. 39 AND 40 ON PLATE I) AND CROSS SECTION

The outcrops of sands are mapped as sandstones

By D. F. Hewett

The Sunshine anticline extends northwest of Greybull River into an area that has not been examined in detail, but it is known not to be continuous with the Pitchfork anticline in T. 48 N., R. 102 W. (See p. 171.) Its southward extension is also a matter of some doubt, as detailed work was not carried southward as far as Gooseberry Creek, and the divide between Gooseberry Creek and Wood River is so completely covered with gravel as to conceal all trace of the fold.

CONCLUSIONS.

As all the Frontier sandstones outcrop along Wood River the only sandstones which could carry oil and gas and which remain buried on the Sunshine anticline are those of the Thermopolis, Cloverly, and Morrison formations. As gas was found in a bed of sandstone in the Morrison on Shoshone River [1] the presence of gas in this formation must be regarded as a possibility. No wells have yet been drilled, and although there is a fair prospect of finding gas in the buried sandstones the chance that commercially important quantities of oil will be found is not great. This conclusion is largely based on the areal relations of the anticline, as it lies between the southern part of the Fourbear anticline, 8 miles to the west, and the western anticline of the West Buffalo anticline, 8 miles to the east, which belongs to the basinward group of anticlines.

On Plate XXVI the smaller or South Sunshine anticline (No. 59, Pl. I) is shown in the N. ½ T. 46 N., R. 101 W., and the highest area is indicated at the point where the crest line crosses Gooseberry Creek. The position and form of this anticline were roughly determined during a rapid reconnaissance in the region by C. T. Lupton, in July, 1915. The anticline is most easily accessible from Sunshine by the road to Gooseberry Creek, but it may also be reached by the road up Gooseberry Creek from Dorr's ranch. In the region southeast of Wood River the streams have cut deep, precipitous valleys among high, rolling hills, and the only routes of travel lie along stream courses.

The outcrops that would show the relation of this anticline to the Sunshine anticline are concealed by Wasatch rocks, but as there are few places in the Big Horn Basin where the crests of two near-by anticlines lie in the same line it is inferred that this relation does not exist here. Beds of the upper part of the Morrison formation are exposed where Gooseberry Creek crosses the crest line of the South Sunshine anticline, and the Cloverly, Thermopolis, Mowry, and Frontier formations are exposed along Gooseberry Creek and along the steep walls of the valley in which this stream flows. The Frontier sandstones on the east limb dip about 40° E. and on the

[1] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 111, 1914.

west limb about 30° W. Thus the east limb of the anticline has a steeper dip than the west, which is the reverse of conditions on the Sunshine anticline.

The only beds that are buried on the crest of the anticline and are known to yield oil or gas elsewhere in the Big Horn Basin are the sands in the middle of the Morrison formation and the Embar and Madison limestones. As this anticline is among the mountainward group of folds the prospect for the discovery of either oil or gas in these beds in quantities that are commercially important is not considered good.

FOURBEAR ANTICLINE.

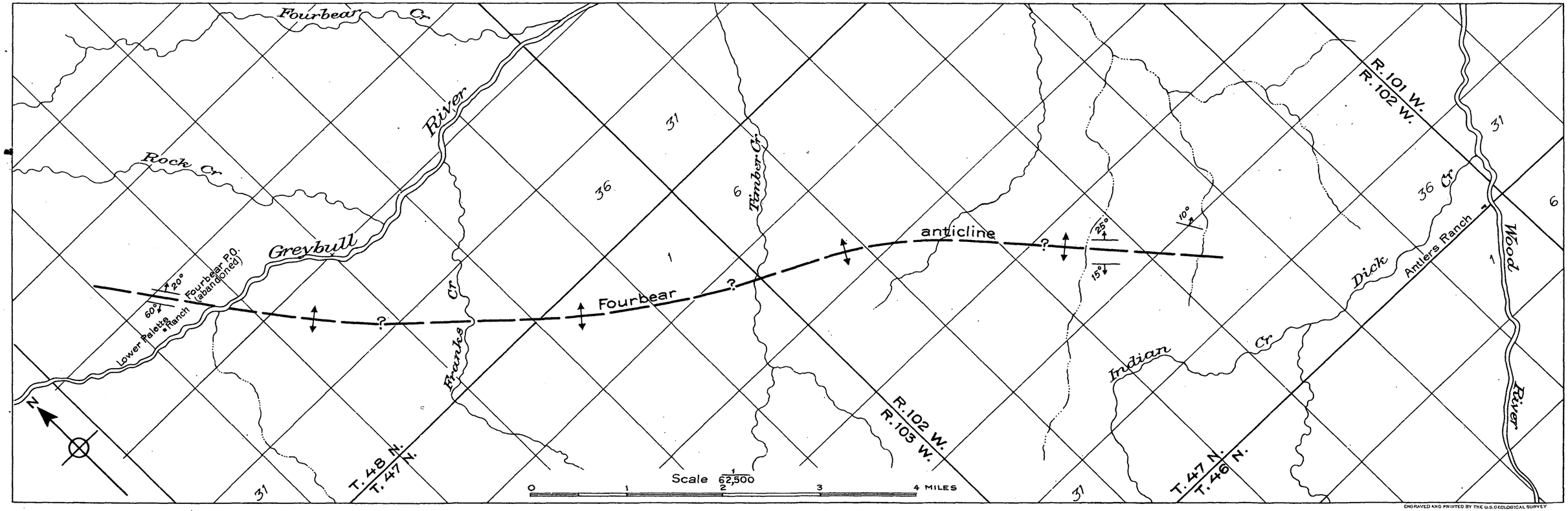
By CHARLES T. LUPTON.

GENERAL FEATURES.

The Fourbear anticline (No. 41, Pl. I) is so named from Fourbear (Lower Palette ranch), an abandoned post office near the crossing of the north end of the anticline by Greybull River. It is on the west side of the Big Horn Basin and lies mainly between Greybull River and its southern tributary, Wood River. No drilling for oil or gas has been done on this anticline, so that it is not known whether or not it contains these substances. The writer, however, judging from the shape of the fold and its position with relation to the probable edge of the basin, recommends part of it as being favorable for the accumulation of oil and gas. The anticline was not examined in detail but was visited on a reconnaissance trip by M. W. Ball and the writer in July, 1915. Fisher's[1] map shows this anticline and the formations that outcrop along and near it in a general way. Instead of being a series of domes, as might be interpreted from Fisher's map, it is a continuous anticline. (See Pl. XXVII.)

The anticline is most easily reached from Cody, the western terminus of a branch of the Chicago, Burlington & Quincy Railroad, by stage over a good road which leads about 38 miles southeast to Meeteetse. From Meeteetse a fairly good road leads up the valley of Greybull River about 20 miles and a second-class road leads about 5 miles farther, to the old Fourbear post office, where the anticline crosses the river and extends southeastward. Other second-class roads cross the anticline along Franks Fork and Timber Creek. The south end of the anticline may be reached from Meeteetse over a fairly good road which follows Wood River to the mouth of Dick Creek and then over a wagon trail up Dick Creek to a point near its junction with Indian Creek. Parts of the anticline between the roads mentioned can be examined most easily on foot or horseback.

[1] Fisher, C. A., Geology and water resources of the Big Horn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, pl. 3, 1906.



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

COMPILED MAP OF FOURBEAR ANTICLINE (No. 41 ON PLATE I)

By Charles T. Lupton

The surface of the area (Pl. XXVII) is crossed by the major valleys of Greybull and Wood rivers at the north and south ends of the anticline, respectively, and the minor valleys of Franks Fork, Timber, and Dick creeks. These valleys have cut steep-sided channels 200 to 400 feet deep in the rocks across the crest of the anticline. In many places between streams hard rocks form the top of the upfold, and the anticline is marked at the surface by a ridge.

The water near this anticline is plentiful and of good quality, as practically all of the streams carry water direct from the mountain springs the year round. As the rainfall is much larger than it is in the interior of the basin it seems probable that the principal sandstone beds that may be penetrated by the drill also contain abundant water.

STRUCTURE.

The Fourbear anticline is a northwestward-trending upfold at least 12 miles long. Its northwest and southeast ends are covered unconformably by Tertiary beds and rocks of volcanic origin, so that it is impossible to determine with certainty if the anticline plunges at each end or not. The anticline is apparently symmetrical in cross section but data on this point are lacking in places. Owing to the great mass of younger rocks that cover the older rocks to the west and southwest it is impossible to determine exactly the limits of the structural basin in that direction. It is entirely probable, however, from the position of the Owl Creek Mountains uplift to the south and from the presence of isolated patches of rocks of the same age as those exposed along the crest of the Fourbear anticline in and south of Yellowstone National Park that the structural basin from which this anticline may derive oil and gas may be of considerable extent, particularly to the southwest and west. From the presence of anticlines not far to the east and northeast it is apparent that little oil and gas can have reached the Fourbear anticline from the depths of the Big Horn Basin, for the anticlines have undoubtedly entrapped any that was migrating from that direction. If, therefore, Fourbear anticline is proved to be an oil or gas reservoir, these substances, in the writer's opinion, must have come for the most part from the west and southwest, where the oil-bearing rocks are covered by volcanic material.

In the reconnaissance trip along the crest of this anticline only a few dips were noted. Two at the northwest end near Greybull River show that near the crest the beds on the west dip as much as 60° and those on the east only 20°. Near the southeast end of the anticline, where the northeast limb is the steeper, a dip of 25° was noted on the northeast and 15° on the southwest side.

The lowest rocks exposed along the crest are believed to belong to the upper part of the Mowry shale, a formation about 300 feet thick,

which is characterized by large numbers of fish scales, and in which oil and gas are found in the Torchlight dome on the east side of the Big Horn Basin. Directly overlying the Mowry is the Frontier formation, 500 feet or more in thickness, which is characterized by predominantly sandy beds interbedded with sandy shale and shale and in places a little bentonite. Overlying the Frontier is the Cody shale, which in this locality is fully exposed only on the northeast limb of the anticline. The top of the anticline has been eroded, and its edges have been obscured by beds of the Wasatch formation that rest unconformably upon the Cretaceous formations beneath. The Wasatch in turn is overlain by a great thickness of tuffs and flows of igneous rocks, which constitute the surface rocks over a broad area in the southwestern part of the Big Horn Basin.

Beneath the surface along the anticline are the lower part of the Mowry shale; the Thermopolis shale, about 600 feet thick, containing about 200 feet above its base a bed of sandstone (Muddy sand) 15 to 20 feet thick, which yields gas in large amounts in the Oregon Basin; the Cloverly formation, ranging from 100 to 125 feet in thickness, with the Greybull sand at its top; and other formations.

No structure contours are drawn on the anticline, as the data on which to base them are too meager.

CONCLUSIONS.

In the writer's opinion the most important reservoir for oil and gas in this anticline is the Greybull sand, the top sandstone of the Cloverly formation, which contains practically all of the gas and oil derived from the Greybull field. The Muddy sand in the Thermopolis shale is believed to be the reservoir of the gas in the Oregon Basin and in other places in the western part of the Big Horn Basin, and it may be of value here. The highest part of the anticline was not determined, but it is probable that it is near the middle of the upfold (see Pl. XXVII) between Franks Fork and Timber Creek. The writer advises that the initial drilling be done near the crest line of the anticline on either of these streams, for here water for drilling and camp use and wood for fuel are both abundant.

It should be kept in mind that from present knowledge of the extent of Big Horn Basin, the Fourbear anticline seems to be a mountainward structure, but there is the possibility that it is a basinward structure of a small structural basin now buried by tufaceous beds, and if so it may be a fairly good oil reservoir. Where the crest of the anticline crosses the creeks the Greybull sand, in which oil and gas may possibly occur, should probably be entered at a depth of not more than 900 feet.

PITCHFORK ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Pitchfork anticline (No. 42, Pl. I) is in the northeastern part of T. 48 N., R. 102 W., near Greybull River and Rawhide Creek, in the western part of the Big Horn Basin. Although it has not been tested for oil and gas its shape and position with relation to the edge of the basin suggest that it may contain these substances.

The data contained in this brief report are based on observations made by M. W. Ball and the writer during a reconnaissance trip in 1915, supplemented by data collected by a party in charge of E. G. Woodruff in 1907.

This anticline, although it lies about 55 miles from the nearest railroad point at Cody, the western terminus of a branch of the Chicago, Burlington & Quincy Railroad, is accessible with comparative ease, as good roads lead to the Pitchfork ranch, from which a second-class road extends along its west flank. Detailed examination, however, must be made mostly on foot or horseback.

The surface of the anticline is characterized by a prominent ridge, the top of which approximately coincides with the crest line. (See fig. 11.) A low pass in the NE. ¼ sec. 14 of this township divides the ridge into two parts—a narrow part at the north end and a broader part at the south end. In many places badlands are developed. The surface altitudes range from about 6,300 feet on Greybull River, at the south end of the anticline near the center of sec. 25, to about 7,000 feet at the highest part of the ridge in the SW. ¼ sec. 11.

The water supply is derived entirely from Rawhide Creek and Greybull River at the north and south ends of the anticline, respectively. An irrigation ditch, which heads in Greybull River, crosses the south end of the anticline about a mile north of the river and would lessen the expense of obtaining water for camp and domestic use in and near the middle of the anticline. The intermittent streams which drain the greater part of the area and empty into Rawhide Creek and Greybull River carry water early in spring, in summer, and after heavy rainstorms. Water will undoubtedly be found by drilling in the sandstones of the Frontier formation, which outcrop along the anticline, for the formation carries much water in the Spring Creek anticline, a few miles north of Rawhide Creek. (See log, p. 176.)

STRUCTURE.

The Pitchfork anticline was not examined in detail, and information regarding it is meager. The writer noted the steeply dipping beds on the west limb, and Woodruff measured one dip on the east

limb and several dips on the west limb adjacent to the outcrop of the coal bed. The anticline seems to be symmetrical, both limbs having about the same dip, and it apparently pitches at both ends, thus making the sandstones beneath the surface fairly good reservoirs for the accumulation of oil and gas. The maximum dip noted

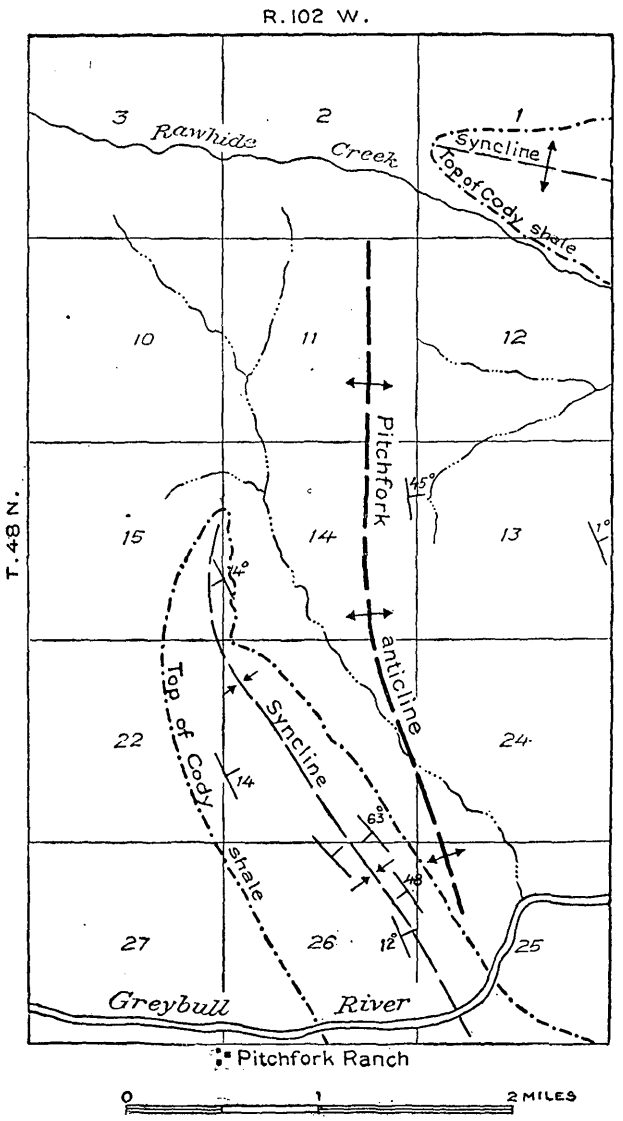


FIGURE 11.—Compiled map of Pitchfork anticline (No. 42, Pl. I).

on the east limb is 45° in the NE. ¼ sec. 14, and on the west limb 63° in the SE. ¼ sec. 23, near the south end of the anticline about one-fourth mile west of the crest line. Westward from this point the beds gradually flatten into the syncline that roughly parallels the anticline.

The lowest rocks exposed at the surface on this anticline are believed to belong to the Mowry shale, a dark-gray to blue, hard, platy shale generally carrying fish scales in abundance. In places it contains one or more sands that in other fields are of economic importance as oil and gas reservoirs. Practically all the oil in the Torchlight dome near Basin, Wyo., is derived from sands in the Mowry shale. Overlying the Mowry is the Frontier formation, consisting mainly of sandstones with intercalated beds of shale and sandy shale. This formation, according to the log of the well on the Spring Creek anticline (p. 176), is about 300 feet thick—less than it is at the south and east edges of the Big Horn Basin.

Beneath the surface on the crest of the anticline are the lower part of the Mowry shale, the Thermopolis shale, a dark-gray to blue shale 400 to 500 feet thick, containing near its middle in places in the Big Horn Basin a sandy phase known to oil drillers as the Muddy sand. This sand, which is 15 to 20 feet thick, is fairly persistent and is believed to contain gas in commercial quantities in the Oregon Basin. Directly underlying the Thermopolis shale is the Cloverly formation, the top sandstone of which, the Greybull sand, carries all the oil and gas so far discovered in the Greybull field and may contain oil or gas in the Pitchfork anticline.

Faults were observed along the west limb of the anticline, but the displacements are not great, the maximum being probably not more than 100 feet. It is not believed that they will seriously affect the accumulation of oil in the Greybull sand, as faults are numerous in the Greybull field, where they seem to have no detrimental effect on the retention of the oil.

No structure contours are drawn, as the data obtained are not sufficient for this purpose. The position of the crest line of the anticline and the troughs of the adjacent synclines, however, give some idea of the extent and shape of the fold.

CONCLUSIONS.

No drilling has been done to determine whether or not the Pitchfork anticline contains oil and gas in commercial quantities. A well on the Spring Creek anticline, in the SW. ¼ sec. 4, T. 48 N., R. 101 W., failed to find oil in the Frontier, Mowry, and Greybull sands, but this fact should not necessarily condemn the anticline, for its shape suggests that it may contain oil and gas in the sandstones below the surface, the most important of which are believed to be the Muddy and Greybull sands. A water well is reported to have been drilled to a depth of more than 1,500 feet at the Pitchfork ranch (fig. 11) without finding oil and gas; but this is not surprising, for the well is too far from the crest line of the anticline. The writer advises that the initial drilling be done near the crest line of the Pitchfork anticline, in the NE. ¼ sec. 14 or the SE. ¼ sec. 11, T. 48 N., R. 102 W.

SPRING CREEK ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Spring Creek anticline (No. 43, Pl. I) lies on the west side of the Big Horn Basin in T. 49 N., Rs. 101 and 102 W., and in the northern part of T. 48 N., Rs. 100 and 101 W. One well, drilled near the crest line not far from the southeast end of the anticline found no oil or gas, but did find water in abundance in the principal sands. From evidence obtained on a reconnaissance trip in July, 1915, it seems probable that the anticline pitches southeast throughout the greater part of its length. If such is the case it has doubtful value as a reservoir for oil and gas, as these materials may have escaped to the surface at the outcrop of the beds along the east flank of the Carter Mountains, which lie a short distance northwest.

That part of the anticline which lies east of a north-south line through the well in the SW. ¼ sec. 4, T. 48 N., R. 101 W., has been mapped in detail by D. F. Hewett, but the part lying west of this line has been examined only in a hasty manner. The location of the outcrop of the top of the Frontier formation at the northwest end of the anticline is based on observations made by M. W. Ball and the writer during a reconnaissance trip in July, 1915. The original field plats, made by a party in charge of E. G. Woodruff in 1907, also were used in locating the crest line near the northwest end of the anticline.

The anticline is most easily accessible from Cody, the western terminus of a branch of the Chicago, Burlington & Quincy Railroad. From this place a good stage road leads in a southerly direction to Meeteetse, about 38 miles distant. From Meeteetse a fairly good wagon road follows the valley of Spring Creek, which empties into Greybull River a short distance to the north. The northwestern part is accessible not only from Spring Creek but also from a southern tributary of Meeteetse Creek, which crosses the northwest end of the anticline and empties into Greybull River a few miles north of the town. The greater part of the surface of the anticline is comparatively smooth and can be traversed by wagons and automobiles almost everywhere except along the streams and at the extreme northwest end of the upfold, where the Frontier formation outcrops. (See Pl. XXIII, *B*, p. 152.) Here the country is too rough for vehicles and must be visited on foot or horseback.

The surface of the anticline is characterized by a comparatively smooth basin that has been eroded along the crest of the anticline. This is more noticeable at the southeast than at the northwest end,

where the surface is made up of terraces cut by fairly narrow stream courses and of scattered prominent hills carried by the streams from Tertiary rocks.

A plentiful water supply is derived mainly from Spring and Meeteetse creeks and their spring-fed tributaries. The well drilled in sec. 4, T. 48 N., R. 101 W., found water in several sands, as other wells in this general locality would undoubtedly do.

Fuel for drilling and camp use consists of coal which outcrops along Greybull River near the mouth of Rawhide Creek, where three or four mines supply the general region. Other mines could probably be opened at much nearer places, for the coal bed is in the lower part of the Mesaverde formation, which surrounds the southwest end of the anticline. Some wood suitable for fuel grows on the uplands.

STRUCTURE.

The Spring Creek anticline is a well-defined upfold, the crest of which is marked in secs. 10, 11, 13, 14, and 24, T. 49 N., R. 102 W., by outcrops of Frontier sandstone and Mowry shale. (See Pl. XXVIII.) The anticline is about 18 miles long, with its broad flank lying to the northeast. The southwest flank is comparatively narrow, ranging in width from 2 to 4 miles. The dips of the beds on the northeast limb range from zero at the crest line to 21° in the NE. ¼ sec. 7, T. 49 N., R. 101 W., and then gradually decrease toward the trough of the syncline several miles to the northeast. The southwest limb is much steeper than the northeast, the maximum dip being about 70° a short distance southwest of the crest line, in the SW. ¼ sec. 11, T. 49 N., R. 102 W. From this locality southwestward the dips are believed to decrease gradually to zero. At the southeast end of the anticline the dips are comparatively gentle, ranging from 2° in sec. 30, T. 48 N., R. 100 W., to about 15° about 2 miles farther southeast. No faults are known at any place along the anticline.

The oldest rocks exposed in the anticline, in secs. 10, 11, 13, 14, and 24, T. 49 N., R. 102 W., belong to the upper part of the Mowry shale, a hard, platy dark-gray shale about 400 feet thick, which is characterized wherever it has been recognized by large numbers of fish scales. In the Torchlight dome, on the east side of the Big Horn Basin, this shale contains two or more beds of sandstone that yield the greater part of the oil. Directly overlying the Mowry is the Frontier formation, about 500 feet thick, consisting mainly of sandstone, with minor quantities of shale and bentonite. This formation contains the sands that carry water in the well, whose log is given below, and that also carry the oil and gas in the Grass Creek and

Little Buffalo Basin fields several miles to the southeast. Overlying the Frontier is the Cody shale, a dark-gray shale about 2,500 feet thick, and above this is the Mesaverde formation, about 1,200 feet thick, which carries coal of economic importance in its lower part. The structure contours are drawn on the top of the principal coal bed.

Beneath the surface in the anticline is the lower part of the Mowry shale. Underlying this is the Thermopolis shale, about 600 feet thick, which contains a very persistent sandstone known as the Muddy sand about 200 feet above its base. This sand, although it yields traces of oil and gas in different parts of the Big Horn Basin, is not known to carry them in commercial quantities except in Oregon Basin, where it is believed to yield a strong flow of gas. Directly underlying the Thermopolis is the Cloverly formation, the top sandstone of which—the Greybull sand, about 20 feet thick—yields practically all the oil and gas found in the Greybull field.

In order to show the character of the beds through which the drill passes, the log of the well drilled by the Peerless Oil Co. during the summer of 1915, in sec. 4, T. 48 N., R. 101 W., is given below.

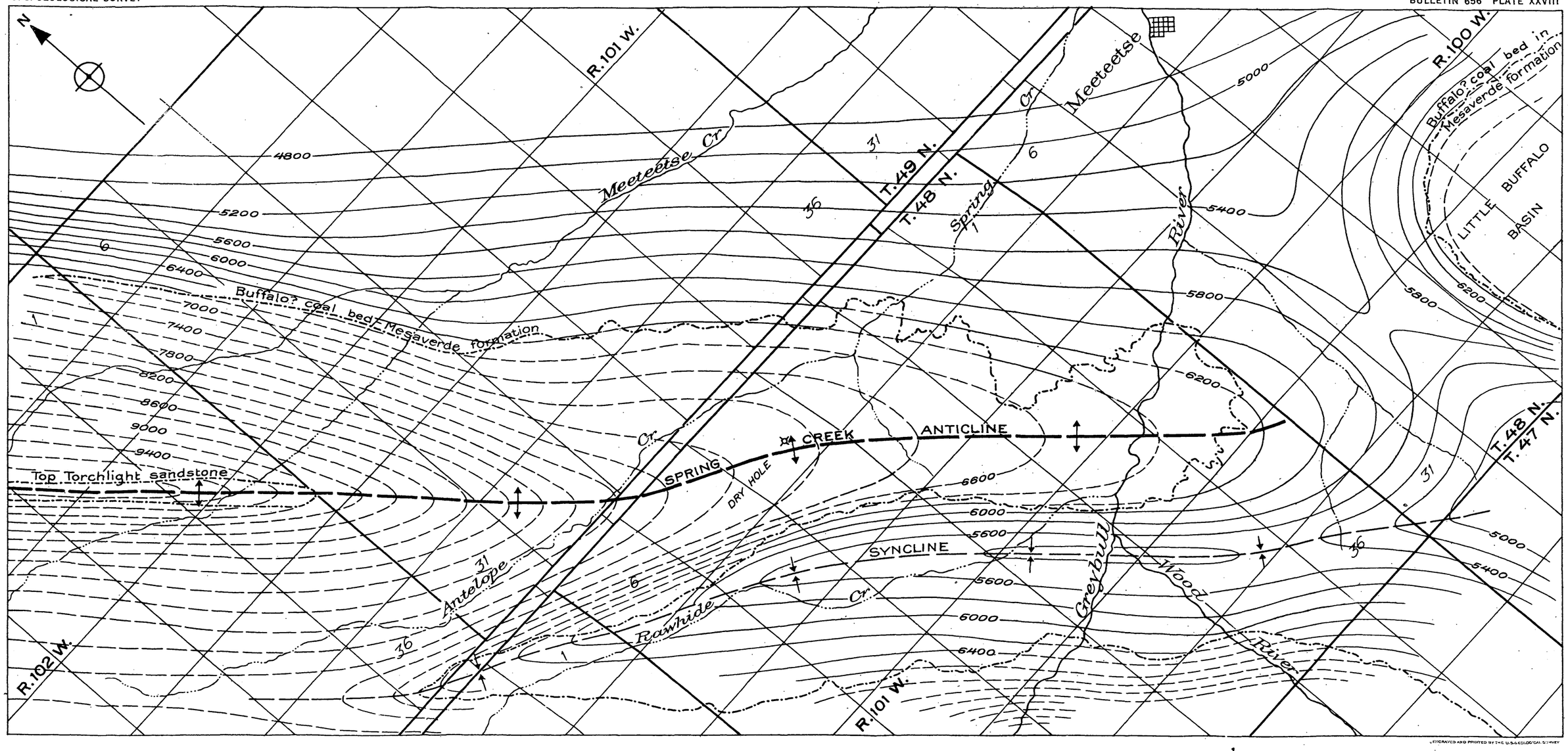
Log of well drilled by the Peerless Oil Co. in sec. 4, T. 48 N., R. 101 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	10	10
Shale, dark	790	800
Greenish sand; trace of gas	10	810
Shale, blue	850	1,660
Sandstone; water	12	1,672
Shale, brown	86	1,758
Sandstone; water	18	1,776
Shale, brown, sandy	114	1,890
Sandstone; water	15	1,905
Shale	15	1,920
Sandstone; water, 11 gallons a minute	35	1,955
Shale	35	1,990
Sandstone, dry	20	2,010
Shale, sandy	20	2,030
Sandstone, dry	45	2,075
Shale	70	2,145
Sandstone; water, 25 gallons a minute	125	2,270
Shale; top shows a little oil	40	2,310

This well is reported to have been drilled about 100 feet deeper, but information regarding the lower rocks was not obtained.

CONCLUSIONS.

From the meager evidence at hand regarding the northwest end it is impossible to state with certainty whether or not the Spring Creek anticline pitches uniformly. The Frontier formation, which outcrops at this end, in the east half of T. 49 N., R. 102 W. (see Pl. XXVIII), is believed to pitch to the southeast, but southeast of the exposure a broad gravel-covered area obscures the outcrops and makes it impossible to determine whether or not a sag separates the



Structure contours (lines of equal altitude) on top of Buffalo? coal bed
Numbers show distance above or below sea level. Solid lines indicate present position of bed below, and broken lines former position above present surface. Contour interval, 200 feet

Scale 1/62,500

0 1 2 3 4 5 Miles

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

STRUCTURE CONTOUR MAP OF SPRING CREEK ANTICLINE (No. 43 ON PLATE I)

The outcrops of sands are mapped as sandstones

By D. F. Hewett and Charles T. Lupton

northwest end of the anticline from the southeast end. If a sag is present, oil and gas would probably be trapped along the crest line of the anticline southeast of the sag. The northwest end of the anticline in the east half of T. 49 N., R. 102 W., may also be a favorable place at which to drill for oil and gas, particularly if the anticline pitches northwest at its northwest end. No information on this point was obtained.

FROST RIDGE DOME.

By CHARLES T. LUPTON.

GENERAL FEATURES.

The Frost Ridge dome (No. 44, Pl. I) is a small upfold in the rocks that lies mainly in the northwestern part of T. 50 N., R. 101 W. It was not examined in detail but was observed by M. W. Ball and the writer on a reconnaissance trip in July, 1915. The outcrop of the Mesaverde formation and the dip symbols are from E. G. Woodruff's field sheets. The location of the dome and Freborg's ranch are believed to be approximately correct.

This dome is most easily reached from Cody, the western terminus of the Chicago, Burlington & Quincy Railroad, 20 miles to the north, over the Cody-Meeteetse stage road to Sage Creek, and thence over a second-class road to the north edge of the dome in sec. 6, T. 50 N., R. 101 W. To examine the dome in detail one must travel mostly on foot or horseback, as the surface is generally hilly and in places cut into badlands.

The main water supply is from Sage Creek, which carries some water throughout the year and which lies within a mile of the west side of the dome. Springs of excellent water are present along the east slope of the Carter Mountains, a mile or more west of Sage Creek. A few seeps of poor water occur east of that stream.

STRUCTURE.

The dome is apparently nearly circular in outline, with comparatively low dips, and is about a mile in diameter. A low syncline is believed to separate it from the monocline on the west, along which the Mesaverde formation outcrops. (See Pl. XXIX, p. 178.)

The lowest rocks outcropping at the top of the dome are believed to belong to the upper part of the Mesaverde formation, which constitutes the "Eagle" and the "Undifferentiated Montana," of Woodruff's [1] classification. Underlying the Mesaverde is the Cody shale,

[1] Woodruff, E. G., Coal fields of the southwest side of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 341, pp. 202-205, 1909.

about 2,500 feet thick, which ranges in color from light to dark gray and consists mostly of shale, except near the top and base, where there are thin beds of sandstone and sandy shale. Directly underlying the Cody shale is the Frontier formation, about 500 feet thick, described by Hewett [1] as the "Middle member of the Colorado." The Frontier formation is the one that yields oil and gas in the Little Buffalo Basin and Grass Creek fields and is the most probable reservoir for these substances under the dome.

CONCLUSIONS.

No drilling is known to have been done on this dome, and it is questionable if oil and gas operators will investigate it until other more easily accessible anticlines and domes, in which the probable oil or gas bearing beds lie nearer the surface, have been tested. Before drilling, it would be advisable to make a detailed examination of the area so as to locate the test well as nearly as possible at the center of the dome.

HALF MOON ANTICLINE.

By CHARLES T. LUPTON.

GENERAL FEATURES.

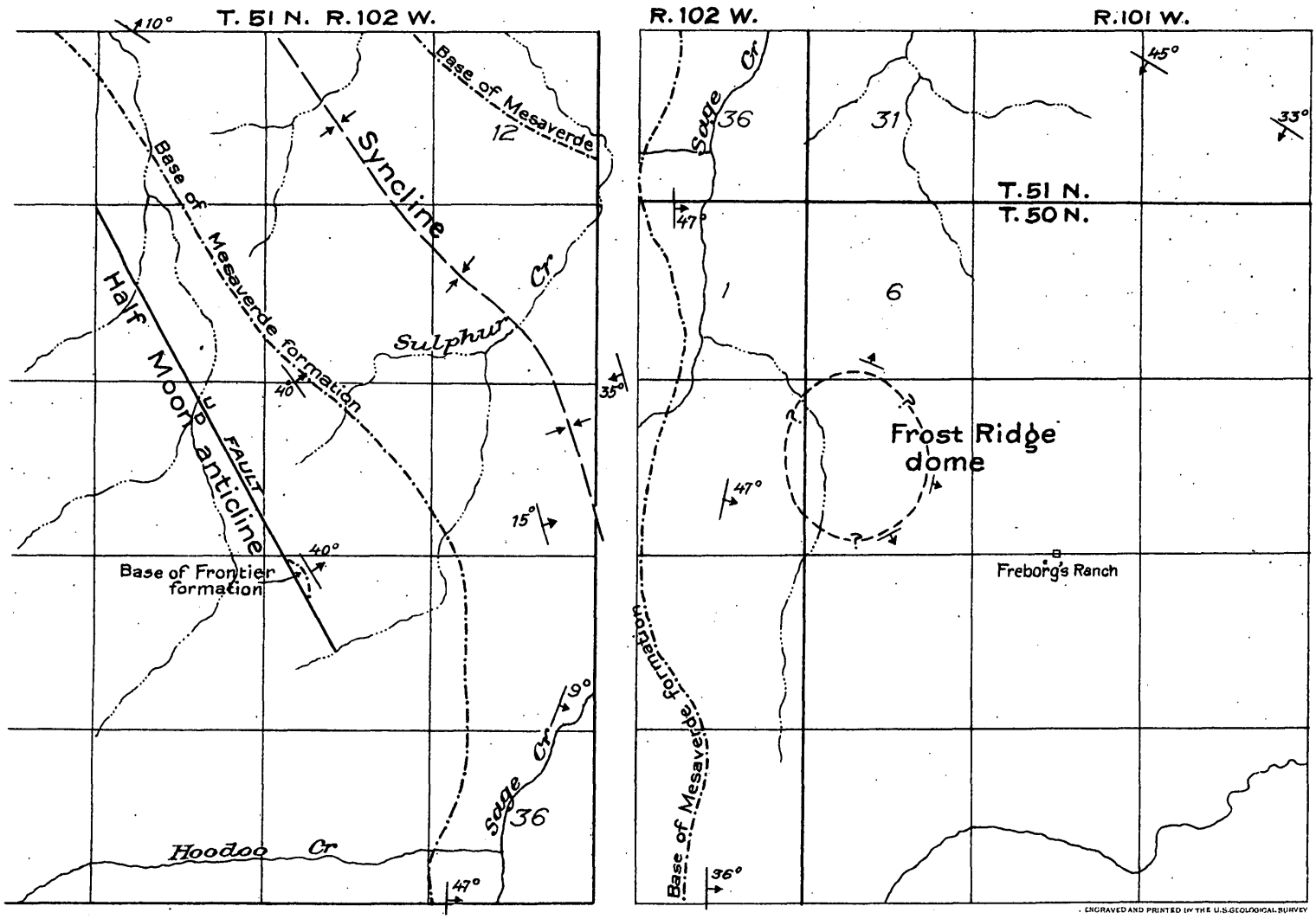
The data in regard to the Half Moon anticline (No. 46, Pl. I) are based on the unpublished notes of a party in charge of E. G. Woodruff in 1907 and on observations by M. W. Ball and the writer during a reconnaissance trip in July, 1915. The information, however, is very meager.

The Half Moon anticline lies on the west side of the Big Horn Basin in the east-central part of T. 51 N., R. 102 W., near the head of Sulphur Creek, which joins Shoshone River a few miles west of Cody.

It is most easily accessible from Cody, the western terminus of a branch line of the Chicago, Burlington & Quincy Railroad, from which a good road follows in general the course of Sage Creek to a place a few miles east of the south end of the anticline. From this locality a good secondary road leads west and northwest along the south and west limbs of the fold. Any detailed examination must, however, be made on foot or horseback, as the surface is in most places too rough for vehicles.

The surface features of the southeastern part of the Half Moon anticline consists of a prominent ridge cut in several places by streams. The northwest half of the upfold is low and is much more

[1] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, pp. 94, 97, 98, 1914.



COMPILED MAPS OF FROST RIDGE DOME AND HALF MOON ANTICLINE (Nos. 46 AND 47, RESPECTIVELY, ON PLATE I)

By Charles T. Lupton

Scale $\frac{1}{62,500}$

0 1 2 3 4 MILES

dissected than the opposite half. The western limb has a smoother surface than the eastern.

Water may be obtained from intermittent streams that drain to Sulphur Creek. Along their valleys there are a few seeps that are of value for drilling but that are too alkaline to be of much use for camp purposes. A few miles to the west, however, along the northeast slope of Carter Mountain, good water may be obtained from several springs and could probably be piped with small expense to the west limb of the anticline. The incomplete Wiley ditch has been constructed across this anticline and, if finished, would supply an abundance of excellent water without hauling or piping.

STRUCTURE.

The Half Moon anticline (Pl. XXIX) in a northwestward-trending upfold faulted near the crest line, with downthrow on the west. It is about 3 miles long and, except for the fault, is apparently symmetrical. Definite information on this point, however, was not obtained, as the surface rocks west of the fault are for the most part covered with loose material. The east limb is about $1\frac{3}{4}$ miles wide and in places the beds dip as much as 40°. These high dips were measured not only at the base of the Frontier formation but also at the base of the Mesaverde formation. Eastward and northeastward from the outcrop of the Mesaverde the dips gradually decrease to zero at the axis of a parallel syncline. The fault, which nearly coincides with the crest line of the anticline, passes into a gentle fold at its southeast end whose extent is unknown, as alluvium and loose material conceal it. No information is at hand regarding the northwest end of the anticline. A dip of 10° near the northwest corner of sec. 10, T. 51 N., R. 102 W., noted by Woodruff's party, suggests a pitch to the northwest.

The lowest rocks exposed near the crest of the anticline belong to the upper part of the Mowry shale, a dark-gray hard, platy shale about 200 feet thick, which, in the Torchlight dome on the east side of the Big Horn Basin, includes two or more beds of sandstone that carry oil and a little gas. A section of rocks measured by Hewett[1] on Shoshone River near Cody shows that the Mowry shale, which is included in the upper 429 feet of the lower member of what he classed as Colorado, contains a few beds of sandstone. Overlying the Mowry is the Frontier formation, 400 to 500 feet thick, consisting mainly of beds of sandstone with minor amounts of shale and bentonite. This formation carries the oil in the Grass Creek field and gas in the Little Buffalo field.

[1] Hewett, D. F., op. cit., p. 97.

The rocks underlying the surface on the crest of the anticline consist of the lower part of the Mowry shale; the Thermopolis shale, about 400 feet thick; the Cloverly formation, about 125 feet thick; the Morrison formation, 200 or 300 feet thick; and lower formations. The Cloverly formation contains at its top a sandstone bed about 20 feet thick which is known as the Greybull sand and which yields all of the oil and gas in the Greybull field. The middle part of the Thermopolis shale contains a persistent bed of sandstone known as the Muddy sand, which is generally present on the east and south edges of the Big Horn Basin and which is believed to yield the gas in the Oregon Basin.

Structure contours are not drawn on this anticline, as the data for determining them are too meager. The dip symbols, the crest line of the anticline, and the trough of the syncline indicate in a general way the extent and shape of the folds. Further examination is necessary to determine whether or not the anticline is of probable importance as an oil or gas reservoir, and the data furnished in this report are intended merely to draw attention to it.

CONCLUSIONS.

It is impossible to predict with certainty whether or not oil and gas will be found in the Half Moon anticline. If the sands have been sealed along the fault, oil and gas may be found in economic amounts in sands of the Frontier formation and of the Mowry shale in the western part of the upfold. East of the fault the Muddy sand and the top sandstone of the Cloverly formation (Greybull sand) are believed to be the only beds of possible value as oil or gas reservoirs, as the Mowry shale and overlying Frontier formation are eroded, thus permitting the escape of any oil or gas that they may have contained.

In September, 1916, the Flathead Valley B. C. Oil Co. started a well in the NW. ¼ SE. ¼ sec. 26, T. 51 N., R. 102 W., which at the end of October had attained a depth of only 250 feet. No oil or gas had been found in that distance.

Any drilling on this anticline should be done with the knowledge that oil or gas in commercial quantities will only be found if the fault is sealed and if the west part of the anticline under cover lies favorably. Attention should be called to the fact that this anticline is apparently a mountainward fold, and it seems doubtful therefore that it contains oil and gas in commercial amounts.

OREGON BASIN NORTH AND SOUTH DOMES.

By D. F. HEWETT.

GENERAL FEATURES.

The Oregon Basin is a roughly elliptical depression about 4 miles wide and 13 miles long, the central part of which is about 12 miles southeast of Cody, in Park County. It is therefore one of the largest basins on the west side of the Big Horn Basin. Outcrops of the uppermost sandstone of the Frontier formation (see Pl. XXXI, *B*) show the presence of two domes, the summit of the southern (No. 45, Pl. I) lying in sec. 32, T. 51 N., R. 100 W., and that of the northern (No. 47, Pl. I), in sec. 5, T. 50 N., R. 100 W. Two wells drilled near the crest line of the south dome struck gas under great pressure, and the dome offers a good prospect for further exploitation. Of three wells near the summit of the north dome two appear to have yielded neither oil nor gas, while the third, located between the other two, has struck gas in several sands. The prospect for the discovery of important quantities of oil and gas is not so good as on the southern dome.

Unlike most of the basins of the region there are several drainage systems in the Oregon Basin, and the surface forms are diverse. The sandstones of the Mesaverde formation form a conspicuous escarpment around the northern and southern parts of the basin but are worn down to a series of low ridges for 9 miles along the east side and are wholly eroded for 5 miles along the west side. On the south the escarpment is broken by several narrow notches, some of which are important stream channels, whereas others represent faults. (See Pl. XXX, *A*.) Two forks of Dry Creek, which rise in the low ridges east of the Carter Mountains, drain the southern part of the basin and discharge eastward through a broad gap. Along the north fork of Dry Creek rise several springs of water of fair quality, the most important of which is in the SE. ¼ sec. 12, T. 50 N., R. 100 W.; but during the summer months the lower courses of both forks contain only a few pools of highly alkaline water. The central part of the Oregon Basin is drained by Oregon Coulee, an intermittent stream which rises in the low hills west of the basin and joins Dry Creek several miles east of the basin. These two drainage systems are separated by a group of ridges that culminate in Elk Butte, an isolated flat-topped hill that rises 700 feet above the average elevation of the basin. The north end of the Oregon Basin contains a flat depression sunk 90 feet below the lowest outlet, in the center of which there is a small alkaline lake that evaporates and deposits alkaline salts during the summer months. A small area is cultivated at the Wiley ranch,

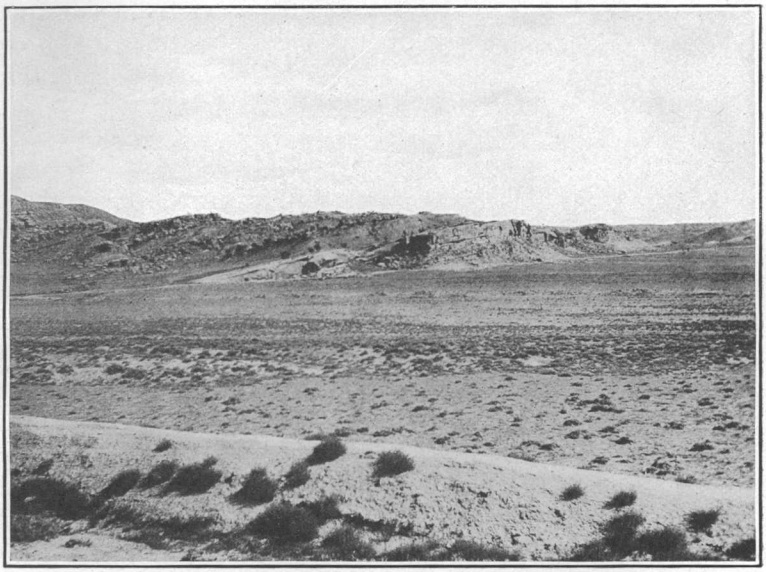
at the western edge of the basin, by the aid of water brought in from South Fork of Shoshone River, 15 miles west.

The stage road from Cody to Meeteetse crosses the western part of the Oregon Basin, and daily stages ply between these two towns. Roads from Greybull River valley also enter the basin from the east and southeast.

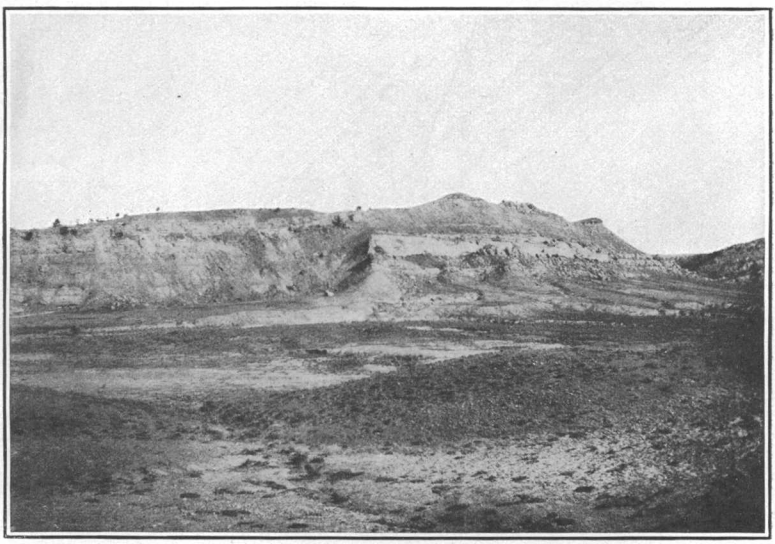
STRUCTURE.

Two domes, here called the North and South domes, are shown by outcrops of the Frontier sandstones and the Cody shale. (See Pl. XXXII.) From the persistent syncline which limits the Spring Creek anticline on the northeast in T. 50 N., R. 101 W., and along the trough of which the Fort Union formation is exposed, the successively lower beds rise with low dips until, at the escarpment of Mesaverde sandstones in secs. 2, 1, and 12, T. 50 N., R. 101 W., a maximum dip of 36° is reached. From this point the dips decrease toward the South dome, which is marked by the sinuous outcrop of the uppermost Frontier sandstone. The South dome merges westward with the southern end of the extensive anticline that forms the Cedar and the Rattlesnake Mountains west of Cody. One small northward-trending fault crosses the summit of the South dome and two groups of faults, some of which produce considerable offset, break the escarpment of Mesaverde sandstone that forms the southern boundary of the basin. One fault, in the eastern group, displaces the sandstone 1,200 feet and produces at the surface a horizontal offset of the beds of 3,600 feet. (See Pl. XXX, *B*.) The western limit of this fault has not been determined, but it appears to die out in the syncline that separates the North from the South dome. A fault of this extent must displace the Frontier sandstones 2,300 feet below the basal Mesaverde sandstone and may displace the sands in the Thermopolis and the Cloverly formations. The structure contours (Pl. XXXII) are drawn on the East Wiley coal bed of the Mesaverde formation, which is separated from the uppermost Frontier sandstone by the Cody shale, 2,300 feet thick, and by the lower 224 feet of the Mesaverde formation. In the vicinity of the summit of the two domes the structure contours coincide closely with the inferred form of the uppermost Frontier sands.

Only the Torchlight sand (?) (the uppermost sandstone of the Frontier formation) outcrops on this dome (see Pl. XXXI, *B*), but the beds between it and the sandstone near the base of the Thermopolis formation are recorded in well No. 2 of the Enalpac Oil & Gas Co., which was drilled near the summit of the dome.

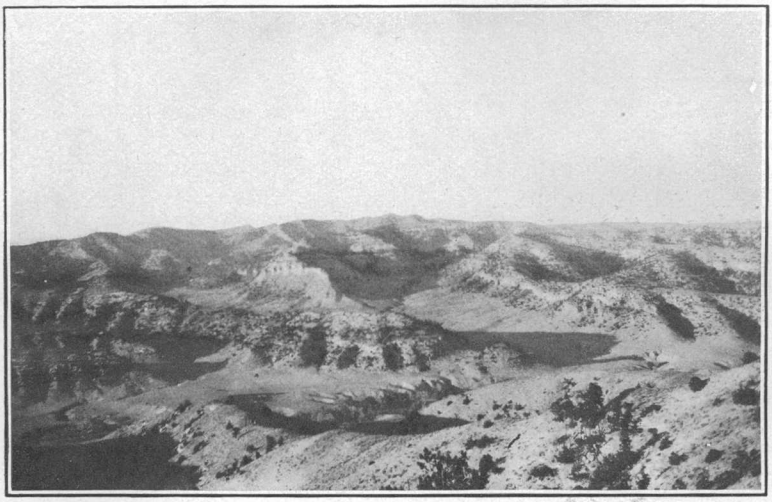


A. OUTCROP OF THE MASSIVE BASAL SANDSTONE AND COAL-BEARING PART OF THE MESAVERDE FORMATION IN SEC. 24, T. 52 N., R. 100 W.

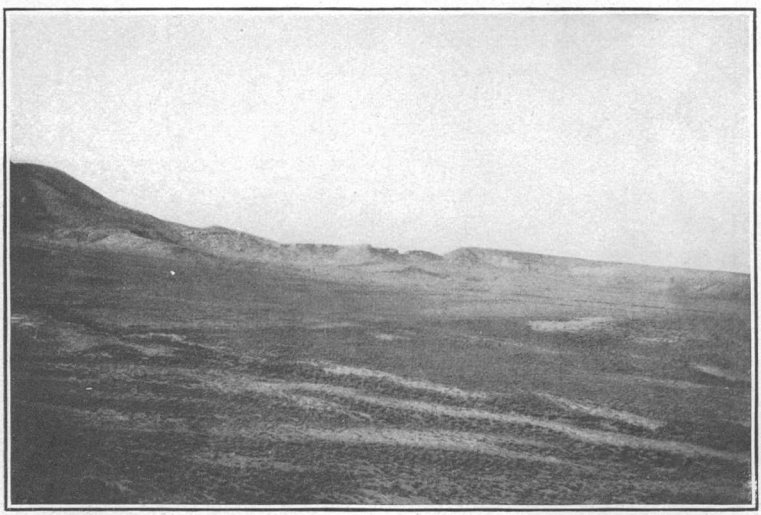


B. FAULT IN SEC. 2, T. 50 N., R. 100 W.

Middle part of the Mesaverde formation (right) abuts against upper part of the Meeteetse formation (left). Horizontal offset, 3,000 feet; stratigraphic displacement, 1,250 feet.



A. ESCARPMENT OF BASAL SANDSTONE OF MESAVERDE FORMATION DISSECTED NEAR CREST OF LOW DOME IN SECS. 15, 16, 21, AND 22, T. 47 N., R. 100 W.



B. OUTCROP OF THE UPPERMOST SANDSTONE (TORCHLIGHT (?) SANDSTONE MEMBER) OF THE FRONTIER FORMATION, EAST OF ELK BUTTE, IN SEC. 32, T. 51 N., R. 100 W.

Well No. 2 was later drilled under the low escarpment on the left.

Log of well No. 2 of the Enalpac Oil & Gas Co., South dome of Oregon Basin.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	2	2
Frontier formation:		
Sand	18	20
Sandy wash	40	60
Shale	221	281
Sand	39	320
Shale	50	370
Sand	10	380
Mowry shale:		
Shale	105	485
Bentonite	20	505
Shale	41	546
Sand	39	585
Shale	20	605
Sand	40	645
Gray lime	10	655
Sand, dark	4	659
Shale, light	231	890
Thermopolis shale:		
Shale, black	105	995
Lime, broken	10	1,005
Sand	10	1,015
Shale	215	1,230
Shale and sand	45	1,275
Sand, gas	46	1,321

Two wells, Nos. 1 and 4, were drilled southeast of well No. 2. No. 1 penetrated the uppermost Frontier sandstone only, but No. 4 went down to the middle of the Mowry shale. The records of these wells show that the sandstone beds of the Frontier formation are highly lenticular and can not be traced for great distances. A single bed of bentonite is reported in well No. 2, but three such beds are reported from the same part of the section in well No. 4.

The summit of the North dome is not so well shown on the surface as that of the South dome. Only the uppermost sandstone of the Frontier formation outcrops, but other formations were penetrated in well No. 3 of the Enalpac Oil & Gas Co., which was drilled near the summit and penetrated as far as the middle of the Morrison formation.

Log of well No. 3 of the Enalpac Oil & Gas Co., North dome of Oregon Basin, sec. 5, T. 51 N., R. 100 W.

	Thickness.	Depth.
	Feet.	*Feet.*
Soil	49	49
Frontier formation:		
Shale, black and sandy	121	170
Sand	5	175
Shale, light	65	240
Sand	20	260
Shale, brown and sandy	120	380
Sand	20	400
Shale, sandy	20	420
Sand	27	447
Shale, with lime and sand	51	498
Sand	42	540
Slate	13	553
Sand	27	580

Log of well No. 3 of the Enalpac Oil & Gas Co., North dome of Oregon Basin, sec. 5, T. 51 N., R. 100 W.—Continued.

	Thickness.	Depth.
	Feet.	*Feet.*
Mowry shale:		
Shale with sand	18	598
Sand	13	611
Bentonite	4	615
Shale, black and brown	80	695
Sand, black	10	705
Shale, black and light	10	715
Sand	27	742
Shale	16	758
Sand, dark	10	768
Shale	36	804
Sand, black	5	809
Shale, hard, brown	77	886
Sand	5	891
Thermopolis shale:		
Shale	439	1,330
Sand	44	1,374
Shale	151	1,525
Cloverly formation:		
Sand	145	1,670
Morrison formation:		
Lime, red	40	1,710
Sand	76	1,786
Shale, green, with sand	4	1,790
Rock, red	40	1,830
Sand, broken	17	1,847
Rock, red	53	1,900
Shale	15	1,915
Sand	7	1,922
Shale	70	1,992
Sand	6	1,998
Shale, gray	162	2,160

Another well, No. 5, was drilled to the base of the Frontier formation half a mile west of No. 3; and a third, No. 6, was sunk to the uppermost Frontier sandstone near the lowest point of the syncline between the two domes. During 1916 another well, No. 9 (new No. 5), was drilled near the summit of the dome. On November 5, 1916, it had attained a depth of 1,495 feet and was drilling in beds of the Morrison formation.

The Wasatch and later formations that cover the surface of much of the central part of the Big Horn Basin unconformably overlie the Meeteetse, Lance, and Fort Union formations along a narrow belt east of the Oregon Basin and were therefore laid down after the larger anticlinal folds had been formed. Although it is improbable, pronounced folds may occur in beds older than the Wasatch and younger than the Mesaverde in the belt where these beds are covered by the Wasatch formation. A low northwestward-trending syncline is shown by outcrops of the Wasatch formation in the north half of T. 50 N., R. 99 W., and it is doubtful whether the deeply buried Frontier sandstones rise without reversed dip from the center of the Big Horn Basin to the domes of the Oregon Basin.

DEVELOPMENT.

The domes of the Oregon Basin were among the first of those on the west side of the Bighorn Basin to be tested for oil and gas. The first wells were drilled by the Enalpac Oil & Gas Co. in the winter

R.101 W.

R.100 W.

T.52 N.

T.51 N.

T. 50 N.

OREGON BASIN

Sage Cr.

Wiley

Wiley Lake

North Oregon Basin dome

Top Torchlight(?) sandstone

FAULT ON SURFACE

FAULT TRACE

Coulee

EAGLE MINE

WILEY MINE

Oregon

South Oregon Basin dome

Elk Butte

East Wiley coal bed in Meaverde formation

East Wiley coal bed

North Fork

36

31

6

1

Scale 62,500

1 0 1 2 3 Miles

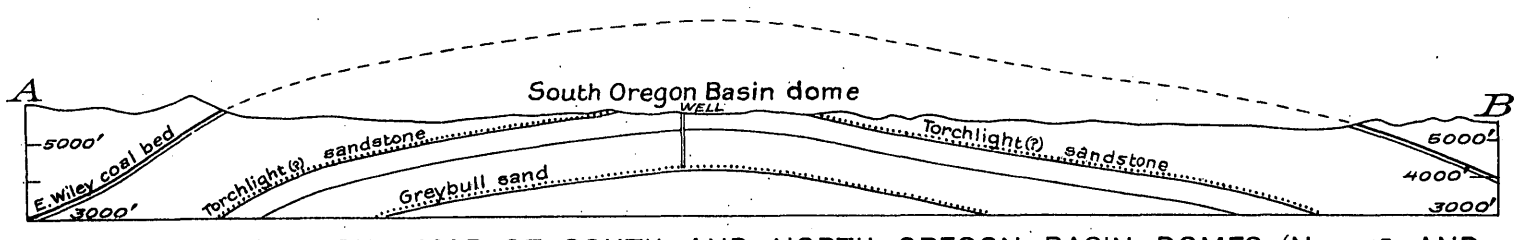
Water well

Gas well

Hole; no data

Structure contours (lines of equal altitude) on top of East Wiley coal bed. Numbers show distance above sea level. Solid lines indicate present position of bed below, and broken lines former position above present surface. Contour interval, 200 feet

Wasatch formation



STRUCTURE CONTOUR MAP OF SOUTH AND NORTH OREGON BASIN DOMES (Nos. 45 AND 48, RESPECTIVELY, ON PLATE I) AND CROSS SECTION

The outcrops of sands are mapped as sandstones

By D. F. Hewett

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

of 1911 and 1912. By November, 1916, eight wells were completed, two near the summit of the North dome, five on the South dome, and one between these two groups. Another well was being drilled at a depth of 1,495 feet on the North dome. Although the company has submitted the logs of these wells data concerning the occurrence of oil, gas, or water in all except two were withheld. It is well known in the region, however, that wells Nos. 2 and 8, near the summit of the South dome, struck gas under considerable pressure. In the first well the gas came from the "Muddy sand" near the base of the Thermopolis shale and could not be controlled for several months. Late in the fall of 1912 the gas was used in the company's camp near the well. It is reported that water was struck in the uppermost Frontier sandstone in well No. 1.

Well No. 7, commonly known as the Jack well, attained a depth of 1,826 feet, and from the log appears to have penetrated the Greybull sand, but except for a show of oil and gas near the top of the Frontier formation found only small flows of water in most of the sands.

Well No. 9 (new No. 5), in the SE. ¼ NW. ¼ sec. 5, T. 51 N., R. 100 W., on the North dome, struck small amounts of gas and water at several horizons on the Frontier formation, Mowry shale, and Thermopolis shale. The Greybull sand (?), however, has temporarily yielded much larger flows of gas.

No seeps of oil are known in the Oregon Basin, but here and there along the dry stream courses a black scum occurs that might be mistaken for oil residuum. The scum has no odor and unlike residuum forms an emulsion with water. It appears to be an organic substance that is leached by alkaline water from the coal beds of the Meeteetse formation and deposited by evaporation.

CONCLUSIONS.

If no drilling had been done, the position of these two domes with respect to the large depression of the Bighorn Basin would indicate that they were fairly favorable territory for exploration. The discovery of an exceptional quantity of gas in a well on the crest of the South dome may be regarded as consistent with this hypothesis and as a favorable augury for the finding of oil farther down on the limbs. The presence of water in well No. 7 in the sands from the Mowry to the "Cloverly" formation indicates that the surface belt on the South dome, within which oil may be found, is not great. In the lack of definite information as to what was found in the two old wells near the summit of the North dome it may be safely assumed that no exceptional quantities of either gas or oil were found. Unless the numerous faults that break the limiting escarpment of the Mesaverde sandstones be regarded as evidence that the possible oil-bearing sands of the Frontier and lower formations are also much broken by faults, there is no apparent reason why the North dome

should not prove as favorable for the accumulation of gas as the South dome. The evidence from the Greybull field and from fields in other parts of Wyoming appears to show that faults trending approximately 90° from the strike of an anticline do not greatly prevent the accumulation of oil and gas. The directions of some of the faults of the North dome of Oregon Basin are obscure, and there may be more faults than are shown on Plate XXXII. It is possible that the faults have affected the accumulation of oil and gas on the North dome, and that instead of occurring near the summit the greatest amounts of these substances will be found in some of the blocks bounded by fault planes on the east side of the crest. It is probable, however, that an important cause of the absence of important quantities of either oil or gas along the summit of the North dome is the presence of the synclinal axis in T. 50 N., R. 99 W., which would hinder if not prevent the migration of these materials from the deeper part of the Big Horn Basin to the summit of the dome.

SHOSHONE ANTICLINE.

By D. F. HEWETT.

The crest of the Shoshone anticline (No. 48, Pl. I) crosses Shoshone River in sec. 28, T. 53 N., R. 101 W., about 2 miles northeast of Cody. The map (fig. 12) is based in part on observations made in studying the section along Shoshone River in 1911[1] and in part on a reconnaissance by C. T. Lupton north of the river in 1915. The Cody branch of the Chicago, Burlington & Quincy Railroad crosses the crest line of the anticline on the north side of the river, and the region adjacent to the anticline is most accessible from roads that diverge from Cody station to the northeast and north.

The work of Fisher in 1904 and Woodruff in 1907 in this region shows that the anticline extends 5 miles northwest of the river, but the information available is not sufficient to warrant the construction of structure contours. The beds that mark the anticline are well exposed in the gorge through which Shoshone River flows, and there are also good exposures along the lower course of Cottonwood Creek, an intermittent stream that joins Shoshone River at the point where the crest of the anticline crosses the river. As large areas near the anticline both north and south of the river are parts of extensive gravel-covered terraces good outcrops are uncommon and the position of the crest line of the anticline is not accurately known.

The lowest rocks that are brought to the surface along the anticline belong to the Frontier formation, the upper 300 feet of which outcrops. On the northeast limb of the anticline the uppermost sandstone of the Frontier dips 53° E. and beyond this the successively

[1] Hewett, D. F., op. cit., p. 89.

higher beds range in dip from 35° to 58°, until along the outcrop of the upper part of the Fort Union formation the dip decreases abruptly to 3°. Southwest of the crest line the beds dip at a maximum of 62° to a synclinal axis, beyond which they rise to a low anticline,

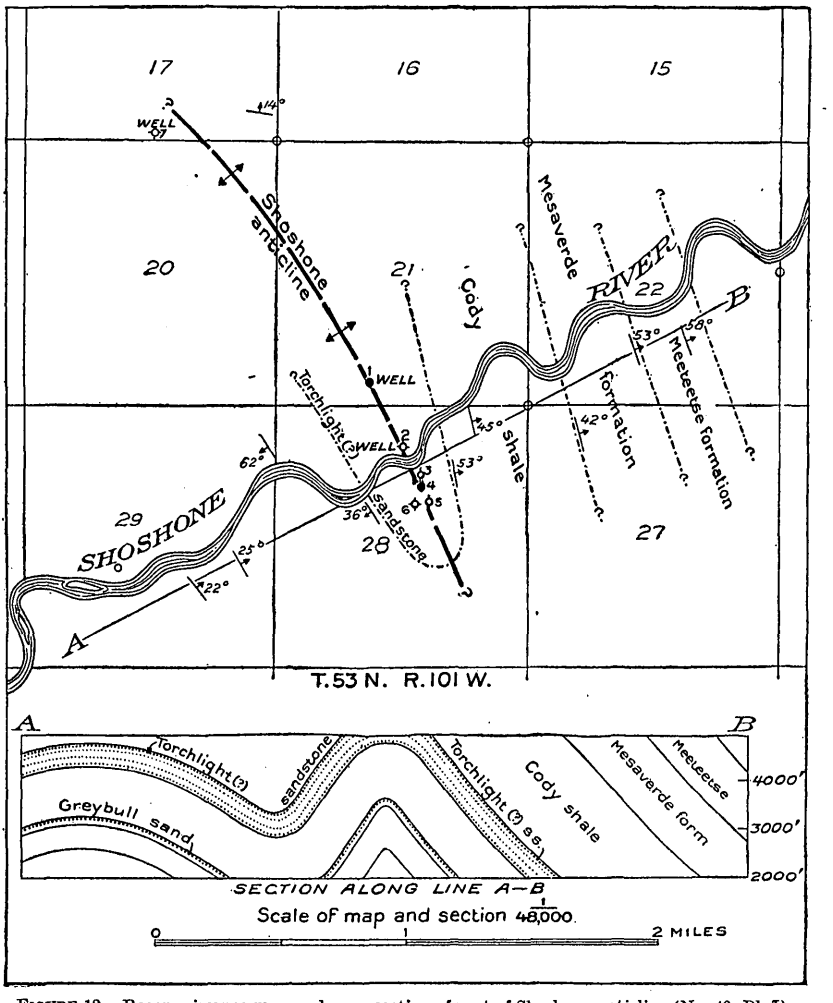


FIGURE 12.—Reconnaissance map and cross section of part of Shoshone anticline (No. 49, Pl. I).

referred to heretofore as the Cody anticline. Judging from the exposures along Shoshone River this anticline is without doubt the southeast end of that which brings the Sundance formation to the surface 5 miles northwest of the river.

Three wells have been drilled along the Shoshone anticline north of the river, in secs. 28, 21, and 17. There is no record of the log of the oldest well, No. 2, but it is reported to have attained a depth of 850 feet; and in 1911 small amounts of oil, water, and gas spasmodically issued from the casing. Well No. 1 of the Shoshone Oil Co. was drilled intermittently from 1909 to 1912 and is reported to have

reached a sandstone in the Morrison formation at a depth of 1,720 feet. This well was started about 200 feet from the top of the Frontier formation and found small amounts of oil in the Mowry and Thermopolis formations and gas in the Thermopolis, Cloverly, and Morrison formations. The greatest amount of oil came from the sandstone near the middle of the Thermopolis shale, but the total production from the well, which was not pumped, did not exceed 200 barrels.[1] Both this and the foregoing well were located close to the crest line of the anticline.

Little information is available concerning well No. 7, which is reported to have been drilled during the summer of 1914 by the Montana-Wyoming Oil Co. It was started in the Cody shale but apparently did not reach the Frontier sandstones. Water at present stands in it about 250 feet below the surface.

Since 1914 six wells have been drilled on the south side of the river by the Mountain States Oil Co. Five of these wells were drilled on an area scarcely 700 feet in diameter, but nothing is known about the logs of two, Nos. 3 and 5. Well No. 4 struck oil in the lowest Frontier sand at 175 feet, and for the first few days that it was pumped yielded 10 barrels of oil a day. The well was shot, and after yielding 40 barrels water came in and shut off the flow of oil. The drilling rig was then moved 25 feet east and another well sunk 700 feet without striking any oil or gas. Well No. 6 was drilled 200 feet but did not strike oil or gas. The sixth well, whose location is not shown on figure 12, was drilled about 4,000 feet southwest of No. 6 to a depth of 1,350 feet. Water having a sulphurous odor and alkaline taste was struck in a sand that is probably the uppermost of the Frontier formation and now flows from the mouth at the rate of 10 gallons a minute. Gas bubbles freely from the surface of the water. This well is located near the trough of the syncline which lies between the Shoshone and Cody anticlines.

In 1916 the Ohio Oil Co. drilled a well in the W. ½ sec. 27, T. 53 N., R. 101 W. The exact position of this well was not determined, and complete information concerning the log is not available. It is reported to have reached a depth of 2,115 feet and to have passed through the entire section of the Frontier formation without finding important quantities of oil or gas.

The position of the highest area on the crest of the Shoshone anticline is not known, but from available data it would appear to lie in the NE. ¼ sec. 20, T. 53 N., R. 101 W. If, as seems probable, the well of the Montana-Wyoming Oil Co. did not penetrate deeper than the top sandstone of the Frontier formation the possibilities of this anticline have not been determined. Its position with respect to the central trough of the Big Horn Basin is sufficiently favorable to warrant further exploration near its crest, in sec. 20, T. 53 N., R. 101 W.

[1] Hewett, D. F., op. cit., pp. 111, 112.

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