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GEOLOGY AND OIL AND COAL RESOURCES OF THE REGION SOUTH OF CODY PARK COUNTY, WYOMING

BY

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GEOLOGY AND OIL AND COAL RESOURCES OF THE REGION SOUTH OF CODY, PARK COUNTY, WYOMING

By W. G. Pierce and D. A. Andrews

ABSTRACT

The region described in this report includes about 385 square miles on the western margin of the Big Horn Basin, in the north-central part of Park County, Wyo. It is a narrow belt extending from Cody southward for about 40 miles. The steep front of the Absaroka Mountains forms its western and southern borders.

Several rock formations that are not exposed in the region but that have been penetrated by wells crop out in Shoshone Canyon 5 miles west of Cody. They include the Madison, Amsden, Tensleep, and Phosphoria formations, of Carboniferous age.

The oldest exposed sedimentary formation is the brick-red Chugwater formation, of Triassic age in this area, which is composed of nearly 1,000 feet of sandstone and shale. Overlying the Chugwater is the Sundance formation, of Upper Jurassic age, a series of fossiliferous marine shales, sandstones, and limestones and unfossiliferous red shales and gypsum with a total thickness of about 500 feet. The Morrison formation, of Upper Jurassic age and continental origin, overlies the Sundance and is about 500 feet thick. It is made up chiefly of brightly colored shales, light-colored sandstones, and conglomeratic sandstones, with some thin beds of freshwater limestone and nodular chalcedony.

The Cloverly formation, the basal unit of the Cretaceous sequence, is restricted in this report to include only 100 to 200 feet of brown and buff thin-bedded sandstones and shales. This restriction places in the underlying Morrison some beds that probably have been assigned to the Cloverly in other regions. Overlying the Cloverly is the Thermopolis shale, a dark-gray to black shale about 600 feet thick, which contains numerous beds of bentonite. The sandstone in the lower part of this formation, generally known as the Muddy sand, is about 30 feet thick. Marine fossils have been found in the muddy sand and also in the shale of the Thermopolis. The overlying Mowry shale, which is about 400 feet thick, consists chiefly of siliceous shales and contains many bentonite beds. The Frontier formation conformably overlies the Mowry and consists of about 500 feet of alternating and lenticular sandstones and shales, with some bentonite beds, which seem to be more persistent than the bentonite beds in the underlying Mowry and Thermopolis shales. Overlying the Frontier formation is the Cody shale, a fossiliferous marine shale about 3,000 feet thick, which includes beds equivalent to parts of the Colorado and Montana groups of the Upper Cretaceous series. The marine Upper Cretaceous series closes with the Mesaverde formation, largely a succession of massive sandstones containing some coal beds near the base, but in part, at least, of marine origin. The

Mesaverde formation is about 1,300 feet thick and forms conspicuous hogbacks on the flanks of the synclines.

The Upper Cretaceous series includes also the overlying nonmarine Meeteetse formation, which is a succession of soft shales and sandstones with prominent thin bands of light and dark gray. The Meeteetse formation is about 1,150 feet thick and contains some lenticular coal beds in the upper part. It is conformably overlain by the Lance formation, which is composed of sandstones and shales of continental origin. The Lance is now classed as Upper Cretaceous in most areas. Only 20 feet of the overlying Fort Union formation, of Eocene age, is present in this area, but in the adjoining area to the east it is 2,000 or more feet thick and has conspicuous local unconformities at its base.

The Wasatch formation is unconformable on all formations from the Fort Union down to the Cloverly. It is 1,700 feet thick and consists of soft sandstones and shales, brightly colored in places, and locally it has a well-rounded quartzite conglomerate at the base.

Two gravel-covered terraces of Tertiary age and three terraces of Pleistocene age form the extensive gently sloping surfaces and benches that are the dominant features of the topography. Surficial deposits of Recent age include materials classed as colluvium, landslide material, and alluvium.

The entire sequence of Mesozoic rocks in the area is essentially conformable. Although uplift and erosion produced an unconformity at the base of the Fort Union, the dominant structural features were formed within the Eocene epoch, between the times of deposition of the Fort Union and the Wasatch formations. The deformation produced the prominent anticlines and synclines of this area, which are elongate northwestward. Most of the anticlines are asymmetrical, with their steeper flanks on the west side, but on the Horse Center, Pitchfork, and Fourbear anticlines the asymmetry is reversed in different parts of the fold. The Heart Mountain overthrust sheet moved across the northern part of the region, as shown by the fact that its remnants lie near the north border of the area. The overthrusting in the Cody region took place between the time of deposition of the Wasatch formation (Eocene) and the time of the extensive lava flows (upper Eocene or lower Oligocene) in the Absaroka Mountains. The deformation that caused the overthrusting may also have produced some of the post-Wasatch deformation in this area.

The Spring Creek, Pitchfork, Fourbear, and South Sunshine anticlines have yielded black oil of A. P. I. gravity less than 20 from the Carboniferous formations at a depth of about 3,000 feet. Initial tests on these anticlines show 200 to 400 barrels of oil a day, but there has been no commercial production. Carbon dioxide gas was obtained from the Carboniferous rocks in a well on the Horse Center anticline, but the hole has since been plugged and abandoned.

Two coal-bearing zones are present near the base of the Mesaverde formation. They are called the Buffalo and Wilson coal groups. The lower or Wilson group attains a thickness of 6 feet 3 inches in the southeastern part of the area, but in many places it is only a foot or two thick. The coal in the Buffalo group is usually not so thick as that in the Wilson group. Lenticular coal beds occur in the upper 400 feet of the Meeteetse formation, but they are seldom more than 3 feet thick and are not readily accessible. Relatively pure bentonite occurs in beds as much as 5 feet thick in the Thermopolis, Mowry, and Frontier formations, but it has not been commercially mined. The surficial hot-spring deposits of native sulphur near Cody were worked sporadically between 1906 and 1917.

INTRODUCTION

Location and extent of the area.—The region covered by this report is in the north-central part of Park County, in northwestern Wyoming. It is a narrow, irregular-shaped area covering 385 square miles on the west side of the Big Horn Basin. (See fig. 10.) It extends southward from Cody for a distance of 40 miles, is 8½ miles wide in the northern part, and has a maximum width of 16½ miles. The western and southwestern boundaries are irregular, being formed in the main by the steep slope separating the Big Horn Basin from the Absaroka Mountains. The eastern boundary, except for a few miles in the southernmost part, coincides with that set by earlier detailed geologic mapping, which extended westward to the 109th meridian.

Previous investigations and publications.—The general geologic features of the region here described have been known for many years. In 1893 Eldridge[1] made a reconnaissance examination of a large part of northwestern Wyoming, including the area covered by this report. A report on a reconnaissance examination of the coal beds in the Big Horn Basin by Fisher[2] included some observations on the coal beds along the east margin of this area, and his more extensive report, on the geology and water resources of the Big Horn Basin,[3] published in 1906, includes the eastern part of the region described in the present report. The sulphur deposits just west of Cody were examined in detail in 1907 by Woodruff,[4] who in 1909 described the coal fields on the southwest side of the Big Horn Basin.[5] A detailed section along the Shoshone River, at the north end of the area, was measured by Hewett,[6] who later made detailed studies in the Oregon Basin and Meeteetse quadranges,[7] which adjoin this area on the east. A report by Hewett and Lupton published in 1917,[8] on the anticlines in the southern part of the Big Horn Basin, gives considerable information on the anticlines in the region south of Cody, and a later paper by Moody and Taliaferro,[9] contains detailed data on the

[1] Eldridge, G. H., A geological reconnaissance in northwest Wyoming: U. S. Geol. Survey Bull. 119, 72 pp., 1894.

[2] Fisher, C. A., Coal of the Big Horn Basin, in northwest Wyoming: U. S. Geol. Survey Bull. 225, pp. 345–362, 1904.

[3] Fisher, C. A., Geology and water resources of the Big Horn Basin, Wyoming: U. S. Geol. Survey Prof. Paper 53, 72 pp., 1906.

[4] Woodruff, E. G., Sulphur deposits at Cody, Wyo.: U. S. Geol. Survey Bull. 340, pp. 451–456, 1908.

[5] Woodruff, E. G., Coal fields of the southwest side of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 341, pp. 200–219, 1909.

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

[7] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, 107 pp., 1926.

[8] Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 656, 192 pp., 1917.

[9] Moody, C. L., and Taliaferro, N. L., Anticlines near Sunshine, Park County, Wyo.: California Univ., Dept. Geology, Bull., vol. 10, pp. 445–459, 1918.

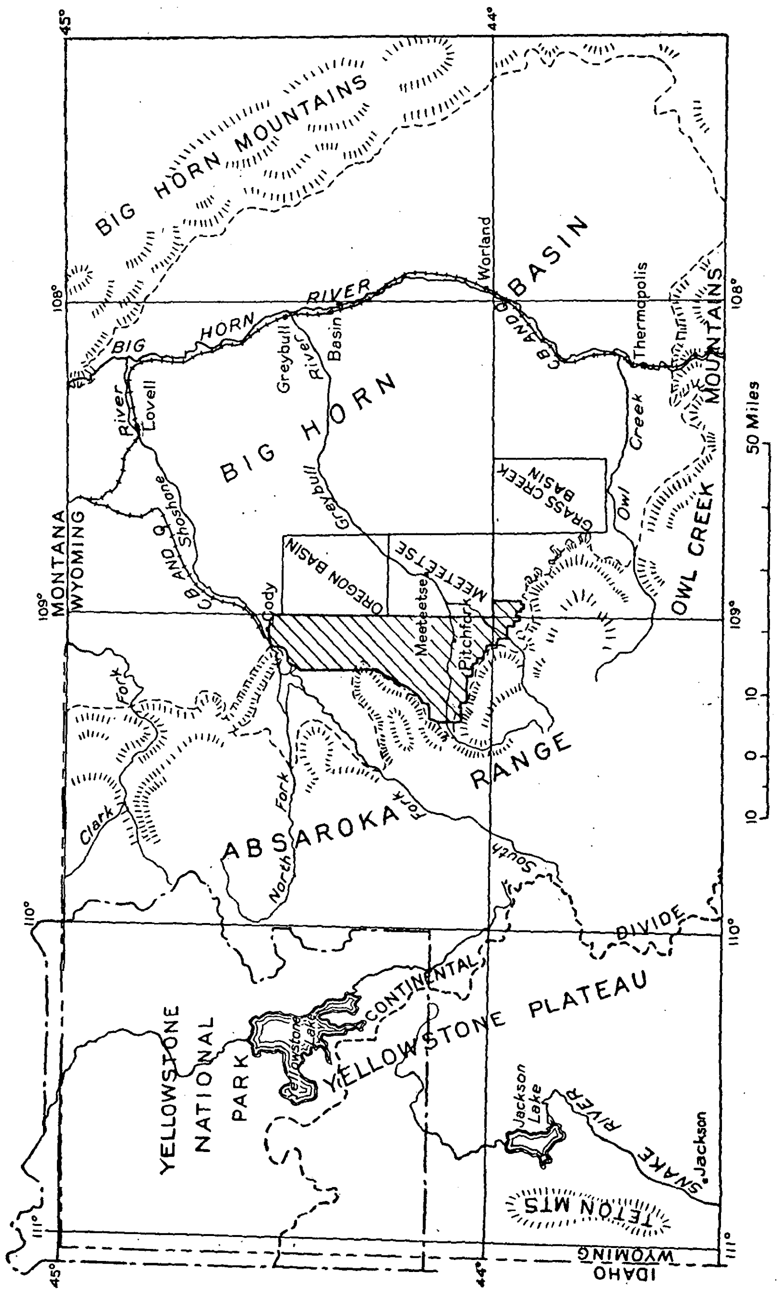

FIGURE 10.—Index map of northwestern Wyoming, showing the principal physiographic features and the location of the area described in this report (cross-lined) in relation to the quadrangles described in United States Geological Survey Professional Paper 145.

South Sunshine anticline. Johnson,[10] in 1934, described a part of the northwest margin of the region covered by the present report, and Mackin,[11] in his discussion of the geomorphology of the northern part of the Big Horn Basin, described the northern part of the region.

Other general papers relating to the regional phases of the geology, paleontology, and stratigraphy of the Big Horn Basin and to the geology of nearby areas, are cited at appropriate places in this report.

Field work and acknowledgments.—The field work on which this report is based was done between July 10 and November 9, 1935. The field mapping was on a scale of 2 inches to the mile, employing the triangulation method, with plane table and telescopic alidade. The positions of the land lines were determined by locating numerous section and tract corners. The base net was compiled from surveys by the United States General Land Office. Most of the General Land Office surveys were made during the period 1907 to 1922. The corners of those surveys are well established, and many of them are marked by iron pipes with stamped caps. The land survey of T. 48 N., R. 103 W., made in 1884, is so old that no set stones could be found, and the approximate corners located could not be reconciled with those indicated by the reported measurements of the old survey; therefore, the section lines inside the borders of that township are not shown. Difficulty was also encountered in adjusting the present mapping in the western part of T. 52 N., R. 101 W., to the land survey of 1907; consequently the position of the land lines shown there is only approximate. Altitudes in the field were based on United States Geological Survey bench marks, those along Greybull River serving for the southern part of the area and those along Shoshone River serving for the northern part.

The authors were capably assisted by F. M. Haase and F. R. Waldron. J. B. Reeside, Jr., spent a week with the party at the beginning of the field season, giving assistance particularly in determining the stratigraphy of the area. The authors wish to acknowledge the helpful criticism of the manuscript by H. D. Miser and the cordial cooperation of H. J. Duncan, district supervisor of the Geological Survey at Casper, and L. C. Snow, petroleum engineer of the survey at Thermopolis, Wyo., who kindly furnished the data available to them on the area.

[10] Johnson, G. D., Geology of the mountain uplift transected by the Shoshone Canyon, Wyo.: Jour. Geology, vol. 42, pp. 809–838, 1934.

[11] Mackin, J. H., Erosional history of the Big Horn Basin, Wyo.: Geol. Soc. America Bull., vol. 48, pp. 813–894, 1937.

GEOGRAPHY

CLIMATE AND VEGETATION

Although the climate of most of the central part of the Big Horn Basin is arid, the narrow belt along the western margin of the basin, which includes the region south of Cody, is semiarid. Although the lower part of the basin receives an annual precipitation of less than 10 inches and in places less than 5 inches, the gaging stations of the United States Weather Bureau located in or near the region south of Cody record an average annual precipitation ranging from 9.11 inches at Cody to 18.88 inches at Quaking Aspen Creek, in the mountains bordering the southwest part of the area. More than half of the annual precipitation falls during the months of April, May, June, and July. This precipitation, however, is inadequate for farming, and the cultivation of crops is successful only where additional water is supplied by irrigation.

The daily and seasonal variations in temperature are large in the Cody region. The average minimum temperature falls below 10° F. during January and February at the Quaking Aspen Creek station and during February at the Fourbear station. The average maximum temperature exceeds 80° F. at Cody only during July and August and at Shoshone Dam only during July. In contrast, the stations along the Big Horn River in the lower part of the basin show average minimum temperatures near zero during the winter months and average maximum temperatures of about 90° during July and August.

A compilation of the records of the United States Weather Bureau [12] is given in the following tables.

The central part of the Big Horn Basin, which receives less than 10 inches of precipitation annually, has a desert brush vegetation,[13] composed chiefly of black sage, matchweed, rabbit brush, shadscale, salt brush, and a small growth of grass and weeds. The precipitation increases near the mountains, and grasses are much more abundant on the broad benches. The principal varieties are wheat bunch grass, gramma grass, western wheat grass, blue grass, mountain timothy, and rye grass. Associated with these grasses are larkspur, lupine, loco weed, balsam root, and yellow dock. Cedar and piñon are found on many of the hills throughout the area, and along the western and southern edges yellow pine, scrub fir, lodgepole pine, Engleman spruce, Douglas fir, balsam, and western yellow pine

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[12] Climatic summary of the United States, section 13, Northeastern Wyoming: U. S. Weather Bureau, 1893 to 1930, inclusive.

[13] Compiled from Aldous, A. E., and Deeds, J. F., Land classification of the northern Great Plains, Montana, North Dakota, South Dakota, and Wyoming, pp. 31, 68, 120–122, U. S. Geol. Survey, 1929. [Mimeographed.]

Average monthly and annual precipitation at Weather Bureau stations in and near the region south of Cody

Station	Number of years	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Cody	[1] 29	0.27	0.32	0.45	1.00	1.25	1.28	1.03	0.84	0.99	0.85	0.51	0.32	9.11
Four Bear	[2] 12	.25	.40	.94	1.33	1.85	1.75	1.05	.97	1.16	.76	.50	.23	11.19
Quaking Aspen Creek	[3] 14	.55	.73	1.27	2.51	3.29	1.80	1.88	1.79	1.77	1.74	1.02	.53	18.88
Shoshone Dam	[4] 26	.42	.33	.56	.94	1.94	1.32	1.23	.99	1.10	.81	.51	.50	10.65
Valley	[5] 11	.63	.37	.64	.99	3.08	1.43	1.45	.89	1.66	1.24	.60	.38	13.36

Average monthly and annual maximum temperature

Station	Number of years	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Cody	22	32.9	38.3	46.2	55.8	64.4	75.7	83.6	81.7	70.2	57.1	44.5	33.4	57.0
Four Bear	11	34.9	34.0	38.0	50.3	58.6	67.7	73.9	75.2	64.4	55.2	43.2	37.4	54.1
Quaking Aspen Creek	14	34.5	36.3	41.7	48.8	59.0	69.3	77.1	75.2	66.4	55.2	41.6	37.0	53.8
Shoshone Dam	25	34.7	39.8	45.6	54.6	62.4	73.1	81.5	79.9	70.1	58.6	47.7	36.1	57.0
Valley	5	35.4	40.0	43.5	50.1	56.5	69.2	78.6	75.5	65.0	57.2	46.5	36.1	54.5

Average monthly and annual minimum temperature

Station	Number of years	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Cody	22	11.2	14.5	21.3	30.9	38.9	46.9	53.3	50.2	41.5	31.9	23.0	12.5	31.3
Four Bear	11	11.6	9.6	14.1	24.7	34.0	40.2	45.1	44.8	35.8	28.6	18.9	15.3	26.9
Quaking Aspen Creek	14	6.0	8.3	13.4	22.1	32.5	39.0	45.3	43.2	35.0	25.7	17.9	10.2	24.9
Shoshone Dam	25	17.1	19.2	24.2	33.0	40.6	49.7	56.7	55.2	46.9	37.4	29.5	20.5	35.8
Valley	5	12.8	17.5	20.0	26.2	32.4	42.0	46.8	48.3	39.4	32.6	25.0	15.0	28.8

[1] Incomplete record 1898–1930.
[2] 1893–1904.
[3] 1917–30.
[4] 1905–30.
[5] Incomplete record 1908–20.

grow in the mountains. Aspen and cottonwood are abundant along some of the permanent streams.

DRAINAGE AND WATER SUPPLY

The major drainage channels of the region are the Shoshone River, which flows along the north boundary, and the Greybull River, which flows through the southern part. (See pls. 15, *C*, and 21, *B*.) The discharge of the Shoshone River is regulated by Shoshone Dam, about 5½ miles west of Cody. According to measurements made by the Geological Survey just below this dam,[14] the discharge of the Shoshone River during the water year 1932–33 varied from a minimum of 14 second-feet on March 29 to a maximum of 10,600 second-feet on June 18, and from a mean of 180 second-feet during March to a mean of 4,910 second-feet during June.

At the gaging station on the Greybull River at Meeteetse,[15] which is 7 miles east of the area mapped, the records for the water year 1932–33 show a mean discharge of 2,200 second-feet during June, 638 second-feet during May, and 481 second-feet during July, the mean gradually decreasing from 207 second-feet during August to a low of 40 second-feet during February. The records of this station, which include those for the years 1920 to 1933, show a maximum discharge of 7,320 second-feet on August 14, 1930, and a minimum of 11 second-feet on March 26, 1931.

The records of the gaging station on the Wood River just above its junction with the Greybull River, 2 miles east of the area shown on plate 11, are incomplete. The record for 1932–33, which is complete, shows a mean flow of 263 second-feet during May and 477 second-feet during June 1932, a maximum of 838 second-feet on June 6, 1932, and a minimum of 30 second-feet on March 24, 1933. Water for irrigation is diverted from this stream above the gaging station, however. Franks Fork (see pl. 13, *A*) is another tributary of the Greybull River that has a considerable flow throughout the year. Other minor tributaries that flow throughout the year are Rock, Rose, Spring, Rawhide, and Meeteetse Creeks, north of the river, and Timber Creek, south of the river. Many tributaries that flow only after rains or when snow is melting drain other parts of the area.

Most of the area north of the high, flat divide known as the Meeteetse Rim, which trends east through the southern part of T. 50 N., Rs. 101 and 102 W., drains into two tributaries of the Shoshone River, Sage and Sulphur Creeks, which are dry throughout most of

[14] Surface water supply of the United States, 1933, part 6, Missouri River Basin: U. S. Geol. Survey Water-Supply Paper 746, p. 101, 1935.
[15] Idem, p. 97.

the summer. Dry and Cottonwood Creeks, which drain eastward to the Greybull River, also head in the area north of the Meeteetse Rim.

Inasmuch as perennial streams cross many parts of this region, the need for other water supplies is not acute, but dams of earth have been built in a few places to store water for cattle during the dry summer months. The Shoshone Reservoir of the Bureau of Reclamation, on the Shoshone River 5 miles west of Cody, has a capacity of 456,000 acre-feet and is used to store water for the irrigation of large tracts of land farther down the river. Since the completion of the field work for this report a reservoir has been constructed along Sunshine Creek, in the northeastern part of T. 47 N., R. 102 W., in order to provide storage to be used for additional irrigation along the Greybull River. This reservoir is fed by a canal from Greybull River, and the water is returned to Greybull River by way of Sunshine Creek when it is needed to augment the flow of that river.

The water from the permanent streams is used for domestic supply, for livestock, and for irrigation. Along the lower courses of the Shoshone, Greybull, and Wood Rivers, however, where the water drainage from the irrigated lands returns to the rivers, the water may show increased mineral content and contamination.

TRANSPORTATION AND SETTLEMENT

Cody, with a population of 1,800 according to the 1930 census, is the only town in the area here described. A branch of the Chicago, Burlington & Quincy Railroad connects Cody with the Billings-Denver line of that railroad at Frannie, 50 miles northeast of Cody. This branch furnishes railway service to Cody from June to September, the tourist season in Yellowstone Park, and in addition the railroad company provides bus service throughout the year along State Highway 14, which also connects Cody with its main line.

A paved highway connects Cody with Thermopolis, in the southern part of the Big Horn Basin (see fig. 10), and passes through Meeteetse, 7 miles east of the mapped area. From Meeteetse, mail and limited passenger service are available by bus over Star Routes to Pitchfork, a ranch post office on the Greybull River, and to Sunshine, a ranch post office on the Wood River, just east of this area.

Other roads that are traversable throughout the year extend along the Greybull and Wood Rivers from Meeteetse, along the Meeteetse Rim, along Sage Creek, and through the northern part of the area from Cody up the South Fork of the Shoshone River. From these, other roads that are traversable most of the year lead to other parts of the area.

At the time of this investigation there were approximately 90 occupied farms and ranches in the area. About 50 of these are in the irrigated country along the northern border, which includes Irma Flats, Diamond Basin, and the bench lands near Cody (see pl. 11). Most of the other farms and ranches are likewise near permanent streams. The three largest ranches—the Palette and Z Bar T, on the Greybull River, and Hoodoo, near the head of Sage Creek—control much of the grazing land. The May ranch, below Sunshine post office, controls considerable land along the Wood River.

SEDIMENTARY ROCKS

GENERAL FEATURES

The sedimentary rocks exposed in the region south of Cody range in age from Triassic to Recent and are about 10,000 feet thick. Older sedimentary rocks that underlie much or all of the area described crop out in the Shoshone River Canyon 5 miles west of Cody. They include strata of Carboniferous, Devonian, Ordovician, and Cambrian age. Pre-Cambrian granites are also exposed in the canyon.

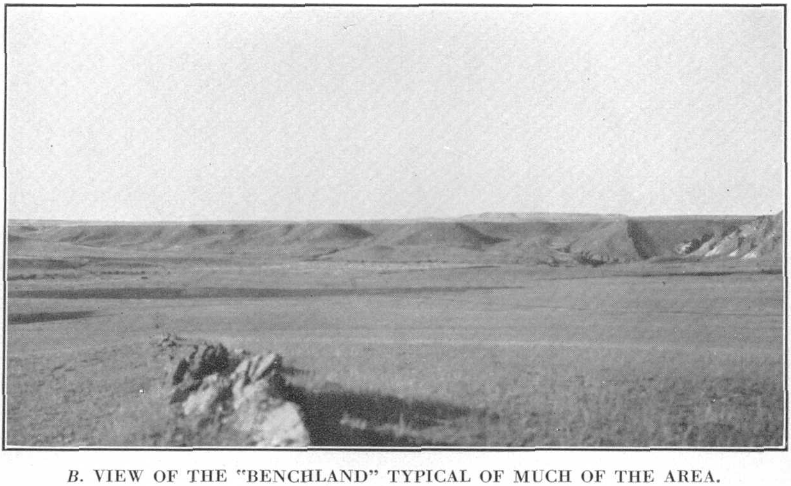
The lithology and thickness of the formations exposed in the region south of Cody are summarized on plate 14, and their distribution is shown on plate 11. The sequence of formations is, in general, conformable from the oldest exposed formation, the Chugwater, of Triassic age, up to the Fort Union formation, of Eocene age. There is, however, a hiatus or unconformity between the Chugwater formation and the Sundance formation, of Upper Jurassic age. The thin sequence of beds assigned to the basal part of the Fort Union formation apparently is conformable with the underlying Lance formation, of Upper Cretaceous age, but Hewett[16] has noted a local erosional unconformity at the base of the Fort Union formation in T. 50 N., R. 100 W., about 8 miles east of the area described in the present report.

The major structural features of this area were formed after the deposition of the Fort Union formation. Erosion then beveled the upturned rocks and produced a fairly level floor, upon which the Wasatch formation was deposited. The lower part of the Wasatch also was involved in some minor deformation, as is shown by the discordant relations between the upper and lower parts of the Wasatch.

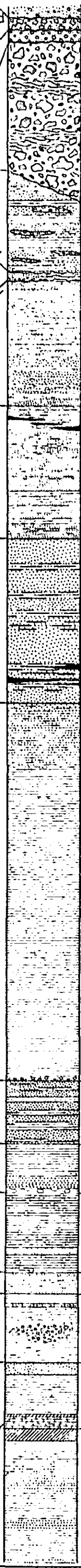
The formations below the Cody shale are exposed only in narrow belts around the sharply folded anticlines. The thick Cody shale is the surface formation over considerable areas between the prominent structural folds. The formations from the Mesaverde up to the Fort Union are preserved only in the larger synclines—the Dry

[16] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 36, 1926.

A. VIEW LOOKING SOUTH UP FRANKS FORK TOWARD FRANKS PEAK.
From northwest corner of sec. 3, T. 47 N., R. 103 W.



B. VIEW OF THE "BENCHLAND" TYPICAL OF MUCH OF THE AREA.
Looking north from NE¼ sec. 10, T. 48 N., R. 102 W. In the foreground is a steeply dipping bed of greensand in Cody shale.



System	Series	Formation	Thickness	Description
QUATERNARY		Alluvium		Unconsolidated sand, clay, gravel, cobbles, and boulders along stream valleys.
		Colluvium and landslide		Unconsolidated debris, angular boulders, cobbles, and gravel along steep slopes.
		Terrace gravels		Unconsolidated gravel, sand, cobbles, and silt deposited by streams.
TERTIARY		Volcanic rocks	1,000'+	Basic breccias with andesitic flows, along western border of area.
		UNCONFORMITY		
		Wasatch formation	1,700'+	Varicolored clay, sandstone, and shale; lenticular beds of quartzite conglomerate; some areas of badlands.
		UNCONFORMITY		
		Fort Union formation		Thin-bedded sandstone, shale, and thin beds of coal; several conglomerate beds in basal part. Present only in a single locality.
		UNCONFORMITY		
CRETACEOUS	Upper Cretaceous	Lance formation	1,050'	Slightly consolidated buff sandstone; drab or green shale or clay; persistent bed of buff, concretionary sandstone at base.
		Meeteetse formation	1,050'	Gray to white clayey sand and sandstone, locally concretionary; gray sandy clay, brown shale, and bentonite; thin beds of coal in upper part.
		Mesaverde formation	1,300'	Massive gray sandstone; laminated sandstone and sandy shale in middle part; lenticular beds of coal in lower 250 feet.
		Cody shale	3,000'	Tan or buff to olive shale; gray in lower part; becoming increasingly sandy at top.
		Frontier formation	500'	Thick, lenticular, gray sandstone with gray shale and brown carbonaceous shale; bentonite.
		Mowry shale	400'	Brown shale; siliceous brown shale weathering light gray to almost white; somewhat sandy in lower part; numerous bentonite beds.
		Thermopolis shale	620'	Soft black shale with numerous bentonite beds. Muddy sand of drillers, 20 feet thick, about 200 feet above base.
	Lower Cretaceous	Cloverly fm.	180'	Thin-bedded, lenticular, buff to yellow-buff sandstone; variegated and gray to buff sandy shale.
JURASSIC		Morrison formation	520'	Variegated red, purple, and pink sandy shales with coarse sandstone and conglomeratic sandstone near middle; thin beds of lilac-colored shale and chalcedony in upper part.
		Sundance formation	530'	Green shale with greenish-gray sandstone at top; thin beds of fossiliferous limestone; red shale and gypsum in lower part; sandy limestone at base.
		UNCONFORMITY		
TRIASSIC		Chugwater formation		Red shales and sandstones; 100± feet of gypsum at top.

SECTION OF ROCKS EXPOSED IN THE REGION SOUTH OF CODY.

Creek, Rawhide, and Sunshine synclines. The Wasatch formation and later unconsolidated deposits, such as alluvium and landslide material, cover the Cody shale and older formations along the western margin of the area. Several gravel terraces also floor considerable areas along Tertiary and later drainage channels.

ROCKS NOT EXPOSED

Rocks older than the Triassic are not exposed in the region south of Cody, but several formations of Paleozoic age as well as pre-Cambrian igneous rocks crop out in the Shoshone River Canyon between Cedar and Rattlesnake Mountains just west of the northwest corner of the area. These formations underlie at depth parts or all of the mapped area, and some of them yield oil in wells on some of the anticlines (see pp. 159–168). Johnson [17] has measured 1,230 feet of beds of Cambrian age exposed along Shoshone River Canyon. The basal sandstone or quartzite he identified as the Flathead sandstone, and to the overlying greenish and gray calcareous shales containing gray-striped conglomeratic and oolitic limestones he applied the name Gros Ventre formation. His next youngest unit is the Gallatin limestone. The Flathead and Gros Ventre formations are Middle Cambrian in age, and the Gallatin limestone is Upper Cambrian.

The Bighorn dolomite, of Ordovician age, is 450 feet thick where exposed along the Shoshone River.[18]

Above the Bighorn dolomite and below the Madison limestone are beds of limestone and shale 200 to 300 feet thick that are probably of Devonian age. To these strata Johnson [19] applied the name Threeforks formation.

The massive Madison limestone of Mississippian age ranges in thickness from 600 to 1,000 feet in the Big Horn Basin.[20] Johnson [21] says it is approximately 900 feet thick in Shoshone Canyon.

The Amsden formation, of Mississippian and Pennsylvanian age, consists of red shales, limestones, sandstones, and cherty beds. A section measured in Shoshone Canyon shows a thickness of 172 feet.[22] As interpreted by the writers, the driller's log of a well on the Horse Center anticline suggests a thickness of about 256 feet on the crest of the fold. (See p. 160.)

The Tensleep sandstone, of Pennsylvanian age, consists of 150 to

[17] Johnson, G. D., Geology of the mountain uplift transected by the Shoshone Canyon, Wyo.: Jour. Geology, vol. 42, no. 8, pp. 814–817, 1934.

[18] Johnson, G. D., op. cit., p. 817.

[19] Johnson, G. D., op. cit., pp. 817–818.

[20] Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 656, p. 17, 1917.

[21] Johnson, G. D., op. cit., p. 818.

[22] Johnson, G. D., op. cit., p. 818.

200 feet of white to buff, thick, massive to cross-bedded sandstone, with some thin-bedded sandstone in the lower part of Shoshone River Canyon. According to the writer's interpretation of driller's logs, the thickness of the Tensleep sandstone on the Horse Center anticline is 160 to 176 feet, on the Spring Creek anticline 227 feet, and on the Pitchfork anticline 159 feet. (See pp. 160–164.)

The Phosphoria formation,[23] of Permian age, is a series of limestones and sandstones, with chert and phosphate near the base, ranging in thickness from a thin layer to 200 feet.[24] Johnson [25] uses the name Embar limestone for this unit and records a thickness of 210 feet on Cedar Mountain. Logs of wells drilled on the crests of the Horse Center, Spring Creek, and Pitchfork anticlines indicate that the Phosphoria ranges in thickness from 222 to 263 feet, except that the log of the Ydoc well, on the Horse Center anticline, records its thickness as 343 feet. (See p. 160.)

ROCKS EXPOSED

TRIASSIC SYSTEM

CHUGWATER FORMATION

The oldest formation exposed in the area mapped is the Chugwater. The name was proposed by Darton [26] for the series of red beds cropping out along the foot of the Big Horn Mountains. It has been traced northward into Montana and southward into Colorado. Although diagnostic fossils are few in the Chugwater, its age is delimited by the marine Phosphoria of Permian age below and the marine Sundance of Jurassic age above. Vertebrate fossils [27] indicate that at least part of the Chugwater is Triassic in age.

The Chugwater formation crops out in the northern part of the region along the crest of the Horse Center anticline in Tps. 51 and 52 N., R. 101 W., and around the plunging end of the Rattlesnake-

[23] The name Embar formation was abandoned in 1934 by the Geological Survey because the rocks previously so designated were found to constitute two formations—the Permian Phosphoria formation and the Triassic Dinwoody formation. The beds in the Big Horn Basin formerly called Embar are assigned in this report to the Phosphoria. Additional work, subsequent to the writing of this report, has led to doubt concerning the advisability of using Phosphoria here, because the rocks differ decidedly in lithology from the Phosphoria of the typical area and because the term Embar is so well established in local usage. Although it is impracticable to change the text and illustrations of this report, each of the writers in subsequent reports on the Big Horn Basin will assign to the Embar the rocks referred to the Phosphoria in this report.

[24] Darton, N. H., Geology of the Big Horn Mountains: U. S. Geol. Survey Prof. Paper 51, pp. 35–36, 1906. Branson, C. C., Paleontology and stratigraphy of the Phosphoria formation: Missouri Univ. Studies, vol. 5, no. 2, 99 pp., 1930.

[25] Johnson, G. D., op. cit., p. 819.

[26] Darton, N. H., Comparison of the stratigraphy of the Black Hills, Big Horn Mountains, and Rocky Mountain Front Range: Geol. Soc. America Bull., vol. 15, pp. 397–398, 1904.

[27] Mehl, M. G., The Phytosauria of the Wyoming Triassic: Denison Univ. Bull., vol. 38, No. 8, Sci. Lab. Jour., vol. 23, pp. 141–172, 1928; Branson, E. B., and Mehl, M. G., Triassic vertebrate fossils from Wyoming: Science, new ser., vol. 67, pp. 325–326, 1928.

Cedar Mountain anticline at the northwest margin of the area. It consists predominantly of red sandy shales and shaly sandstones and contains some beds of gypsum. Most of the weathered surfaces are brick red in color, although the fresh surfaces are generally orange red. The lamination and regularity of the bedding and the uniformity of its lateral extent suggest that the Chugwater formation is marine.[28] At its top is a massive bed of gypsum ranging from 90 to 100 feet in thickness in the northern part of the area. Along the Shoshone River, however, the thickness of this gypsum bed seems to vary greatly and the contact between the Chugwater and the overlying Sundance appears to be irregular and unconformable. This is probably due to leaching by the river water, because no evidence of disconformity was found where the gypsum was not leached.

No measurement was made of the thickness of the Chugwater formation in this area, but Johnson[29] measured 800 feet of beds in the Chugwater west of Cody. The logs of four wells, however, showed red beds that are presumably part of the Chugwater. The location of these wells and the thickness of the red beds shown in their logs are as follows: Well on the crest of the Spring Creek anticline, 958 feet; well on the Pitchfork anticline, 1,022 feet; well on the Fourbear anticline, 935 feet; well on the South Sunshine anticline, 1,292 feet.

JURASSIC SYSTEM

UPPER JURASSIC SERIES

SUNDANCE FORMATION

The Sundance formation is a marine formation of Upper Jurassic age. Wherever rocks of this age are exposed in Wyoming, the characteristic Sundance has been recognized, except along the western margin of the State. The Sundance has also been recognized in the adjacent States of Montana, South Dakota, and Colorado.

In the region south of Cody the Sundance formation crops out along the crest of the Horse Center anticline in the eastern part of T. 52 N., R. 102 W., and as a thin band on the flanks of this anticline from the northwestern part of T. 51 N., R. 101 W., northwestward to the margin of the area, and along the Shoshone River west of Cody. Characteristically this formation is composed of green shales. greenish-gray sandstones and calcareous sandstones, red shales and sandy shales with veins and thin beds of gypsum, and gray sandy fossiliferous limestones. The Sundance is about 530 feet thick along the Shoshone River just west of Cody.

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[28] Branson, E. B., Triassic-Jurassic "Red Beds" of the Rocky Mountain region: Jour. Geology, vol. 35, pp. 618–627, 1927.

[29] Johnson, G. D., Geology of the Mountain uplift transected by the Shoshone Canyon, Wyo., Jour. Geology, vol. 42, p. 819, 1934.

The lower 70 feet of the formation is composed of alternating limestones, sandy limestones, and clays, which together stand out as a low scarp ridge. The limestones are extremely fossiliferous, and the thinner beds appear to be made up of a mat of shells cemented with calcium carbonate. It is very difficult to obtain a detailed section of this part of the formation because these beds are strongly contorted by the buckling of the underlying 100-foot bed of gypsum at the top of the Chugwater. At a few localities where there is little or no buckling, the Sundance seems to be conformable with the underlying Chugwater formation. This lower 70-foot zone of the Sundance contains an abundance of *Pentacrinus asteriscus* (star-shaped crinoid stems), a few echinoids, both horn and colonial corals,[30] a small species of *Camptonectes*, abundant *Ostrea strigilecula*, and occasional *Lima occidentalis* and *Trigonia quadrangularis*.

About 60 feet of red shale and gypsum overlie the basal sequence of limestone and clay. Together with the overlying green shales these less resistant beds produce valleys in which exposures are very poor. In many places the lower part of the red shale unit contains a rather pure white granular gypsum discolored by the red strata above it. The red shales, sandy in some places, are rather evenly and regularly bedded and are crisscrossed by numerous thin veins of gypsum. No fossils were found nor have any been reported in this sequence of beds.

Overlying the red shale beds are the characteristic green shales of the Sundance, which in the area here described are 250 to 300 feet thick. These shales are green on fresh surfaces, but on weathered surfaces they appear more nearly gray. The green color is probably due to glauconite.[31] In the lower 40 feet of these green shales more sandy or limy beds stand out as ledges in the good exposures. The green shales are very evenly and regularly bedded. In the upper part of these green shales *Gryphaea calceola* var. *nebrascensis* occurs so abundantly that weathered slopes may be actually covered with a paving of these hard and resistant fossils. *Gryphaea* is more abundant in the upper part of the shale, and *Belemnites densus* ("fossil cigar") is relatively abundant in the lower part of the shale. Other fossils commonly encountered in this unit are *Camptonectes bellistriatus* and various species of *Trigonia* and *Cardioceras*.

The topmost unit of the Sundance formation is a gray, somewhat greenish sandstone and shale unit about 100 feet thick that forms a hogback comparable to that formed by the basal limestone unit. The lower half of this topmost unit is more sandy and more resist-

[30] Brainerd, A. E., and Keyte, I. A., Some problems of the Chugwater-Sundance contact in the Big Horn district of Wyoming: Am. Assoc. Petroleum Geologists Bull., vol. 11, pp. 747–752, 1927.

[31] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 92, 1914.

ant than the upper half. The sandstone is calcareous in places, and some layers appear to be entirely made up of the shells of *Ostrea strigilecula*. The upper half of the unit is composed of shaly sandstone and shale, definitely green in some layers. It appears to be completely gradational into the overlying Morrison formation and the contact has been drawn to include all marine beds in the Sundance and to exclude from it, as far as possible, the pale-red shales and fresh-water deposits of the overlying Morrison. In addition to the *Ostrea strigilecula* noted above, this upper zone of the Sundance is characterized by an abundance of *Rhynchonella myrina*. The following section on the Shoshone River 1¼ miles west of Cody is typical of the Sundance in this area.

Section of Sundance formation on Shoshone River[32]

[Measured by D. F. Hewett]

	Feet
Shale, gray, sandy, and sandstone, lower half shaly, upper half firm and massive	42
Sandstone, gray, massive, cross-bedded, with several poorly indurated layers and a number of thin limestone beds composed of *Ostrea* fragments	60
Sandstone, gray, with numerous shale layers	6
Shale, dark	15
Shale, green, highly fossiliferous near the base, becoming sandy above; the upper more sandy portions are uniformly glauconitic	240
Shale, green, sandy, containing a number of fossiliferous layers	22
Shale, green, sandy, with several thin nodular limestones	16
Shale, red, sandy, traversed by numerous gypsum veinlets	48
Gypsum	12
Limestone, gray, fossiliferous, and greenish-gray shale in alternating beds	23
Limestone, gray, fossiliferous	2½
Clay, gray	1
Limestone, gray, fossiliferous	2
Limestone, gray, fossiliferous, and yellowish-gray clay, in alternating layers	3½
Clay, dark	2
Limestone, gray, fossiliferous, composed largely of fossil fragments	5
Clay	3
Limestone, gray, fossiliferous, containing many fragments of fossils	21½
Sandstone, gray, fossiliferous	4½
Clay, gray, compact	1
	530

MORRISON FORMATION

The Morrison formation crops out in a thin band of steeply dipping beds around the Horse Center anticline and extends northwest to the northwest margin of the area. It is exposed also at the center

[32] Hewett, D. F., The Shoshone River section, Wyo., U. S. Geol. Survey, Bull. 541, pp. 92–93, 1914.

of the South Sunshine anticline, along Gooseberry Creek, in T. 46 N., R. 101 W.

The Morrison formation has been recognized throughout most of the Rocky Mountain region. Although it contains too few known fossils for precise correlation, the characteristic lithology has been widely recognized. The Morrison has been assigned by different geologists to the Jurassic, to the Lower Cretaceous, and even to the Upper Cretaceous period; it is now placed by the Geological Survey in the Upper Jurassic.[33]

In the region here described the Morrison seems to be gradational into the Sundance formation below, the contact being drawn at the top of the highest marine bed of the Sundance, which in most places is the base of the first red or variegated shale of the Morrison formation. The contact of the Morrison with the overlying Cloverly is fairly sharp in most places, changing abruptly from the variegated shales of the upper part of the Morrison to the rusty sandstones or shaly sandstones of the Cloverly. The most marked break was found in the northeast corner of sec. 30, T. 52 N., R. 101 W., where the upper 40 feet of the Morrison is cut out by a channel filled with typical sandstones of the Cloverly. At other places no apparent disconformity or unconformity was noted.

According to measurements made, the thickness of the Morrison ranges from 388 feet on the west side of Horse Center anticline to 580 feet along the Shoshone River west of Cody. The accuracy of the measurement on the west side of the Horse Center anticline is doubtful, because the upper part of the Morrison is poorly exposed there and the thickness of the overlying Cloverly is greater than normal or average. The average thickness of the Morrison in the region south of Cody is probably about 500 feet.

The lower half of the Morrison is composed of shales and sandy shales, mainly red, gray, or buff, and zones or lenses of white to light-gray sandstone. In the middle or lower part of the upper half of the Morrison rapid lateral variation is conspicuous. Near or slightly above the middle is a lenticular bed of coarse-grained sandstone containing prominent lenses of conglomerate. Many of the pebbles in the conglomerate are poorly rounded. Most of them consist of chert and quartzite, but a few are limestone. Pebbles a quarter of an inch in diameter are common, and some are as much as a three-quarters of an inch in diameter. This conglomeratic sandstone reaches a maximum thickness of about 100 feet in the northwest part of sec. 5, T. 51 N., R. 101 W., where it forms a conspicuous hogback higher than any of the hogbacks formed by steeply dipping beds on either side

[33] Baker, A. A., Dane, C. H., and Reeside, J. B. Jr., Correlation of the Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: U. S. Geol. Survey Prof. Paper 183, pp. 58–63, 1936.

of it. Along the north flank of the Horse Center anticline the conglomeratic sandstone is absent, and this zone is occupied in some places by one, two, or three beds of light-gray muddy sandstone and in other places entirely by shale. Along the South Fork of Shoshone River the conglomeratic sandstone is sufficiently persistent to be useful as a horizon marker for detailed mapping, particularly in places where the structure is complex. In the upper part of the Morrison is a zone of distinctive lithology that does not occur anywhere else in the section. This zone is made up of clays and shales in variegated bright colors, including pink, mauve, lilac, and red. Near the middle of this zone, but not always at a definite horizon, there may be one or more thin beds of nodular siliceous limestone or concretionary masses of chalcedony. The color of this limestone-chalcedony unit and of its associated shales is their most distinctive feature. Moody and Taliaferro [34] appropriately described them as lilac limestone and lilac shale. Associated with the limestones and shales and also present at other horizons in this variegated shale zone are fragments of unidentifiable bones. The highly polished well-rounded cobbles sometimes called "gastroliths" are abundant in this upper zone of the Morrison. A careful examination of the bedrock, however, does not reveal them in the numbers to be expected from their abundance on the surface, especially along the foot of the slopes. Probably they are concentrated at the surface by the removal of the finer surrounding materials.

The following sections of the Morrison show the character of the formation in the northern part of the area here described.

Section of Morrison formation in secs. 23 and 24, T. 52 N., R. 102 W.

Cloverly formation.	
Morrison formation:	*Feet*
Shale, variegated mauve, purple, red, and gray, with thin beds and concretions of nodular, siliceous limestone	70
Sandstone, coarse, with lenses of conglomerate	24
Shale, gray and red; sandstone, thin, buff	68
Sandstone, light gray to tan, massive in part, thin-bedded in part; extremely cross-bedded in places	85
Shale, red, gray, and light gray; sandy	77
Shale, gray and light gray; sandstone, muddy	47
Sandstone, shaly, tan to buff; shale, green, with lenses of coal not more than 2 inches thick	17
	388
Sundance formation.	

[34] Moody, C. L., and Taliaferro, N. L., Anticlines near Sunshine, Park County, Wyo.: California Univ., Dept. Geology, Bull., vol. 10, p. 450, 1918.

Section of Morrison formation on Shoshone River

[Measured by D. F. Hewett [35]]

	Feet
Shale, maroon and gray, sandy	50
Sandstone, buff	6
Shale, gray, sandy	12
Sandstone, buff	4
Shale, gray, sandy	10
Sandstone, buff, cross-bedded	8
Clay, gray, sandy	50
Sandstone, buff, fine-grained, evenly bedded, and ripple-marked	6
Clay, maroon and yellow, sandy	44
Clay, dark brown to black, containing saurian vertebrae, limb bones, and gastroliths	20
Sand, gray, argillaceous, only locally indurated, containing wood silicified in place as well as rounded pebbles of similar material; carbonized plant remains and small calcareous concretions	50
Clay, maroon, sandy	55
Sandstone, white, homogeneous, only locally indurated	25
Clay, prevailingly gray and olive-colored, but with three broad maroon bands, sandy	100
Shale, green, sandy, transitional to upper sandstone of Sundance formation	140
	580

CRETACEOUS SYSTEM

LOWER CRETACEOUS SERIES

CLOVERLY FORMATION

The Cloverly formation was named by Darton [36] from Cloverly, a former post office on the east side of the Big Horn Basin, and he expressed the opinion that it is equivalent to the Lakota sandstone and Fuson shale of the Black Hills. In a later and more detailed paper, he correlated it with the Dakota sandstone.[37]

In the region south of Cody and, in fact, along a considerable part of the western margin of the Big Horn Basin, the conglomerate or grit beds, which are taken by some geologists, including Darton [38] and Fisher,[39] as the basal unit of the Cloverly formation, are too lenticular to serve satisfactorily as a defining basal bed. In addition, the overlying 100 to 200 feet of strata are lithologically similar to

[35] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 95, 1914.

[36] Darton, N. H., Comparison of the stratigraphy of the Black Hills, Big Horn Mountains, and Rocky Mountain Front Range: Geol. Soc. America Bull., vol. 15, pp. 398–399, 1904.

[37] Darton, N. H., Geology of the Big Horn Mountains: U. S. Geol. Survey Prof. Paper 51, pp. 50–53, 1906.

[38] Darton, N. H., Geology of the Owl Creek Mountains, with notes on resources of adjoining regions in the ceded portion of the Shoshone Indian Reservation, Wyo.: U. S. 59th Cong., 1st sess., S. Doc. 219, pp. 21–22, 1906.

[39] Fisher, C. A., Geology and water resources of the Big Horn Basin, Wyo.: U. S. Geol. Survey Prof. Paper 53, pp. 26–28, 1906.

the Morrison of other regions. From his investigations in the area west of Cody, Johnson[40] concluded that there was no reliable criterion for differentiating Morrison from Cloverly, and therefore did not differentiate them in mapping. Hewett,[41] on the other hand, differentiated Cloverly and Morrison strata, but the term Cloverly as used by him is more restricted in scope than the same term as used by workers preceding and following him in the western part of the Big Horn Basin.

The writers of the present report follow the usage of Hewett[42] and place in the Morrison formation the lenticular conglomerate or grit beds and overlying purple and lilac-colored shales that have previously been included in the lower part of the Cloverly.

The Cloverly formation is exposed in two widely separated parts of the region south of Cody. The larger area of outcrop extends along the flanks of the Rattlesnake-Cedar Mountain anticline and southeastward along the Horse Center anticline, where it can be traced for 15 miles. In the southeast corner of the region the formation is exposed in the deep and narrow valley of Gooseberry Creek, which cuts across the steeply dipping beds of the South Sunshine anticline. (See pl. 20, *B*.)

The Cloverly formation consists mostly of yellow-buff or gray sandstone and gray shale. The topmost and lowermost beds are usually of sandstone and lie adjacent to shale beds of the overlying and underlying formations. Some of the shales within the Cloverly may be reddish in color. The Cloverly sandstones are not continuous for any great distance laterally—they usually grade into sandy shale—and consequently the thickness of the formation as determined on the basis of lithology is not uniform. Along Shoshone River, just west of Cody, Hewett[43] measured a thickness of 110 feet. The thickness as measured by the writers on the Horse Center anticline ranges from 118 feet on the east side of the anticline to 192 feet on the west side. On the South Sunshine anticline about 200 feet of strata are included in the Cloverly. These variations in thickness, however, are not due to true thickening or thinning of the formation but to the inclusion in the Cloverly of greater or smaller thicknesses of the overlying or underlying strata, depending upon the lithology at the particular place examined.

The two following sections of the Cloverly formation, measured on opposite limbs of the Horse Center anticline, show the variation

[40] Johnson, G. D., Geology of the mountain uplift transected by the Shoshone Canyon, Wyo.: Jour. Geology, vol. 42, p. 820, 1934.

[41] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, pp. 95–96, 1914.

[42] Hewett, D. F., op. cit.

[43] Hewett, D. F., op. cit., p. 96.

in lithology of the sandstone and shale units that is characteristic of the formation.

Section of the Cloverly formation in NE¼NE¼ sec. 19, T. 52 N., R. 101 W.

	Ft.	in.
Thermopolis shale.		
Cloverly formation:		
Shale, gray; shale, buff, sandy	10	
Sandstone, soft, buff, with alternating beds of hard brown sandstone	8	
Shale, sandy; shale and shaly sandstone	21	
Sandstone, buff, thin-bedded, resistant; weathers brown		8
Sandstone, shaly, with thin beds of buff and gray sandstone	9	6
Sandstone, buff; weathers brown		6
Sandstone, buff, thin-bedded	6	
Shale, sandy, gray; sandstone, shaly, buff	18	
Sandstone, buff; sandstone, shaly, gray to buff	3	
Sandstone, dark brown, ledge-forming		6
Shale, gray and buff; shale, sandy; ripple-marked sandstone at top	17	
Sandstone, buff, thin-bedded; ripple-marked at top	3	6
Shale, gray and buff; shale, sandy	10	
Shale, sandy, limonitic, brown and yellow; laterally forms brown ironstone		6
Sandstone, buff, ledge-forming	8	
Sandstone, gray, alternating with gray sandy shale	2	
	118	2
Morrison formation.		

Section of the Cloverly formation in sec. 23, T. 52 N., R. 102 W.

	Ft.	in.
Thermopolis shale.		
Cloverly formation:		
Sandstone, tan, thin-bedded, ledge-forming; shale, sandy	85	
Shale, gray and red	36	
Sandstone, rusty tan and gray, thin-bedded; shale, gray, with thin streaks of coal near middle	27	
Shale, gray and red	25	
Sandstone, tan and rusty, cross-bedded	17	
Conglomerate, consisting of limestone pellets as much as ¼ inch in diameter in a quartz-sand matrix	2	
	192	
Morrison formation.		

The sandstone near or at the top of the Cloverly formation is called the Greybull sandstone member.[44] It is an important oil and gas producer in some of the Wyoming fields. The Greybull member stands out prominently in the South Sunshine anticline, in the south-

[44] Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 656, p. 19, 1917.

east corner of the area. It is about 50 feet thick in the exposures north of Gooseberry Creek and is extremely resistant to erosion, so that it stands like a great tilted wall. This sandstone is medium-grained, very hard, and light gray to yellow-buff in color, with some pink and purple streaks. It is slightly cross-bedded, massive, and ripple-marked. South of the creek the sandstone becomes lenticular and softer at the crest of the fold (pl. 20, *B*), and the escarpment outlining the anticline is not as pronounced.

In an earlier publication [45] the base of the Cloverly formation on the South Sunshine anticline has been placed at the base of a clean white quartz sandstone, but the writers of this report believe that this sandstone and the lilac-colored limestone and shale above it should be placed in the Morrison formation. Accordingly, they have placed the base of the Cloverly formation on the South Sunshine anticline above the lilac-colored limestone and shale and about 200 feet below the top of the Greybull sandstone member.

UPPER CRETACEOUS SERIES

THERMOPOLIS SHALE

The Thermopolis shale is most extensively exposed in the northern part of the area—on the flanks of the southern nose of the Rattlesnake-Cedar Mountain anticline and along the Horse Center anticline. The formation is also exposed in its entire thickness in the South Sunshine anticline, in the southeastern corner of the area, and its uppermost part is exposed near the crests of three other anticlines—the Spring Creek, in T. 49 N., R. 102 W., the Pitchfork, in T. 48 N., R. 102 W., and the Fourbear, in T. 48 N., R. 103 W.

The Thermopolis is predominantly a dark-gray to black, nonfissile shale. It contains many beds of bentonite, some of which are a foot or two thick. A fairly persistent sandstone 15 to 36 feet thick, generally known as the Muddy sand (pl. 15, *B*) occurs about 200 feet above the base of the Thermopolis. Marine fossils occur in both the sandstone and the shale. The Muddy sand yields considerable gas in the Grass Creek field,[46] which is in the northern part of the Grass Creek Basin quadrangle (see fig. 10). The section given below, from the top of the Thermopolis shale to the base of the Muddy sand, was measured at the south end of the Horse Center anticline. It is noteworthy that this section reveals 17 beds of bentonite.

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[45] Moody, C. L., and Taliaferro, N. L., Anticlines near Sunshine, Park County, Wyo.: California Univ., Dept. Geology, Bull., vol. 10, p. 450, 1918.

[46] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 13, 1926.

Partial section of Thermopolis shale, from top of formation to base of Muddy sand, measured near center of W½ W½ sec. 8, T. 51 N., R. 101 W.

	Ft.	in.
Shale, laminated, gray to brown	30	
Shale, somewhat siliceous	8	
Bentonite	2	3
Shale, light gray, somewhat siliceous	3	
Shale, poorly exposed in lower half	66	
Bentonite	1	
Shale	5	
Bentonite		4
Shale	8	4
Bentonite, impure	2	6
Shale	1	7
Bentonite		3
Shale	10	6
Bentonite		10
Shale, with iron-stained concretions	3	6
Bentonite	1	1
Shale, with iron-stained concretions	4	
Bentonite		6½
Shale, with iron-stained concretions	12	
Sandstone, shaly, yellowish-greenish-gray	2	6
Shale, with hard brown concretions	57	
Bentonite, impure	7	
Shale	51	
Bentonite		8
Shale	19	
Bentonite		7
Shale	15	
Shale, bentonitic	4	
Shale; brown concretionary sandstone near top	17	
Bentonite	3	
Shale	7	
Shale, bentonitic	2	
Bentonite	2	5
Shale, soft	2	5
Bentonite, thinly laminated		6
Shale		6
Bentonite	1	11
Shale		1
Bentonite	3	10
Shale, soft, bentonitic	4	
Bentonite		8
Shale, dark gray, soft, bentonitic	5	
Shale, fissile, with thin streaks of gray to yellow shaly sandstone	19	
Sandstone, light gray to tan, cross-bedded, ledgy (Muddy sand)	36	
	422	9½

There is no sharp distinction between the upper part of the Thermopolis shale and the lower part of the overlying Mowry shale. As mapped by the writers, the Thermopolis is 600 to 650 feet thick and includes most of the soft, dark-gray shale, whereas the siliceous and brown shales are included in the Mowry. At most places on the Horse Center anticline the top of the Thermopolis was arbitrarily drawn at the base of a resistant tan fine-grained sandstone and sandy shale series which is about 80 feet thick.

A distinctive type of phosphatic concretion is present in the dark shale at the base of the Thermopolis. In some places, owing to their concentration on the surface by weathering and removal of the shale, these concretions are so abundant that they can be picked up by the basketful. Because of their spherical shape and "cauliflower" surface, the concretions are called locally "fossil chestnuts." They range in diameter from ¾ of an inch to 1¾ inches but average about 1¼ inches. Most of the larger ones are in the form of a cluster of several interpenetrating spheres. Their weathered surfaces are light gray, but where they are embedded in the shale their surfaces are dark gray. The central part of the concretions is usually dark brown and has no conspicuous structure, but it is surrounded by a mass of radiating gray or grayish-brown fibers, lighter in color than the inner part and darker than the weathered surface.

These concretions have been studied by McConnell,[47] who found that they consist principally of dahllite, whose composition may be represented approximately by the formula $Ca_{10}CO_3(PO_4)_6$, with perhaps a combined molecule of water.

The base of the Thermopolis in most places is concealed by debris and surface wash from the dip slope of the underlying Cloverly formation. In places where the lower part of the Thermopolis is sandy, the base of the formation is below the lowest dark-gray shale.

MOWRY SHALE

The Mowry shale is exposed on the plunging south nose of the Rattlesnake-Cedar Mountain anticline, on the flanks of the Horse Center anticline, and in the Spring Creek, Pitchfork, Fourbear, and South Sunshine anticlines. (See pls. 18, *B*, 20, *A* and *B*.)

The Mowry is composed almost entirely of shale, a large part of which is hard and siliceous.[48] Much of the shale is brown in color, although some beds are blue and gray. The siliceous beds weather to a light bluish gray or white, and as they are harder than the nonsiliceous beds they usually form the prominent part of the shale outcrop. The siliceous shale is moderately thin bedded, and when it breaks across the bedding it displays a subconchoidal fracture. Fish scales are characteristic of the formation, and many beds of bentonite

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[47] McConnell, Duncan, Spherulitic concretions of dahllite from Ishawooa, Wyo.: Am. Mineralogist, vol. 20, no. 10, pp. 693–698, 1935.

[48] Rubey, W. W., Origin of the siliceous Mowry shale of the Black Hills region: U. S. Geol. Survey Prof. Paper 154, pp. 153–170, 1929.

ranging from less than an inch to 4 feet in thickness are present. In the fine exposure of the Mowry along the road on the west side of the Pitchfork anticline (see section following) 27 bentonite beds, with a combined thickness of 39½ feet, were observed. The Mowry also contains a few thin beds of sandstone.

A very hard bed of sandstone, a foot or two thick, was found to occupy a position ranging from 74 to 87 feet below the top of the Mowry wherever that part of the formation was examined. This bed serves as a good stratigrahic marker, the more so because it lies in a zone about 10 feet thick, of white to light-gray weathered siliceous shale that supports little or no vegetation.

The Mowry is 375 to 425 feet thick. Along Horse Center anticline its base was drawn at the base of an 80-foot unit of light-tan fine-grained sandstone and sandy shale. The top of the formation is placed at the base of the lowest sandstone in the Frontier formation.

Section of Mowry shale, exposed in road cut on west side of Pitchfork anticline, near center of sec. 14, T. 48 N., R. 102 W.

	Ft.	in.
Frontier formation.		
Mowry shale:		
Shale	2	
Bentonite	1	6
Sandstone, hard		3
Bentonite	3	6
Shale and sandstone; shale is laminated and contains fish scales in the dark-brown beds in lower half; fine-grained sandstone throughout unit, particularly in upper half	73	
Sandstone, steel-gray, very hard	1	6
Shale, siliceous, thin-bedded, conchoidal fracture, brownish-gray, weathers to a lighter gray; contains fish scales	5	
Bentonite	3	
Shale, like 5-foot unit above	15	
Bentonite	1	6
Shale, like 5-foot unit above	20	
Bentonite	4	
Shale, like 5-foot unit above	25	
Bentonite		4
Shale	2	6
Bentonite		3
Shale, light grayish-brown, hard; conchoidal fracture; contains fish scales	2	
Bentonite		1½
Shale, like 2-foot unit above	4	
Bentonite		4
Shale, like 2-foot unit above	5	
Bentonite	1	
Shale, like 2-foot unit above	2	
Bentonite		5
Shale, sandy, buff-tan; contains fish scales and weathers blue	3	
Bentonite		4

Section of Mowry shale, exposed in road cut on west side of Pitchfork anticline, near center of sec. 14, T. 48 N., R. 102 W.—Continued

	Ft.	in.
Mowry shale—Continued.		
Shale, bluish-gray	2	
Bentonite		8
Shale, alternating blue and gray	2	
Bentonite		2
Shale	4	6
Bentonite		8
Shale	1	
Bentonite		½
Shale, bluish-gray	2	
Bentonite	2	
Shale; alternating 6-inch beds of blue and gray color	11	
Bentonite	1	3
Shale, sandy, light-gray and buff	5	
Bentonite	1	
Shale, sandy, light-gray and buff	2	
Bentonite		5
Shale, sandy, light-gray and buff	10	
Bentonite	2	6
Shale, silty, siliceous, hard, blue and tan	3	
Bentonite	4	
Shale, sandy, soft, brown; upper 2 feet harder and more sandy	15	
Bentonite	4	
Shale, brown, sandy, soft; at top is a 5-inch bed of hard brownish-gray speckled sandstone, with a calcareous cement; contains fish fragments	9	
Bentonite, white		5
Shale, sandy, gray and tan; slightly nodular	18	
Bentonite	4	
Shale, sandy, medium-gray; near mddle of unit are two 1-inch beds of bentonite 6 inches apart	12	
Bentonite	1	6
Shale, in part hard and sandy	30	
Bentonite	3	
Shale, mostly dark grayish-brown; upper 2 feet contains abundant fish scales; lower half poorly exposed	37	
Concealed	40	
	405	8
Thermopolis shale.		

FRONTIER FORMATION

The Frontier formation crops out in a narrow band on the east side of the Horse Center anticline and over a wide area between the west side of the anticline and the Half Moon fault. It is exposed on the west side of the fault at the north end of the Spring Creek anticline and also around the crest of the main part of that anticline to the southeast. It crops out on the Pitchfork anticline and is the surface formation at many places along the crest of the Fourbear anticline. (See pls. 20, *A*, and 21, *A*.) A narrow band of Frontier is exposed on the north side of Dick Creek, a tributary of Wood River. In the southeast corner of the area the Frontier is exposed not only around the South Sunshine anticline but also on the plunging crest of the Sunshine anticline and along Gooseberry Creek.

The Frontier formation consists of 500 to 600 feet of sandstone and interbedded shale. It contains thick sandstones at or near the top and base and from one to three or more fairly thick sandstone units in the intervening part. The sandstones in the Frontier are lenticular, particularly in the upper part, and some of them are conspicuously ripple marked. (See pl. 16, *C*.) Interbedded between the sandstones are brown or black carbonaceous shale and some gray shale, with locally a few thin lenses of impure coal. In the lower half of the Frontier there are some beds of shale similar to those of the Mowry.

Several beds of bentonite 2½ to 8 feet thick occur in the Frontier. Most of them lie in two zones, one 85 to 140 feet below the top of the formation and the other 90 to 140 feet above its base. (See fig. 11.) The middle half of the Frontier does not seem to contain any very persistent beds of bentonite.

Chert pebbles are present at several horizons but have been seen most often near the top of the formation. Most of them are well rounded and dark on the outside but commonly gray or white on the inside. They range in diameter from less than ¼ inch to 1¾ inches. They commonly occur as layers in both the sandstones and shales, but a few large isolated pebbles were observed in some of the sandstones.

The thickness of the formation, as indicated by the following measurements made in the area, ranges from about 500 to 600 feet: Along Shoshone River, 494 feet; [49] on the Spring Creek anticline, 575 feet; on the Pitchfork anticline, 498 feet; on the Fourbear anticline, 535 feet; on the South Sunshine anticline, about 600 feet.

[49] Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 656, p. 23, 1917.

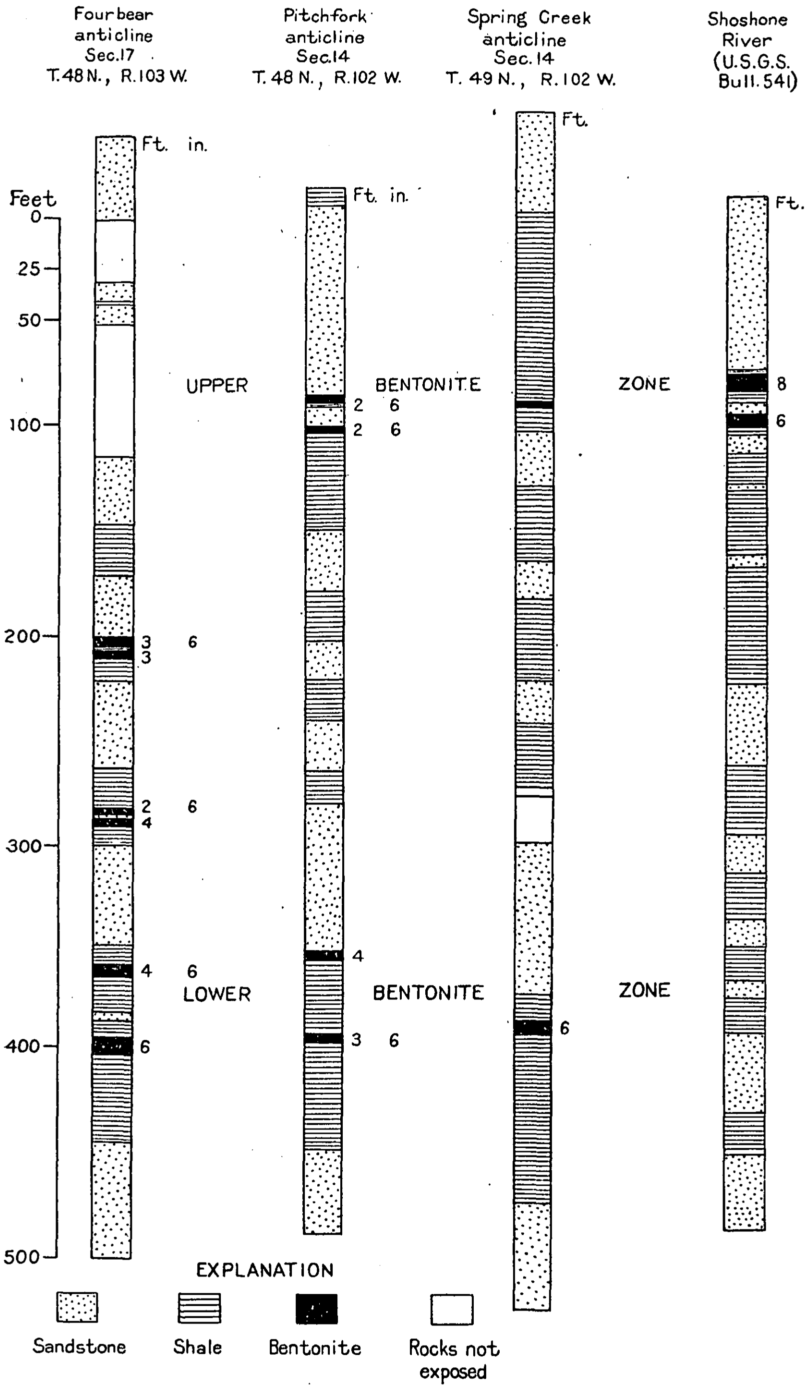

FIGURE 11.—Sections showing position of bentonite beds in the Frontier formation. Each section represents the full thickness of the formation.

246234—41——3

Section of Frontier formation measured on east side of Pitchfork anticline in S½SE¼ sec. 14, T. 48 N., R. 102 W.

	Ft.	in.
Cody shale:		
Shale, dark gray	20+	
Frontier formation:		
Shale, dark gray to black, carbonaceous, with thin streaks of sandstone	8	
Sandstone, light gray, cross-bedded in thin beds, ledge-forming	12	
Sandstone, soft, shaly, light buff; contains a few beds of shale	80	
Bentonite	2	6
Shale, carbonaceous, brown to black	2	
Sandstone, soft in lower part	9	
Bentonite	2	6
Shale, gray, with some brown and black carbonaceous shale	46	
Sandstone, soft; hard ledge 2 feet thick at top	30	
Shale, brown	6	
Shale, siliceous, with carbonaceous fragments; grades into a thin white laminated sandstone at top and base	3	
Shale and sandstone	15	
Sandstone, varies laterally from a soft sand to a hard ledge-forming sandstone	7	
Sand, muddy	11	
Shale, upper part brown to black, lower part brown and carbonaceous	20	
Sandstone, light gray to buff; upper part ledge-forming; lower 13 feet is soft yellow sand	23	
Shale, brown and gray	15	
Sandstone, fine grained, light gray with minute dark laminations; 2-foot bed of hard sandstone at top	19	
Sandstone, muddy, dirty-gray color; contains thin lenses of hard light-gray sandstone that weathers brown	43	
Shale and sandstone, drab	10	
Bentonite	4	
Shale, dark gray; contains some sandy streaks; upper part earthy, with 1-foot bed of hard laminated sandstone at top	28	
Shale, hard, siliceous (?); contains pelecypods and fish scales	7	
Bentonite	3	6
Shale, like 7-foot unit above	52	
Sandstone, light gray to buff, locally ledge-forming; upper two-thirds massive; lower one-third bedded and grades laterally into shale	40	
	498	6
Top of Mowry shale.		

In the vicinity of the town of Basin, on the east side of the Big Horn Basin, the Frontier contains two persistent sandstones—the Torchlight sandstone member, at the top, and the Peay sandstone member at the base. The upper member has been tentatively extended to the west and south sides of the Big Horn Basin, where the top sandstone of the Frontier was designated the Torchlight (?) sandstone member.[50] In the Cody region, however, the sandstones of the Fron-

[50] Hewell, D. F., and Lupton, C. T., op. cit., p. 20.

tier are lenticular and it seems inadvisable at present to extend the use of these names into the area.

Fossils from the upper sandstone of the Frontier formation and the lower part of the Cody shale represent, according to Reeside,[51] a faunal zone that occurs in the Niobrara formation of the Great Plains and contiguous areas. Additional collections made by the writers after the completion of this report and studied by Reeside indicate that the Frontier of the Big Horn Basin is pre-Niobrara in age.

CODY SHALE

The Cody shale crops out over a larger area than any other formation in the region here described. It is well exposed along the Shoshone River, just beyond the northern limit of this region, and the entire formation is fairly well exposed on the east side of the Pitchfork anticline, particularly along the Greybull River. At other places a mantle of soil conceals much of this shale.

The Cody shale was named by Lupton [52] from the town of Cody. It is conformable with both the underlying Frontier and overlying Mesaverde formations. The Cody is predominantly an olive-gray marine shale ranging in thickness from 2,150 to 3,200 feet. The lower third or more is mostly dark-gray shale, whereas the upper third or more is a medium-gray to olive-gray sandy shale, with thin beds of laminated sandstone near the top. (See pl. 16, *B*.) Fossils are common in the lower half of the formation but are rare in the upper 200 to 300 feet.

The thickness of the Cody shale is hard to measure accurately, for where the top and base are exposed observed dips are steep and are not uniform. Measurements on the south and east sides of the Horse Center anticline indicate a thickness of 2,500 feet, and the calculated thickness on the east side of the Pitchfork anticline is 3,100 to 3,200 feet. Hewett measured its thickness as 2,150 feet on Shoshone River,[53] and in the Oregon Basin quadrangle he determined it to be about 2,300 feet. In the Meeteetse quadrangle his estimates of the thickness of the Cody range from 2,200 feet, on the northeast side of the Spring Creek anticline, to 3,400 feet, on the west side of the Sunshine anticline, and his estimate of its thickness on the east side of the Sunshine anticline is 2,500 feet.[54]

A bed of sandstone about 1,175 feet above the base of the Cody

[51] Reeside, J. B., Jr., Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyo.: U. S. Geol. Survey Prof. Paper 150, p. 2, 1927.

[52] Lupton, C. T., Oil and gas near Basin, Big Horn County, Wyo.: U. S. Geol. Survey Bull. 621, p. 171, 1916.

[53] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 98, 1914.

[54] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, pp. 16, 18, 1926.

contains much greensand and is useful as a key bed in the vicinity of the Pitchfork anticline. This sandstone, according to C. S. Ross, who has briefly examined some specimens, is composed of abundant feldspar, probably of volcanic origin, grains of chert, a little quartz, and glauconite which occurs as aggregates in calcite and as grains. The bed has a total thickness of about 9 feet. In places its upper 2 feet is a chert-pebble conglomerate, with abundant shark teeth, some bone fragments, a few vertebrae, and fragments of *Inoceramus*. The bed was found only in the eastern half of T. 48 N., R. 102 W., where the lower part of the Cody has been upturned on the flanks of the Pitchfork anticline. The outcrop of this greensand bed is not shown on the geologic map, plate 11, but during the field mapping it was traced on both the east and west flanks of the Pitchfork anticline. In the eastern parts of sections 3 and 10 it is exposed almost continuously for nearly 2 miles. As shown in plate 13, *B*, the greensand is more resistant to erosion than the adjacent shale and stands out as a narrow ridge a foot or two in height. A lenticular bed of greensand was noted about 500 feet above the persistent bed, and still others probably occur in the Cody shale. In the Oregon Basin quadrangle Hewett [55] found numerous shark teeth in coarsely laminated ripple-marked sandstones about 1,300 feet above the base of the Cody.

Regarding the age of the Cody shale, Reeside [56] says:

> In the upper 350 feet [of the Cody] a fauna of Eagle age was collected near Shoshone River by Hewett. * * * The association of species from the lower part of the Cody shale and the upper sandstone of the Frontier formation identifies a faunal zone that occurs in the Niobrara formation of the Great Plains and contiguous areas; in the middle of the Mancos shale of New Mexico, Utah, and Arizona; and in the upper part of the Colorado formation of Montana.

Additional collections studied by Reeside indicate that the lower part of the Cody includes all of the Niobrara equivalents.

The contact between the Cody shale and the underlying Frontier formation is fairly sharp. The lower part of the Cody is neither sandy nor carbonaceous and therefore is readily distinguishable from the Frontier. In places a bed of shale in which chert pebbles are embedded lies at the base of the Cody shale. This bed ranges in thickness from a knife edge to 2 feet. The pebbles are similar to those in the Frontier formation, previously described. The upper limit of the Cody is not sharply defined. Its upper part is sandy and gradational into the overlying Mesaverde formation. Therefore the top of the Cody is placed at the base of the lowest massive sandstone of the Mesaverde formation.

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[55] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 17, 1926.

[56] Reeside, J. B., Jr., Cephalopods from the lower part of the Cody shale of Oregon Basin, Wyo.: U. S. Geol. Survey Prof. Paper 150, pp. 1–2, 1928.

MESAVERDE FORMATION

The Mesaverde formation in the region here described is confined in general to synclinal depressions. The strip of Mesaverde in the northeast corner of the region lies on the west flank of the Sage syncline; south of this the Mesaverde is exposed around the flanks and plunging end of the Dry Creek syncline; it then continues southward around the end of the Frost Ridge dome, and from there extends southeastward along the southwest side of the small syncline in T. 50 N., R. 101 W. The Mesaverde is also the surface formation in the Rawhide and Sunshine synclines. At one time it probably extended over all of the region south of Cody. Pre-Wasatch erosion removed much of the Mesaverde, particularly over the anticlinal folds.

The Mesaverde formation is made up largely of sandstone but contains shale and several coal beds. The sandstone beds are massive and resistant and most of them form prominent escarpments, particularly the hard basal ones that are underlain by the easily eroded Cody shale, as illustrated in plate 15, *A*. Although massive beds of sandstone are typical, thin-bedded sandstones and beds of shale and sandy shale occur throughout the formation. The thickest coal beds in the Mesaverde occur 75 to 225 feet above the base of the formation. The maximum measured thickness of the coal, including several shale partings, is 8 feet 10 inches, but, as the coal beds are lenticular and commonly contain several partings, the average thickness is considerably less.

The basal unit of the Mesaverde consists of 75 to 125 feet of massive sandstone; in the Rawhide and Sunshine synclines and in the northern part of the area the lower two-thirds of the basal unit is buff-colored and the upper third is white to light gray. Overlying this is the Wilson coal group [57] which is as much as 15 feet thick and contains beds of coal, shale, and bone. A sequence of massive sandstones, some thin-bedded sandstone, and shale, measuring 45 to 105 feet in thickness, overlies the Wilson coal group, and above that sequence is the Buffalo group of coal beds. In the region south of Cody the coal beds in the Buffalo group are thinner and more lenticular than those in the Wilson group. A few beds of coal occur in the strata above the Buffalo coal group, but their thickness in most places is less than 1 foot and only locally is as much as 2 feet. The coal beds are discussed in detail on pages 170–174.

The average thickness of the Mesaverde formation is 1,350 feet. In the Shoshone River section [58] the thickness of the Mesaverde (called at the time it was measured there the † Gebo [59] formation) is

[57] Hewett, D. F., op. cit., p. 95.

[58] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, pp. 56, 100–101, 1914.

[59] A dagger (†) preceding a geologic name indicates that the name has been abandoned or rejected for use in classification in publications of the United States Geological Survey.

1,120 feet. The calculated thickness in the northeast corner of the area is 1,400 feet, and the measured thickness on Cedar Ridge is 1,361 feet. Close agreement in measurements of the thickness of the formation is not to be expected, as neither its top nor its base is sharply defined.

Section of the Mesaverde formation measured southeast of the Frost Ranch, in the NW¼NW¼ sec. 29, T. 51 N., R. 101 W.

	Ft.	in.
Meeteetse formation.		
Mesaverde formation:		
Sandstone, brown	2	
Sandstone, white, thin- to massive-bedded	85	
Sandstone, mostly light-tan, massive	357	
Shale, gray to yellow	36	
Sandstone, massive, tan	49	
Shale, gray	60	
Sandstone, tan, massive	85	
Sandstone, massive, mostly gray to light-tan	110	
Shale, carbonaceous	3	
Sandstone, mostly light-tan, massive	102	
Shale, light gray	34	
Sandstone, massive gray	10	
Shale, gray, with some thin beds of sandstone	145	
Sandstone, massive, gray to light-tan	34	
Coal (Buffalo group, see section 5, pl. 24)	2	3
Unexposed, probably shale and thin-bedded sandstone	25	
Sandstone, massive, buff	10	
Sandstone, thin-bedded; shale	39	
Sandstone, massive, buff	31	
Coal and shale (Wilson group, see section 5, pl. 24)	10	
Shale, gray	7	
Shale, carbonaceous	3	
Sandstone, buff to gray, massive	92	
Shale	4	
Sandstone, buff	2	
Shale, buff, with thin beds of sandstone	14	
Sandstone, buff, massive	10	
	1,361	3
Cody shale.		

As previously noted, the upper part of the Cody shale consists of alternating beds of shale and sandstone, with the proportion of sandstone increasing toward the top. It was found that, with such relationship, the most clearly definable contact between the Mesaverde and the Cody was at the base of the lowest massive sandstone in the Mesaverde. The thin-bedded sandstones below were included in the Cody, although in places their thickness might be 25 feet or more. The top of the Mesaverde formation is placed at the top of the highest group of thick, massive sandstones.

MEETEETSE FORMATION

The Meeteetse formation was named and described by Hewett[60] from exposures at Meeteetse, Wyo., 7 miles east of the area covered by this report. Hewett collected plants from the Meeteetse that were identified by F. H. Knowlton as belonging in the Montana group. The Meeteetse overlies the Mesaverde formation, also in the Montana group, and it is overlain by the Lance formation, of Upper Cretaceous age. The Meeteetse formation has been recognized throughout the southern part of the Big Horn Basin.[61]

The Meeteetse formation is present only in the northeastern part of the area mapped in this report. It crops out in the eastern part, north of the Meeteetse Rim. The small patches of the formation shown on the geologic map (pl. 11) south of the Meeteetse Rim are almost entirely concealed by slope wash.

The lower half of the Meeteetse formation is not well exposed, because its soft clays and sands are so much less resistant than the massive sandstones of the Mesaverde that it everywhere underlies broad valleys bordered by a hogback ridge of the Mesaverde. The best exposures of the upper part of the Meeteetse are in T. 50 N., R. 101 W., where a prominent escarpment is held up by the more resistant sandstone of the overlying Lance formation. (See pl. 16, *A*.) There the upper part of the Meeteetse consists of many light and dark beds in alternating bands. The dark bands are restricted mainly to carbonaceous shales, shale and coal, and the light bands are made up of sand, sandstone, light shale, or clay and various mixtures of these materials. The color or textural bands are not continuous laterally, but they intergrade and pinch out. The coal beds are confined to the upper part of the formation. They are not persistent, and individual beds cannot be correlated from one measured section to the next one. (See fig. 13.) Since the coal beds in the Meeteetse formation could not be traced laterally with any degree of assurance, they are not shown individually. Instead, one line is drawn on the geologic map (pl. 11) to indicate the presence of one or more beds in the upper part of the Meeteetse that have a thickness of more than 18 inches. Since exposures are poor, it is possible that coal beds of comparable thickness may be present beyond the line of outcrop shown.

As already stated, the base of the Meeteetse formation is not well exposed in the region south of Cody. In the adjoining area to the east Hewett[62] noted that the base was generally sharply defined, and

[60] Hewett, D. F., The Shoshone River section, Wyo., U. S. Geol. Survey Bull. 541, pp. 102–103, 1914.

[61] Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 656, p. 27, 1917.

[62] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, pp. 22–26, 1926.

he placed it at the bottom of the lowest gray clay and sandy clay characteristic of the formation. Along the western margin of this area the Wasatch formation, of Eocene age, overlaps the Mesaverde or older formations, and all formations between the Mesaverde and Wasatch are missing. The top of the Meeteetse formation in this area as well as in the adjoining area [63] was placed at the base of the persistent buff to brown sandstone at the base of the Lance. The Meeteetse formation as thus delimited is about 1,150 feet thick in this area.

The following sections show the character of the Meeteetse formation:

Section of the upper part of Meeteetse formation measured in the NE¼NW¼ sec. 5, T. 50 N., R. 101 W.

	Ft.	in.
Lance formation.		
Meeteetse formation:		
Shale, yellowish-tan	17	
Shale, carbonaceous, with thin seams of coal	2	6
Sand, clayey, gray	6	
Sandstone, compact, gray, ledge-forming	1	6
Shale, sandy, gray	4	
Coal	3	
Clay, sandy, gray	14	
Coal	3	
Shale, gray	2	
Coal, dirty	1	
Shale, gray	5	
Shale, carbonaceous	1	
Sand, clayey; clay	24	
Coal, dirty	1	
Shale, carbonaceous	1	6
Sand, gray	11	6
Clay, gray	2	6
Clay, sandy, light-tan	3	
Sand, gray to white	5	6
Sandstone, brown, ledge-forming	1	6
Sand, clayey, light-gray	15	6
Sandstone, brown, ledge-forming		4
Sand, clayey, gray	8	6
Shale, carbonaceous	11	6
Sand, white	3	8
Shale, carbonaceous	6	
Sand, clayey, gray	8	6
Sandstone, brown, ledge-forming		6
Sand, clayey, gray	18	
Sand and clayey sand; light-yellow	22	
Shale, carbonaceous	7	
Sand, light-gray	6	
Shale, carbonaceous	2	6
Sand, mostly white	20	

[63] Hewett, D. F., op. cit.

Section of the upper part of Meeteetse formation measured in the NE¼NW¼ sec. 5, T. 50 N., R. 101 W.—Continued

	Ft.	in.
Meeteetse formation—Continued.		
Shale, carbonaceous	3	
Sand, clayey, and clay, gray	24	
Shale, carbonaceous	1	
Sand, clayey, and clay, gray	24	
Shale, carbonaceous, with thin seams of coal	12	
Shale, gray	3	
Shale, carbonaceous	3	
Sand, white	10	
Shale, carbonaceous	1	
Sand, white	4	
Sandstone, ledge-forming	8	
Sand, clayey, gray	30	6
Shale, carbonaceous	6	
Sand, clayey, gray	30	
Coal, dirty	5	
Sand, clayey, gray, with thin seams of coal	54	
Clay, olive-green	3	
Sand, mostly white with sandstone concretions up to 7 feet in diameter	103	
	564	0

Section of Meeteetse formation along Shoshone River 3 miles east of Cody, Wyo.

[Measured by D. F. Hewett] [64]

	Ft.	in.
Shale, brown, carbonaceous	3	
Shale, gray	6	
Shale, carbonaceous	2	
Shale, gray	8	
Shale, carbonaceous	3	
Sand, olive-colored, argillaceous, with zones of sandy clay	210	
Shale, gray, sandy, with thin beds of carbonaceous shale	60	
Shale, carbonaceous	3	6
Sand, olive-colored, argillaceous	60	
Coal {Coal, 30 inches; Shale, 1 inch; Coal, 23 inches}	4	6
Sandstone, buff and pale olive-gray, argillaceous	750	
	1,110	0

LANCE FORMATION

The Lance formation of Upper Cretaceous age crops out only in T. 50 N., R. 101 W., and a small adjacent part of T. 51 N., R. 101 W. The basal part of the Lance is sufficiently indurated to form the top of the scarp ridge of the underlying Meeteetse. The remainder of the

[64] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 103, 1914.

Lance is very poorly exposed. The following description of this formation was made by Hewett [65] from observations in the adjoining area where exposures are better and more extensive:

Like the underlying Meeteetse formation, the Lance is characterized by dominance of sand and sandstone over clay and shale and general lack of induration of the beds; it contrasts with the Meeteetse in containing practically no coal beds. Furthermore, the colors and the degree of induration of the Meeteetse formation persist throughout the region, whereas these qualities of the Lance formation show considerable variation. * * * Badlands have been developed in a few areas underlain by these beds, but the areas are small and widely separated.

The following section along Shoshone River 4 miles northeast of Cody illustrates in a general way the character of the Lance formation.

Section of Lance (? Ilo) formation on Shoshone River

[Measured by D. F. Hewett] [66]

	Feet
Sandstone, with zone of conglomerate of the Fort Union formation.	
Sandstone, buff and olive-green, unconsolidated, with minor zones of sandy clay	1,555
Shale, carbonaceous	6
Sandstone, olive-green, argillaceous	160
Shale, carbonaceous	4
Clay, gray, sandy	25
Sandstone, white, unindurated	40
	1,790

The thickness of the Lance formation, computed from exposures in secs. 8 and 9, T. 50 N., R. 101 W., is 1,050 feet.

Vertebrate fossils collected from the Lance by D. F. Hewett [67] and identified by C. W. Gilmore indicate that the formation here called Lance is essentially equivalent to the Lance of other regions because of the presence in it of the last of the dinosaur faunas, called the "Ceratops" fauna.

[65] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 26, 1926.

[66] Hewett, D. F., The Shoshone River section, Wyo.: U. S. Geol. Survey Bull. 541, p. 104, 1914.

[67] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin. Meeteetse and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 28, 1926.

TERTIARY SYSTEM

EOCENE SERIES

FORT UNION FORMATION [68]

A bed of conglomerate, sand, and red shale and gray shale about 20 feet thick is exposed under the high gravel terrace in the east half of sec. 9, T. 50 N., R. 101 W. This bed has been provisionally considered as part of the Fort Union formation, as no red shale or conglomerate has been found in the Lance formation. A maximum thickness of 5,600 feet was measured by Hewett [69] along the Shoshone River 5 miles northeast of Cody.

WASATCH FORMATION

The Wasatch formation was named and described by Hayden [70] from exposures near Evanston, Wyo. The name has since been applied to beds at many widely separated localities in Wyoming and adjacent States, although some of the beds called Wasatch in the Big Horn Basin are older than the type Wasatch.[71] In the Big Horn Basin the name Wasatch formation is well established in the literature and has long been applied to the beds overlying the Fort Union formation.

In the area here described the Wasatch formation is exposed along the western margin, adjacent to the lava cliffs, and in a few isolated localities on the Sunshine syncline, in T. 47 N., Rs. 101 and 102 W.

The Wasatch rests on the beveled strata of Cretaceous formations ranging from Cloverly to Mesaverde. There was a relief of 200 or 300 feet on the pre-Wasatch surface on the Fourbear and South Sunshine anticlines (see pl. 21, *A*), and it may have been even greater, because none of the basal conglomerate found in Ts. 48 and 49 N., Rs. 102 and 103 W., is present along these two anticlines. Deposition may therefore not have begun over the axial parts of the Fourbear and South Sunshine anticlines until somewhat later than it did on the lower parts of the pre-Wasatch surface.

The basal conglomerate in the southern part of T. 49 N., Rs. 102 and 103 W., and in the northern part of T. 48 N., Rs. 102 and 103 W. (see pl. 17, *A*), is a conspicuous bed and is composed principally of well-rounded quartzite boulders, as much as a foot in diameter, and to a lesser degree of sandstone, chert, and limestone boulders. The

[68] Paleocene was recognized as a series term in the Tertiary system by the Geological Survey in June 1939, after the preparation of this report. The Fort Union formation of the Big Horn Basin which is referred to the Eocene in this report, is now assigned to the Paleocene.

[69] Hewett, D. F., op. cit., p. 30.

[70] Hayden, F. V., Geological report: U. S. Geol. Survey Terr. 3d Ann. Rept. (1869), reprint 1873, p. 191.

[71] Granger, Walter, On the names of lower Eocene faunal horizons of Wyoming and New Mexico: Am. Mus. Nat. Hist. Bull., vol. 33, pp. 201–207, 1914. Simpson, G. G., Glossary and correlation charts of North American Tertiary mammal-bearing formations: Am. Mus. Nat. Hist. Bull., vol. 67, pp. 113–114, 1933.

material is not well sorted, for the conglomerate contains lenses of sand 3 feet or more in thickness and some beds that consist of a mixture of sand and cobbles. All the boulders except those of quartzite are much weathered, and all except those of limestone may have been derived from conglomerate in the Fort Union formation.

The conglomerate was apparently deposited on a very even floor. In the northern part of T. 48 N., Rs. 102 and 103 W., the boulders and cobbles remain as a capping on hills and level surfaces although the matrix has been eroded away, and because of the resemblance of such gravel-capped hills and surfaces to stream terraces considerable care is required to distinguish these remnants of Wasatch conglomerates from the many terraces of the region. The basal conglomerate is 45 feet thick in the SW¼ sec. 6, T. 48 N., R. 102 W., and probably maintains a comparable thickness over several square miles.

The Wasatch formation is very poorly exposed along most of the western margin of the region because of its position just below the high escarpment made by the more resistant overlying lavas. The clays and loosely consolidated shales and sandstones of the Wasatch slump readily, so that the formation is mostly obscured by landslide material, debris, and colluvium. Its thickness in the northeastern part of T. 48 N., R. 104 W. was computed to be 1,700 feet.

Along Franks Fork on the flanks of the Fourbear anticline the Wasatch is better exposed than along the marginal lava escarpment, and here a maximum discordance of 50° with the underlying Cretaceous sediments was observed. Although the sediments on the Fourbear anticline are dominantly of clays and shales, somewhat sandy in places, they differ markedly in coloring on the two sides of the anticline. The lower part of the Wasatch on the mountainward (southwestern) side of the anticline is vivid in its coloring, with bright red dominating but with pink, orange, and lavender present in addition to the normal gray. On the basinward (east) side of this anticline in contrast the Wasatch is strikingly somber; light gray predominates and is relieved only by subdued shades of red in small areas.

North of Greybull River in T. 48 N., R. 103 and 104 W., the lower 300 feet of the Wasatch consists of red shale and sandstone. These beds are overlain unconformably by a much thicker sequence of sandstones, shales, and clays that are a dull blue-gray in color. This unconformity is displayed north of the Greybull River and west of the Fourbear anticline, where the blue-gray beds dip less than 5° to the west and northwest and the lower red beds dip as much as 20° in about the same direction. This discordance in attitude probably indicates a continuation, throughout the period of deposition of the lower part of the Wasatch, of the structural deformation that produced the Fourbear anticline, followed by a period of little or no structural deformation throughout the remainder of the period of deposition of the Wasatch. (See pl. 21, *A*.)

In the SW¼ sec. 34, T. 47 N., R. 101 W., 8 feet of tuff, containing fossil plants, is present 65 feet above the base of the formation. Considerably more tuff might be found if the Wasatch were studied in more detail.

Fossils collected by J. B. Reeside, Jr., from the lower part of the Wasatch formation near the center of sec. 18, T. 48 N., R. 103 W., were examined by C. L. Gazin, of the United States National Museum, who reports as follows: [72]

> The teeth from the Fourbear structure are *Hyopsodus*, a species more advanced than its Fort Union relatives, and *Hyracotherium* (=*Eohippus*). These are undoubtedly Wasatch in age.

Near this vertebrate-fossil locality, several specimens of *Belemnites densus* and *Gryphaea calceola* var. *nebrascensis* were also collected from a conglomerate bed. These invertebrate fossils are abundant in the Sundance formation of Jurassic age and obviously are reworked from that formation. Their well-preserved character indicates that rocks as old, at least, as the Sundance formation were being eroded not far away at the time of the deposition of the lower part of the Wasatch formation.

TERTIARY SYSTEM (UNDIFFERENTIATED)

TERRACE GRAVELS

Gravels presumably of middle or late Tertiary age floor the flat stream divides and cap isolated high mesas in the region south of Cody. The oldest (highest) gravels are younger than the volcanic rocks (Eocene or early Oligocene) of the Absaroka Mountains, to the west, for the gravels contain material derived from them; and the youngest gravel is older than late Pleistocene, for a terminal moraine of probable late Wisconsin age rests upon it. Because the complete description of these gravels involves so many geomorphologic considerations, the entire sequence of gravel deposits is discussed under the heading "Geomorphology" on pages 152–158.

QUATERNARY SYSTEM

COLLUVIUM

In the region here described there are both large and small areas underlain by heterogeneous aggregates of rock detritus, such as talus and avalanches, resulting from the transporting action of gravity. For such aggregates of rock material the terms "colluvial deposits" [73]

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[72] Gazin, C. L., personal communication.

[73] Merrill, G. P., A treatise on rocks, rock weathering, and soils, pp. 307–308, London, Macmillan Co., 1906.

and colluvium [74] have been proposed. The larger areas of colluvium and also some areas in which the bedrock formations are covered by material of undetermined origin are shown on the geologic map (pl. 11). Landslide material, a type of colluvial deposit, is so distinct and so widely distributed in the region south of Cody that it has been mapped separately.

The largest areas of colluvium shown on the geologic map (pl. 11) are below and adjacent to the high escarpment held up by the volcanic rocks along the western border of the area. Several long, narrow strips of colluvium are also shown along the Meeteetse Rim on the slopes below the high terrace bench.

The colluvial deposits consist of debris derived for the most part from nearby sources. In the deposits near the volcanic rocks, the material is largely a mixture of debris derived from them and from the underlying Wasatch formation. The materials range in size from fine sand to boulders and blocks several feet in diameter. The resulting topography is hummocky.

In places where there are sufficient outcrops to identify with certainty the underlying formation, the geologic map shows that formation as the surface rock; consequently, the areal distribution of the colluvium is not completely shown on the geologic map. The colluvium as mapped represents to a considerable extent areas in which the bedrock is entirely concealed by slope wash or rubble. Small areas of landslide material other than those differentiated on the geologic map (pl. 11), are undoubtedly present, and, if land forms had been mapped in detail, probably some of the deposits here mapped as colluvium would have been separated and mapped as landslide material.

Much of the colluvium is Recent in age and is still in the process of forming, but some of it undoubtedly dates bask to the Pleistocene and some may be older.

From the nature of the colluvium, it is obvious that it has a wide range in thickness. Much of it is 5 to 25 feet thick, but in places it is estimated to be 75 feet thick or more.

LANDSLIDE MATERIAL

Seven distinct landslide masses occur in the region; they are covered by heterogeneous masses of strata that have slumped into their present position because of the action of gravity. These masses range in size from the small block about 300 feet wide and 1,000 feet long in the SE¼ sec. 33, T. 47 N., R. 101 W., to the large mass north of Greybull River in T. 48 N., R. 104 W., which occupies nearly 3 square

[74] Allen, V. T., Terminology of medium-grained sediments: National Research Council, Ann. Rept., App. 1, Report of committee on sedimentation, 1935–36, p. 44, September 1936.

miles. This large landslide mass is nearly a mile wide and extends southeastward from the cliff of volcanic rock for a distance of 2½ miles to the Greybull River. (See pl. 18, *A*.) The difference in altitude from the top of the landslide near the lava cliff to its base at Greybull River is 1,400 feet. As indicated on the geologic map (pl. 11), the Greybull River has been crowded against its south bank by the southward creep of this landslide mass, and the river has gradually shifted its course southward, forming a large bend around the landslide.

Another large landslide mass occurs in the southeast corner of the area, near the center of the northwest quarter of T. 46 N., R. 101 W. It seems apparent from the large curve in Gooseberry Creek that this creek has also been gradually moved from its normal course by the continued crowding of the landslide as it moved in a general northwesterly direction (see pl. 11). The large bend in Elk Creek in the same township suggests that it also has been deflected by the landslide mass of Wasatch strata to the east of it.

Other areas of landslides shown on plate 11 are near the southwest corner of T. 48 N., R. 103 W.; on the crest of the Fourbear anticline in the northeast quarter of T. 47 N., R. 103 W.; in T. 50 N., R. 102 W., just north of the Meeteetse Creek; and near the south line of T. 47 N., R. 101 W., as noted by Moody and Taliaferro.[75]

The topography of the landslide masses in the region south of Cody is hummocky and irregular, with innumerable undrained depressions, some of them as much as several hundred feet across. Although many of these depressions retain some water for a short time immediately after a rain, only a few retain water throughout the year. Outflowing streams are rare, but headward erosion has permitted some streams to eat into the landslides. Most of the rocks involved in the landslides are from the Wasatch formation, but some are volcanic rocks.

The landslides are probably of Recent age, but it cannot be positively stated that they may not have begun in late Pleistocene time. The landslide north of Greybull River in T. 48 N., R. 104 W., is later than the Sunshine terrace and also later than the higher alluvial terraces, for example, the Greybull terrace of Hewett.[76] Evidence that movement is still in progress is given in a few places by trees that have been tilted from their normal vertical position and also by the fact previously noted that in some places the landslide material extends down to and forms the banks of perennial streams, with no alluvial deposits or flood plain intervening.

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[75] Moody, C. L., and Taliaferro, N. L., op. cit., pl. 38.

[76] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 7, 1926.

ALLUVIUM

Although narrow bands of alluvium are present along most of the permanent and many of the intermittent streams, these bands were wide enough and continuous enough to be mapped only along Greybull and Wood Rivers and a few other streams. Alluvium is present along Shoshone River, but in such small discontinuous patches that it was not mapped. The alluvium consists dominantly of silts, sands, and clays, but includes also some gravel. Along Greybull and Wood Rivers the alluvium as mapped occupies a position as much as 50 feet above stream level, with its outer limits 80 feet or more above the streams. At several places along Greybull River it includes a well-defined bench 40 to 50 feet above the river, and another about 15 feet above the river. In some places the areas shown on plate 11 as alluvium could thus be mapped as an alluvial terrace similar to the Greybull terrace of Hewett.[77] The higher bench may possibly represent the Cody terrace along the Shoshone River.

Alluvial lands are the most valuable lands for agriculture in the region, not only because of their rich soil but because they can be irrigated without excessive cost.

IGNEOUS ROCKS

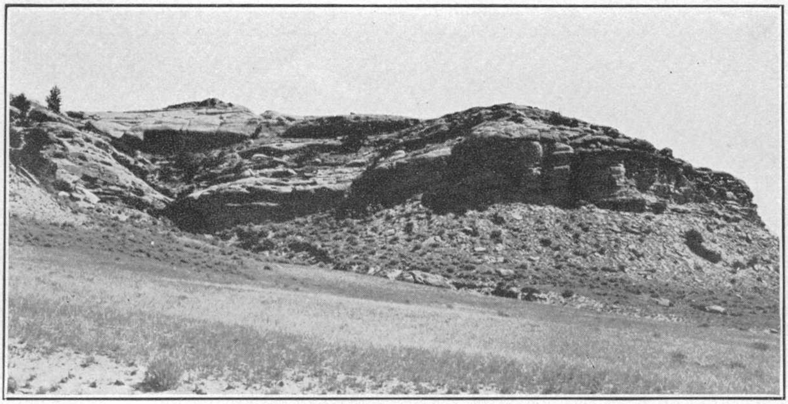
LAVA FLOWS

Volcanic rocks occur along the west and south borders of the area and range from a thousand to several thousand feet in thickness (see pl. 21, *B*). In the Ishawooa and Crandall quadrangles, west of this area, the volcanic rocks of the Absaroka Mountains have been divided into several groups.[78] Most, if not all, of the lavas in the region here described belong to the early basic breccia group. So far as known, these volcanic rocks are andesitic breccias and porphyritic andesites, usually dark in color and consisting of both coarse and fine material.

Three thin sections of the andesites were examined by J. C. Reed. He found that in general the groundmass consists mostly of plagioclase (oligoclase to andesine), considerable pyroxene, small grains of magnetite, and some biotite, chlorite, and serpentine. The phenocrysts are pyroxene, feldspars (some oligoclase-andesine, others altered to serpentine), goethite (?), and a few large crystals of magnetite.

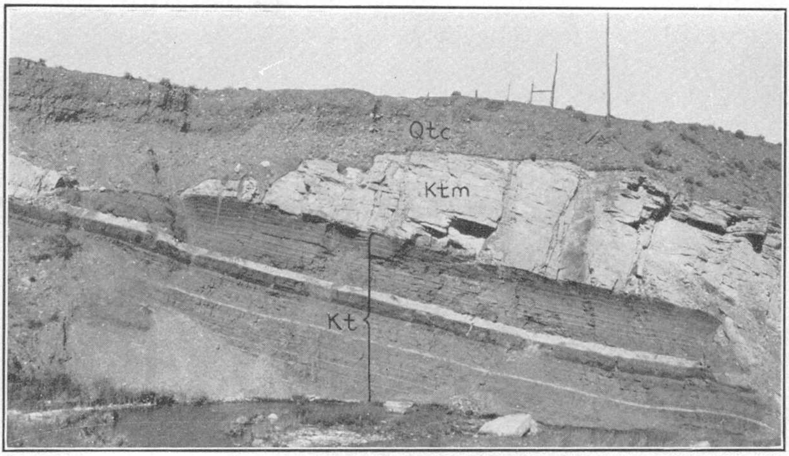
Later field work of Pierce to the west of this area shows that there the "early basic breccia" is not composed entirely of surface flows but also of intruded materials in the form of fissure filling, plugs, and small sills. It seems likely that this is also true along the southern border of the mapped area.

[77] Hewett, D. F., op. cit., p. 7.
[78] Hague, Arnold, U. S. Geol. Survey Geol. Atlas, Absaroka folio (No. 52), 7 pp., 1899.



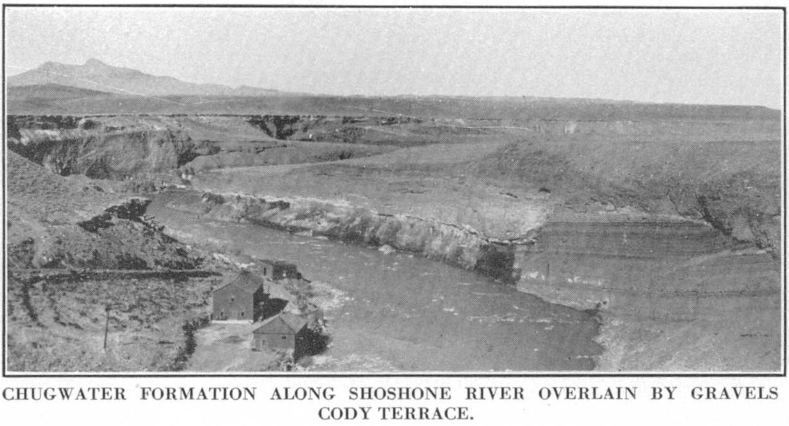
A. BASAL SANDSTONE OF MESAVERDE FORMATION AND UPPER PART OF CODY SHALE.

In the southeast corner of sec. 28, T. 49 N., R. 101 W.



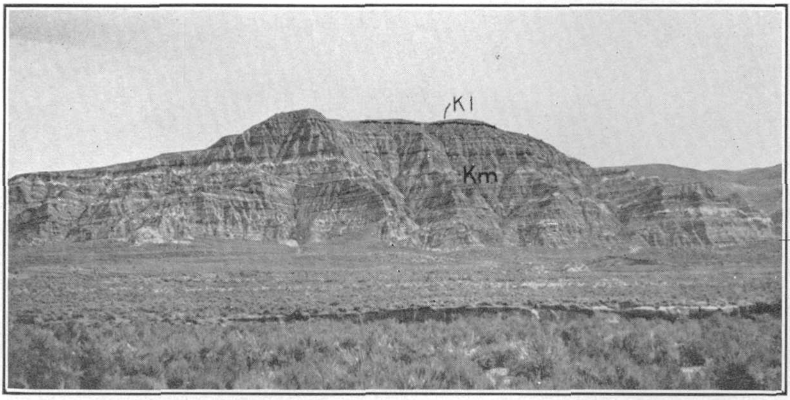
B. MUDDY SAND (Ktm) IN LOWER PART OF THERMOPOLIS SHALE (Kt) OVERLAIN BY GRAVELS OF THE CODY TERRACE (Qtc).

On the northwest side of Sulphur Creek, along U. S. Highway 20, a quarter of a mile southwest of Cody.

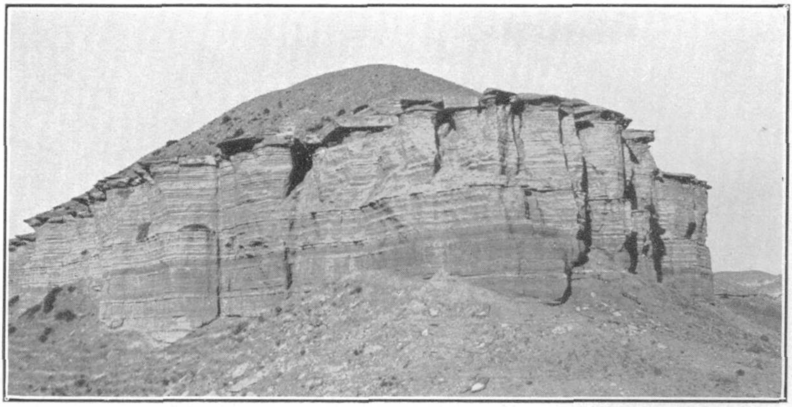


C. CHUGWATER FORMATION ALONG SHOSHONE RIVER OVERLAIN BY GRAVELS OF CODY TERRACE.

Powell terrace in center background, Heart Mountain on left skyline, De Maris Springs along river.

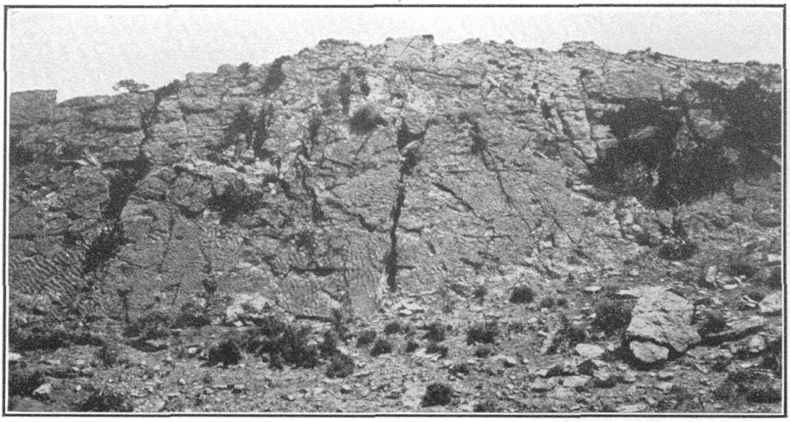


A. UPPER PART OF MEETEETSE FORMATION (Km) IN NORTHWESTERN PART OF T. 50 N., R. 101 W., CAPPED BY THE LANCE FORMATION (Kl).



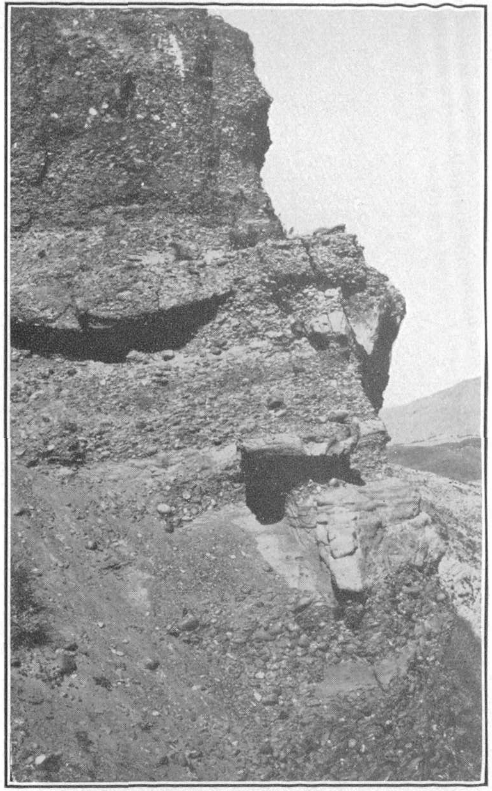
B. THIN BEDS OF SANDSTONE ALTERNATING WITH SHALE AND LAMINATED SANDY SHALE IN UPPER PART OF CODY SHALE.

SW ¼ sec. 3, T. 48 N., R. 102 W.

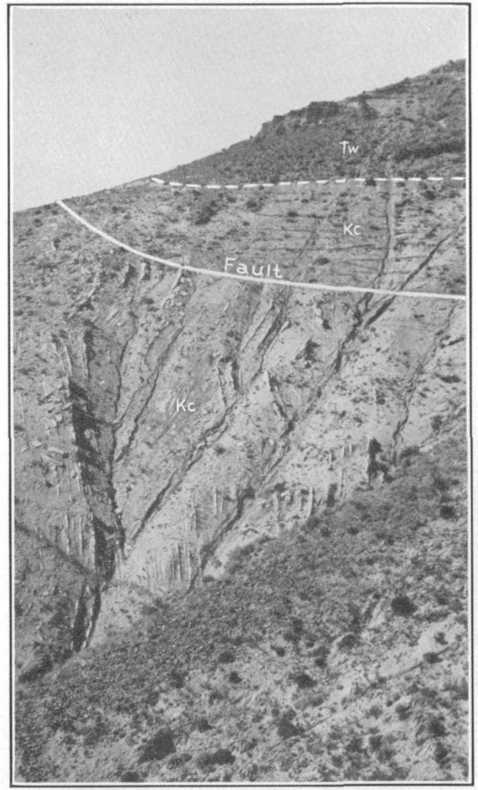


C. RIPPLE-MARKED SANDSTONE IN FRONTIER FORMATION.

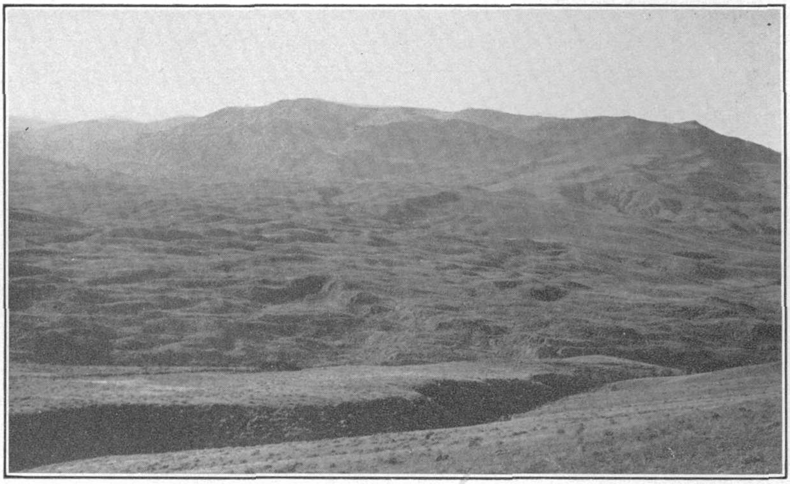
On the west limb of the Pitchfork anticline, SW ¼ sec. 11, T. 48 N., R. 102 W.



A. BASAL QUARTZITE CONGLOMERATE OF THE WASATCH FORMATION IN W½ SEC. 6, T. 48 N., R. 102 W.

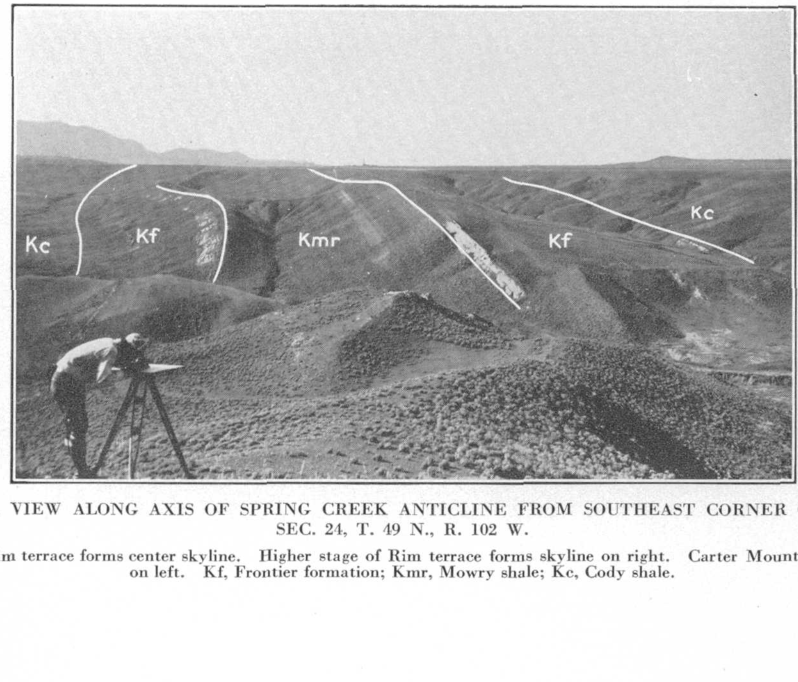


B. THRUST FAULT IN CODY SHALE (Kc) OVERLAIN BY BASAL CONGLOMERATE OF THE WASATCH FORMATION (Tw) IN SEC. 6, T. 48 N., R. 102 W.



A. LANDSLIDE IN FRONT OF LAVA ESCARPMENT.

In T. 48 N., R. 104 W. Viewed from the south side of Greybull River.



B. VIEW ALONG AXIS OF SPRING CREEK ANTICLINE FROM SOUTHEAST CORNER OF SEC. 24, T. 49 N., R. 102 W.

Rim terrace forms center skyline. Higher stage of Rim terrace forms skyline on right. Carter Mountain on left. Kf, Frontier formation; Kmr, Mowry shale; Kc, Cody shale.

The age of the early basic breccia was first considered as Miocene (Neocene) on the basis of the Lamar flora from the Yellowstone Park region.[79] As early as 1909, Cockerell[80] questioned the Miocene age of the Lamar flora and concluded that it was upper Eocene in age or at least older than Miocene. From a study of the geologic history of the Grand Canyon of the Yellowstone, Jones and Field[81] concluded that the designated age of the Tertiary volcanics must be set back to allow time for the complex series of events that have taken place. Recent work by C. B. Read[82] indicates that the Flora from the Lamar River is upper Eocene or lower Oligocene in age. Accordingly, the early basic breccia is here tentatively assigned an upper Eocene or lower Oligocene age.[82a]

DIKES

Four igneous dikes are present in the region south of Cody. The longest is in T. 47 N., R. 102 W., and has a length of nearly 4 miles. Two of the others are in T. 48 N., R. 104 W., and the fourth is in T. 47 N., R. 103 W. All these dikes trend northeastward.

The dikes differ from the volcanic rocks in that they do not contain breccia fragments, but in composition they are similar to the lavas. Four thin sections of the dike rocks were examined by J. C. Reed. He reports that they are andesites. Two specimens are porphyritic. The groundmass is composed principally of plagioclase and pyroxene, with some serpentine, and crystals of magnetite. Phenocrysts include plagioclase, biotite, hornblende, and augite.

None of the dikes in the area mapped were traced to the lava flows, so that their relative age is not determinable; but field studies in the area to the west show that there the dikes cut the early basic breccia and therefore are younger than the breccia.

STRUCTURE

GENERAL FEATURES

The Big Horn Basin is not only a large topographic basin but a great structural basin as well, bounded on the east by the Big Horn

[79] Hague, Arnold, Weed, W. H., and Iddings, J. P., U. S. Geol. Survey Geol. Atlas, Yellowstone National Park folio (No. 30), p. 2, 1896.

[80] Cockerell, T. D. A., The Miocene trees of the Rocky Mountains: Am. Naturalist, vol. 44, p. 45, 1910.

[81] Jones, O. T., and Field, R. M., The resurrection of the Grand Canyon of the Yellowstone: Am. Jour. Sci., 5th ser., vol. 17, pp. 260–278, 1929.

[82] Read, C. B., Fossil floras of Yellowstone National Park, Part 1, Coniferous woods of Lamar River flora: Carnegie Inst. Washington Pub. 416, p. 7, 1933.

[82a] Since this report was prepared G. L. Jepson (see Geol. Soc. America Bull., vol. 50, No. 12, pt. 2, p. 1914, 1939) found vertebrate fossils in the tuffaceous sediments near the base of the early basic breccia. He suggests the beds are "not older than late Early Eocene and may be of Middle Eocene age."

Mountain uplift, on the south by the folded rocks forming the Owl Creek Mountains, and on the west by the volcanic rocks of the Absaroka Mountains.

The region here described is a part of the western margin of the Big Horn structural basin (see fig. 10). As is true also in other marginal areas of the basin, there are many pronounced anticlinal and synclinal folds, some of which have considerable structural relief. The maximum structural relief, from the lowest syncline to the highest anticline, is 9,000 feet. The principal folds in this area are shown in plate 19, as are also those in the area to the east. The general trend of the folds is northwestward.

Both the anticlines and synclines are sharply folded, the intensity or tightness of the folding increasing from east to west. In the eastern half of the area shown in plate 19, dips of the folded strata range from 10° to 35°, whereas in the western half dips of 30° to 70° are common.

Remnants of the Heart Mountain overthrust lie just beyond the northwestern part of the area. A short distance northwest of the southwest corner of T. 51 N., R. 102 W., there is a mass of Madison limestone that rests on Cody and Wasatch strata. It seems fairly certain that at one time an overthrust mass extended into part of the area and that this mass has been removed by erosion.

METHOD OF STRUCTURE CONTOURING

The structure of the region south of Cody is shown on plate 12 by means of structure contours drawn on the top of the Frontier formation at intervals of 200 feet. Such contours are admirably suited for portraying the structure of the region except in localities where the dips are extremely steep. No serious difficulty is encountered in converting altitudes to a common datum for localities where the dips are not more than 35°, but for localities where the dips are 45° to 70° or more, several factors that cannot be properly evaluated enter into the conversion computation. The principal difficulty in contouring when dips are steep is the determination of the proper allowance to make for the thickening and thinning of incompetent beds on the axes and flanks of folds. After some experimentation, the writers concluded that the most satisfactory procedure is that recommended by Rubey,[83] in which the vertical distance to the datum bed is considered equal to the normal stratigraphic thickness of the beds involved, although it was recognized that the procedure was inconsistent with an assumption used in calculating the thickness of

[83] Rubey, W. W., Determination and use of thickness of incompetent beds in oil field mapping and general structural studies: Econ. Geology, vol. 21, no. 4, p. 345, 1926.

certain formations. The "normal stratigraphic thickness" of a thick formation such as the Cody shale is not known, because its thickness is determinable only on the flanks of folds, and the common methods for calculating it are all based upon an assumption of parallel (concentric) folding.

In the drawing of the contours it has been assumed that the axial planes of the folds are vertical. This assumption has been made because it is felt that the field observations on the axial planes in several folds have little significance, a fact that seems to be demonstrated by a reversal in the inclination of the axial planes in different parts of the Pitchfork and Fourbear anticlines and by a downward change in direction of the axial plane of the Horse Center anticline from a westerly inclination at the top of the fold to an easterly inclination at the lowest depth observable. Most, if not all, of the axial planes of the folds may have had an original northeasterly inclination, as discussed later. If so, then this should be a controlling factor in contouring, regardless of the few observations that can be made on the relatively small vertical exposures of surface beds. But, in the absence of concrete information concerning the inclination of the axial planes at depth, the contours are, as a matter of convenience, drawn on the assumption—perhaps erroneous—that the axial planes are vertical.

ANTICLINES

As shown on plate 12, the region south of Cody contains seven separate anticlinal structures. From north to south they are the Horse Center anticline, the Half Moon faulted fold, the Frost Ridge dome, the Spring Creek anticline, the Pitchfork anticline, the Fourbear anticline, and the South Sunshine anticline.

HORSE CENTER ANTICLINE

The crest of Horse Center anticline, which trends northward through the eastern part of sec. 6, T. 51 N., R. 101 W., and the center of sec. 31, T. 52 N., R. 101 W., forms a nose at the southern end of the much larger and higher Rattlesnake-Cedar Mountain anticline, which adjoins the northwest corner of the area here described. Near the crest of the anticline the west limb is steeper than the east limb, but away from the crest the dips become lower on the west flank. This suggests that the axial plane curves downward. The beds on the east flank dip from 60° to 85° except in the eastern part of sec. 20, T. 52 N., R. 101 W., where the Frontier formation is slightly overturned. A structural saddle more than 1,000 feet below the highest point on the Horse Center anticline separates this anticline from the Rattlesnake-Cedar Mountain anticline. The anticline has the greatest structural relief of all those in the area (see pl. 12). The structural relief in the 2 miles between the crest of the anticline and the trough of the Dry Creek syncline on the southwest, along the line of structure section A–A′, is 5,000 feet. The east limb of the anticline descends 8,000 feet in 2 miles.

The red beds of the Chugwater formation are exposed along the crest of the anticline, and the harder beds of many younger formations form hogbacks on the flanks.

HALF MOON FAULTED FOLD

The Half Moon fold is cut by a fault that trends southeastward along the crest, from the center of sec. 4 to the southern border of sec. 23, T. 51 N., R. 102 W., where it dies out abruptly. The fault may extend northwest of sec. 4, but surficial deposits conceal the bedrock. Although the fault passes into an anticline at its southern end, it is not possible to say that an anticline is present throughout the length of the fault. On the east side of the fault the sandstones of the Frontier formation dip eastward, but on the west side the Cody shale only is present at the surface and the few available strike and dip readings do not indicate that it is the west limb of a simple anticline. Because of the extensive cover of terrace gravels and the poor exposures of Cody shale in the western half of T. 51 N., R. 102 W., the writers do not believe that it will be possible to determine satisfactorily from surface exposures alone the details of this faulted fold.

FROST RIDGE DOME

The Frost Ridge dome is a low, somewhat elongate dome whose crest is in the northwest part of T. 50 N., R. 101 W. Northwestward it ends abruptly at the northwest corner of the township, but southeastward it can be traced nearly across the township. The rocks of the Meeteetse and Lance formations crop out at the surface over most of the dome.

SPRING CREEK ANTICLINE

The Spring Creek anticline extends southward and southeastward from the center of T. 50 N., R. 102 W., through T. 49 N., Rs. 101 and 102 W., to and beyond the eastern border of this area. A sag or structural saddle in secs. 34 and 35, T. 50 N., R. 102 W., separates two structural highs on the crest. The northern and smaller structural high is faulted on the east side of the crest, near the SW¼NE¼ sec. 27, but the extent of the fault, both to the north and to the south, is unknown on account of the covering of colluvium and terrace gravels, which also conceal much of the western flank of the anticline.

PITCHFORK ANTICLINE

The Pitchfork anticline has a closure of 1,500 feet or more and reaches its highest altitude in T. 48 N., R. 102 W. The rocks that crop out on it form a topographic ridge that rises above the general level of the surrounding country (see pl. 20, *A*). The oldest formation exposed at the surface is the uppermost part of the Thermopolis shale, which crops out in the NW¼ sec. 14; the Mowry shale crops out in a narrow strip to the north and south-southeast, and also in two small areas farther north; and the Frontier formation, which is conspicuously exposed along the flanks, contains resistant sandstones that give the anticline its ridgelike form. (See pl. 16, *C*.)

As shown in plate 12, the crest of the Pitchfork anticline is bow-shaped; it trends almost due south at its north end, but farther south it bends gradually to the south-southeast and then to the southeast. The anticline is decidedly asymmetrical, in general, with the west side much steeper than the east. In detail, however, there is an exception to this, not evident from the structure contours, in sec. 2, T. 48 N., R. 102 W., where the crest, if followed toward the north, turns sharply to the east for 700 feet and then continues its northward trend. Coincident with this change in position of the crest there is a reversal in asymmetry, with the east side of the anticline showing steeper dips than the west side. This reversal in direction of asymmetry seemingly takes place as the Pitchfork anticline approaches the steeply folded beds in the Rawhide syncline. It seems likely that this reversal of asymmetry and change in the position of the crest of the anticline is the result of movement similar to the movement that has formed the faults, along whose north sides there has been eastward movement.

Six transverse faults with northeast trend displace the strata on the Pitchfork anticline. They are tear faults, in which the principal movement seems to have been horizontal. These faults are discussed in more detail on page 149.

FOURBEAR ANTICLINE

The Fourbear anticline is a long, narrow curving fold in the southwestern part of the region here described. All of it is not revealed, for both ends are concealed by the little-deformed Wasatch formation and later deposits. From the west-central part of T. 48 N., R. 103 W., it extends in a straight line southeastward to sec. 3, T. 47 N., R. 103 W., and thence east-southeast through secs. 2, 11, and 12 of this township to sec. 7, T. 47 N., R. 102 W., where it turns south as a result of displacement along a northeastward-trending fault in sec. 17. On the southeast side of this fault the axis of the anticline is displaced about 1,700 feet to the southwest. From that point the anticline runs south-southeast for more than a mile before its crest is completely covered by the Wasatch formation, but the northeast flank, in which the Frontier formation is revealed, can be traced a mile farther to the southeast along the margin of the Wasatch formation.

Dips of 70° or more on the Mowry and Frontier formations along the northeast flank of this anticline are confined to a small area about 1 mile south of the Greybull River. Along most of the remainder of the anticline the dips do not exceed 50°. As a whole, from the northern end of the Fourbear anticline to the vicinity of Franks Fork, the anticline is asymmetrical in cross section, with the steeper dips on the southwest flank; dips of 29° to 41° are common on that flank, whereas on the northeast flank dips of 14° to 30° prevail. Eastward and southeastward from the vicinity of Franks Fork to the fault in sec. 17, T. 47 N., R. 102 W., the northeast flank is the steeper of the two, with the dips averaging 25° to 50° and some of them reaching more than 70°; the southwest flank generally has dips of less than 25° but in places they are as much as 50°. South of the fault the anticline is symmetrical, and the dips range from 12° to 30° at most places.

The Thermopolis shale is exposed along the crest about a mile south of the Greybull River. Elsewhere the Mowry and Frontier are the surface formations and outline the anticline (see pl. 21, *A*). In places the Cody shale flanks the northeast part of the anticline, but the Wasatch overlaps the Frontier nearly everywhere on the southwest margin and extends across the axis in several places.

SOUTH SUNSHINE ANTICLINE

The South Sunshine anticline is the most picturesque fold in the area. It stands out in relief not only because of its hard sandstone bed but also because of the deep and narrow valley of Gooseberry Creek, which cuts across its highest part (see pl. 20, *B*). The anticline is asymmetrical; the beds on its east flank commonly dip from 60° to 70°, whereas most of the beds on its west flank dip from 25° to 35°. Just north of the north line of T. 46 N., R. 101 W., the anticline dies out by plunging downward at a dip of about 50°. The extent of the anticline southeastward beyond the middle of the township is not known because of the cover of Tertiary rocks. The northeast flank of the anticline is much steeper than the southwest flank and descends to a small sharp syncline which plunges steeply to the southeast.

The Morrison, the oldest formation exposed in the anticline, crops out only in a small area along Gooseberry Creek, but younger strata—the Cloverly, Thermopolis, Mowry, and Frontier formations—are also exposed. The Wasatch formation rests unconformably on the older strata and conceals their structure except in the valleys of Gooseberry and Elk Creeks and other streams.

SYNCLINES

The three most prominent synclines in the area are the Dry Creek, Rawhide, and Sunshine synclines. (See pl. 12.) The Dry Creek and Rawhide synclines both of which extend beyond the eastern border of the area here discussed are 15 and 12 miles long, respectively. The Sunshine syncline, which is entirely within the area, is almost 12 miles long. A somewhat unusual feature of these synclines is that the inclination of the strata on their limbs does not lessen appreciably toward the axes—that is, the normal or average dip of each limb continues without noteworthy flattening to the axis of the syncline. The structurally lowest point of the area is in the trough of the Dry Creek syncline, along the east border of the area, in T. 50 N., where the Frontier formation is approximately at sea level. The trough of the Dry Creek syncline rises to the northwest.

The Rawhide syncline is distinctly asymmetrical, the dips on the northeast flank ranging from 35° to 50°, whereas those on the southwest flank commonly range from 10° to 15°. The trough rises rather rapidly to the northwest and pinches out between the Pitchfork and Spring Creek anticlines.

A striking feature of the Sunshine syncline is the general **S**-shape of its axis and the resulting crescent shape of its lower part, which gradually changes its trend 90°—from southeast to southwest. The trough of the syncline parallels the crest of the Pitchfork anticline less than a mile to the northeast and is 2,800 to 3,600 feet structurally below the crest of the anticline. The dips on the east side of the Sunshine syncline are steep, commonly ranging from 40° to 64°, whereas most of those on the west limb range from 7° to 15°.

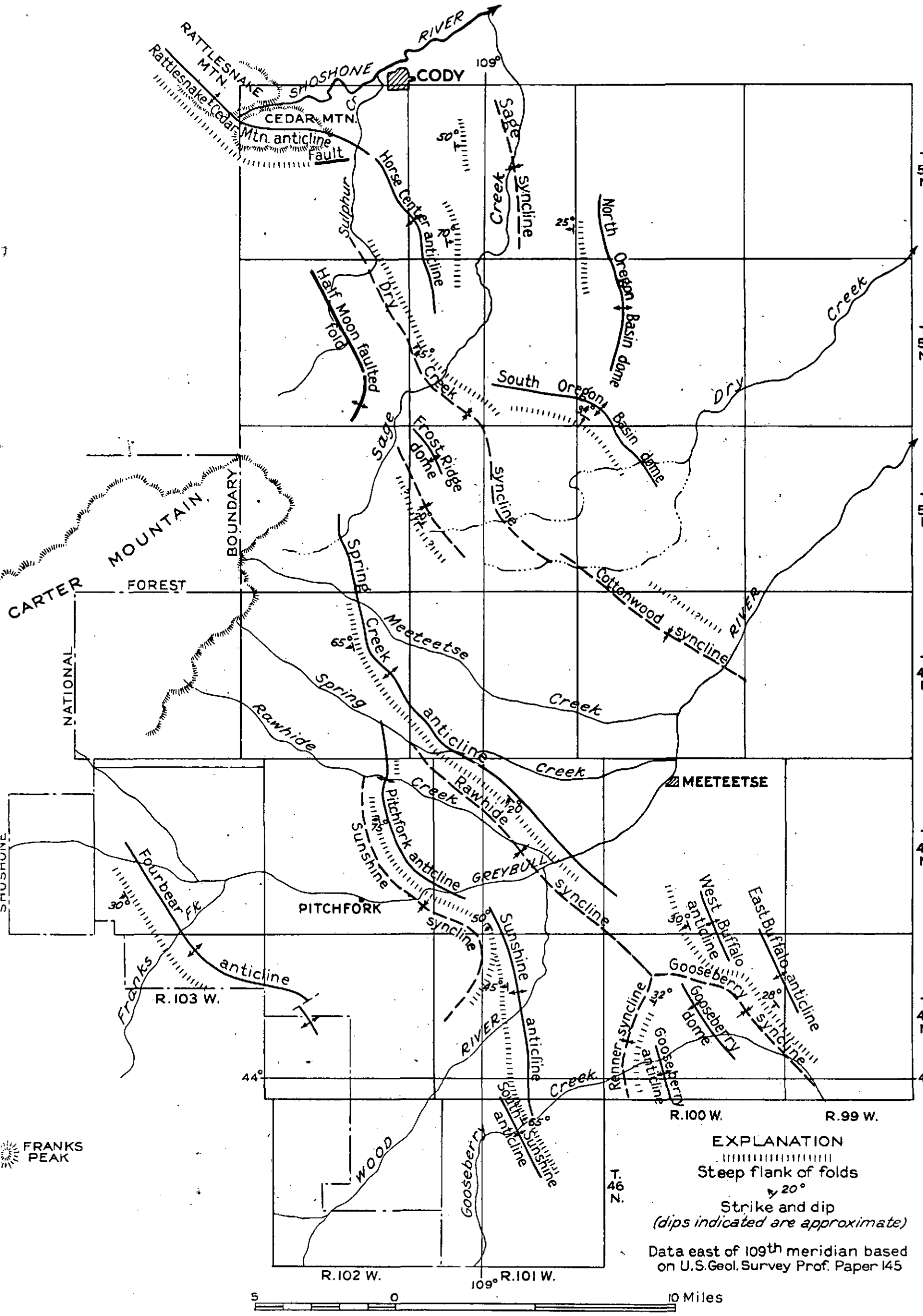
ASYMMETRY OF THE FOLDS

The asymmetry of the prominent folds of the region, as well as those lying east of it, is shown on plate 19. Of the folds shown on the plate, 9 anticlines are steeper on their west flanks and 6 synclines are steeper on their east flanks, whereas 2 anticlines are steeper on their east flanks and 2 synclines are steeper on their west flanks. Thus, 15 folds have a theoretical northeast or basinward inclination of their axial planes and 4 folds have a southwestward inclination.

The 4 folds that have southwestwardly inclined axial planes are the Horse Center and South Sunshine anticlines, the Sage syncline, and an unnamed syncline southwest of Frost Ridge dome. Horse Center anticline is a continuation of the Rattlesnake-Cedar Mountain anticline, which is very strikingly asymmetric, with the southwest limb much steeper than the northeast one. It seems quite probable that at one stage in the folding of the Rattlesnake-Cedar Mountain-Horse Center structure its crest formed a fairly straight line, but that further deformation produced the bend from a northwesterly to a westerly direction now existing. If so, then the part of the fold called the Horse Center anticline most likely had an original basinward inclination of the axial plane, which later was reversed in the upper part as the area became more tightly folded. The small anticline and syncline shown on plate 11 about 3 miles southeast of Cody seem to be only superficial folds, which may well have been formed in response to additional compressive force on the east limb of the Horse Center anticline. The direction of asymmetry of the South Sunshine anticline can also be considered as reversed by later compressive stress. As shown by structure contours on plate 12, both limbs of the anticline are steep, with a sharp syncline passing between the Sunshine and South Sunshine anticlines. In that zone the beds are tightly compressed. The north end of the South Sunshine anticline is paralleled by a small, sharp anticline, which is probably of only surficial extent, and is similar to the one noted above in association with the Horse Center anticline. It is indicated by an anticlinal axis on plate 11 but is too small to show by structure contours. The asymmetry of the Sage syncline seems to bear a closer relation to the east flank of the Horse Center anticline, which has already been discussed, than to the synclinal fold. The syncline southwest of the Frost Ridge dome is not a clear-cut exception to the regional direction of asymmetry, for, as shown by the contours on plate 12, the fold is not distinctly defined and the difference in dip between the two limbs is slight. The conclusion therefore seems justified that the compressive force which produced the folds imparted to them an original asymmetry in accordance with which their axial planes were inclined northeastward toward the Big Horn Basin.

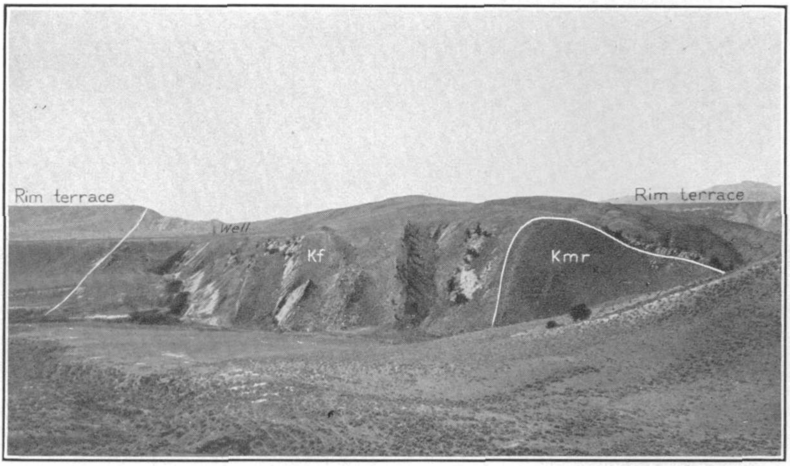
FAULTS

Half Moon fault.—The Half Moon fault extends southeastward through the central part of T. 51 N., R. 102 W. Although the south end of this fault is partly obscured by gravel deposits, it seems definitely to pass into a plunging anticline near the south line of sec. 23, T. 51 N., R. 102 W. It can be traced northwestward to sec. 4, where a gravel deposit again obscures the bedrock. The fault may extend a few miles north of this point, but the vertical displace-



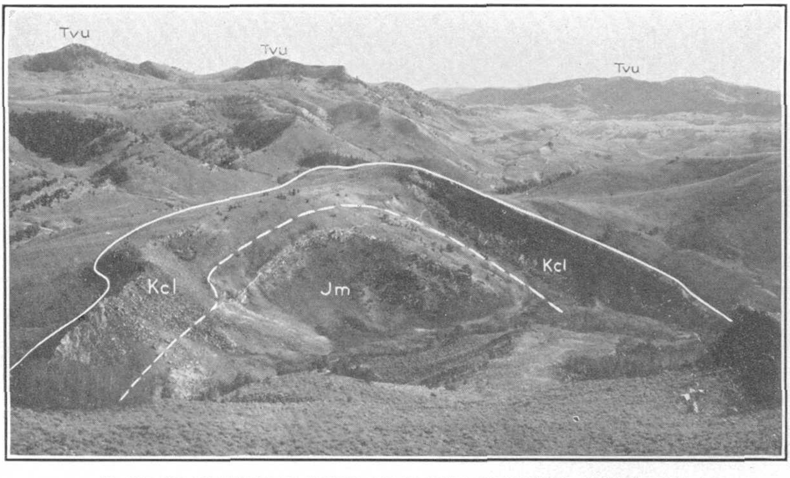
SKETCH MAP SHOWING LOCATION OF PRINCIPAL STRUCTURAL FEATURES ALONG PART OF WESTERN MARGIN OF BIG HORN BASIN.

Steep flank of folds indicated by hachures; dips indicated are approximate.



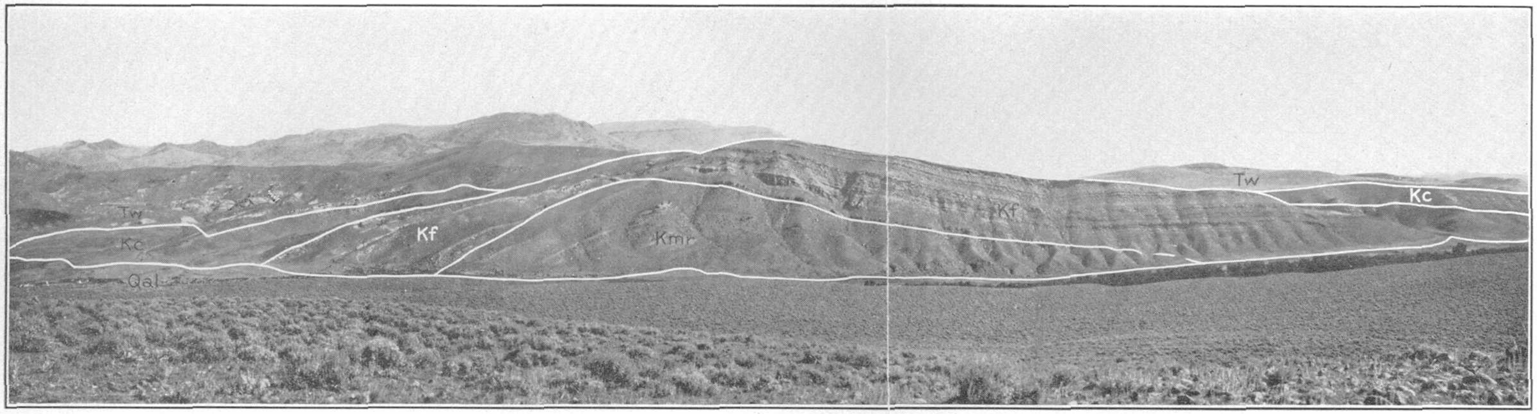
A. NORTH END OF PITCHFORK ANTICLINE AS VIEWED IN CROSS SECTION.

Looking south across the valley of Rawhide Creek from about the center of the N½N½ sec. 2, T. 48 N., R. 102 W. The Mowry shale (Kmr) in the center of the fold is overlain by the Frontier formation (Kf). Remnants of the Rim terrace are shown on the left and right.



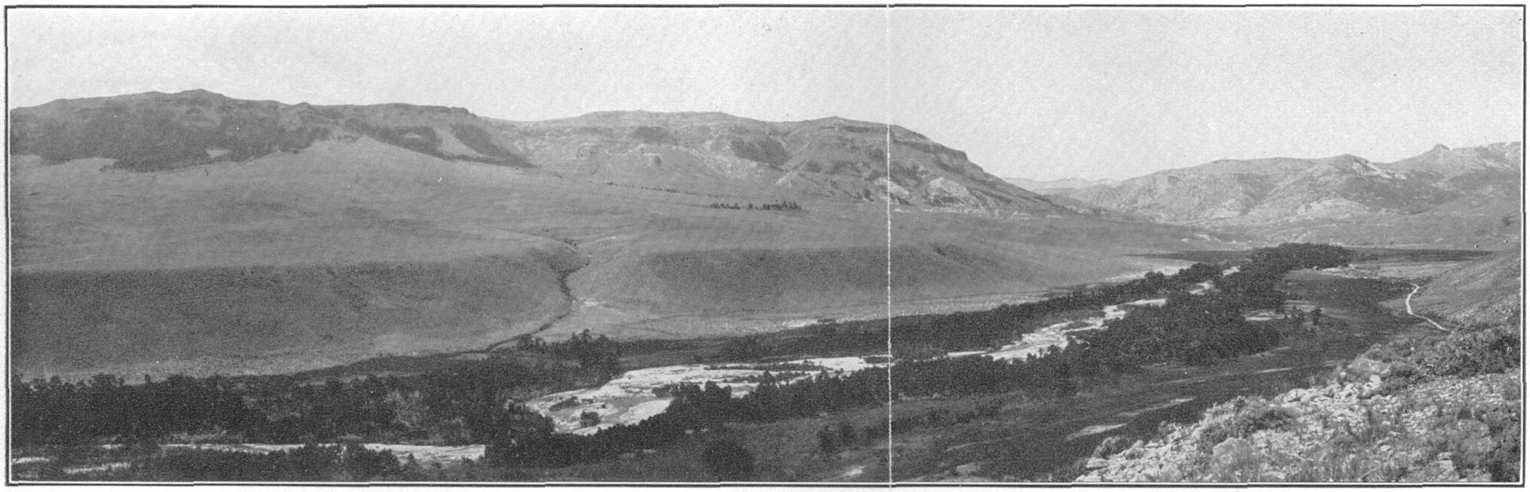
B. CROSS-SECTIONAL VIEW OF SOUTH SUNSHINE ANTICLINE.

Looking south across Gooseberry Creek from center of SE¼ sec. 4, T. 46 N., R. 101 W. Kcl, Cloverly formation; Jm, Morrison formation; Tvu, volcanic rock.



A. VIEW LOOKING NORTH ACROSS GREYBULL RIVER TO FOURBEAR ANTICLINE.

Pallette No. 2 Ranch in extreme left. Kmr, Mowry shale; Kf, Frontier formation; Kc, Cody shale; Tw, Wasatch formation, which lies unconformably on the beds below; Qal, alluvium.



B. VIEW LOOKING SOUTHWEST FROM NE¼ SEC. 20, T. 48 N., R. 103 W., TOWARD LAVA CLIFFS AND HEADWATERS OF GREYBULL RIVER.

In center of picture a pediment surface slopes down to the level of Sunshine terrace along south side of Greybull River.

ment in sec. 4 is so much less than it is farther south as to indicate that the fault does not extend northward very far. The fault plane is nearly vertical at many places, but some observations indicate that parts of the plane dip northeast and other parts dip southwest. The vertical displacement exceeds 500 feet through secs. 10 and 15 and 700 feet at the boundary between these sections. The downthrow is on the southwest side. Northward and southward from secs. 10 and 15 the vertical displacement decreases rapidly to the limit of the fault as mapped.

Fault at north end of Spring Creek anticline.—The fault at the north end of the Spring Creek anticline, in T. 50 N., R. 102 W., is not well exposed, but the relationships that can be observed indicate that it is similar to the Half Moon fault. The Frontier formation on the west side of the fault lies adjacent to the Cody shale on the east, so that the relative movement has been the west side up or the east side down. The amount of displacement along the fault cannot be determined directly because of the lack of recognizable beds within the thick Cody shale, but by the process of using dips in the Cody shale and projecting the top of the Cody to the fault, a maximum stratigraphic displacement of about 1,800 feet is arrived at. The strata on the east side of the fault dip northeastward, and those on the west dip westward or southwestward, so that the fault seems to be near the crest of a fold which is on the projected trend of the Spring Creek anticline.

Tear faults on the Pitchfork anticline.—Six small tear faults were observed on the Pitchfork anticline. Five of them are on the west flank and one is on the east flank. As shown on plate 11, they are roughly parallel and trend northeastward. Slickensides and the offset of the beds indicate that movement was horizontal and that each of the blocks on the northwest side of the faults moved northeastward in relation to the blocks on the opposite side of the faults. As far as could be observed, the fault planes are nearly vertical. The maximum observed horizontal displacement is 300 feet, but the displacement decreases northeastward, and thus most of the faults die out before they reach the crest of the anticline. The largest tear fault, which passes through the NW¼ sec. 14, dies out as it approaches the crest of the anticline by dividing into innumerable small faults, which radiate northeastward like the ribs of a fan and have only a few feet of displacement. To the southwest this fault passes into the Cody shale and cannot be traced across the NE¼ sec. 15, but in the SW¼ of that section it is again exposed.

These faults were probably formed during or shortly after the folding of the rocks in the Pitchfork anticline. They may not extend to great depth, but it is possible that similar faults have been formed deeper in the anticline.

Faults near center of T. 48 N., R. 102 W.—The high gravel-capped butte in secs. 15 and 22, T. 48 N., R. 102 W., is not only a striking topographic feature, but the basal Mesaverde sandstones that occur near its top are considerably above their normal stratigraphic position. On the north and east sides of the butte there are a number of faults, some of them high-angle reverse faults of small displacement and others tear faults. This intricately faulted area lies in the trough of the Sunshine syncline. It seems likely that the reverse faulting was of local extent and was caused by the sharp folding of the syncline. The north-trending fault in the east part of secs. 15 and 22 is the main reverse fault in this small area. Although the fault surface was not actually observed, the dips of 55° to 85° in the strata on the east side of the inferred location of the fault in contrast to the dips of 15° to 40° on the west side indicate its presence.

The fault near the center of the west line of sec. 15 seems to be both a reverse and a tear fault. The fault surface dips northwest about 45°, and the movement appears to have been both upward and northeastward on the northwest side. On a horizontal surface the trend of the fault would be approximately N. 45° E., but owing to the topography and the dip of the fault surface, the fault trace is curved. (See pl. 11.) It cannot be traced northeastward in the Cody shale, but its trend suggests that it may connect with the tear fault south of the center of the west line of sec. 11.

The fault that passes through the center of sec. 15 is a tear fault. All trace of it in the northeast quarter of the section is lost in the Cody shale, but it probably continues and joins the fault exposed on the west side of the Pitchfork anticline. About 800 feet southeast of and parallel to it is another tear fault. Between these two faults is a block of sandstone of the Mesaverde formation about 300 feet wide and 1,000 feet long, which has a vertical dip. The Cody shale to the northeast of this block and between the two tear faults is jumbled and contorted.

The northeast-trending fault in the NE¼ sec. 22 seems to be a reverse fault, in which the relative movement has been up on the northwest side. The throw of the fault is about 200 feet. It probably joins the seemingly larger north-trending reverse fault.

Faults near northwest corner of T. 48 N., R. 102 W.—The two faults in sec. 6, T. 48 N., R. 102 W., occur within the Cody shale. (See pl. 11.) They are of the thrust type and lie one above the other. The upper one has a low-dipping plane, and the lower one a high-dipping plane. They are difficult to trace, but their approximate location can be determined by the marked discordance of the dips on opposite sides of each. It seems likely that they both pass into high-angle reverse faults and are not of great lateral extent.

Plate 17, *B*, illustrates the discordance in the dips in the Cody shale above and below the upper thrust. The vertical displacement of the base of the Wasatch by the *upper* thrust fault is about 200 feet and by the *lower* fault an additional 100 feet, making a total vertical displacement by both faults of about 300 feet. No indication of the amount of horizontal movement could be obtained.

In and near the southwest corner of T. 49 N., R. 102 W., the Cody shale and the Wasatch formation are cut by several faults. (See pl. 11.) The easternmost fault in tract 63 has a strike of N. 15° W. Its surface dips eastward about 62° but appears to be curved and to dip less at depth. The slickensides along it are nearly horizontal, with perhaps a dip of about 2° to the north. The fault gouge is from 1 to 3 inches thick. On the west side of the fault the Wasatch formation dips about 50° northeast, and on the east side about 5° southwest. The boulders in the basal conglomerate of the Wasatch reveal in a striking way the pressure that presumably accompanied the faulting, especially in a zone a foot or two wide bordering the fault, where all gradations of deformation of the boulders in place were observed. The least deformation is shown by percussion marks and indentations made by adjoining boulders, and the greatest by the fracturing and breaking of the boulders.

The fault nearest the west line of T. 49 N., R. 102 W., strikes due north. The fault surface dips west about 40°, and the west side is down in relation to the east side, which suggests that it is a normal fault, but, without slickensides to indicate the direction of movement, it could also be a tear fault. The throw could not be determined, but there is a suggestion of a stratigraphic displacement of about 500 feet.

Fault in northwest quarter of T. 47 N., R. 102 W.—In sec. 17, T. 47 N., R. 102 W., a fault offsets the crest of the Fourbear anticline about 1,700 feet. The trend of the fault is nearly normal to the axis of the fold. Information is lacking on the inclination of the fault surface or its relative movement. The horizontal offset of the crest of the fold suggests that it is a tear fault. The offset could have been produced by uplift on the northwest side or by downthrow on the southeast side of a normal fault, provided the axial plane of the fold dips northeastward, but the inference to be drawn from surface dips is that any inclination of the axial plane would be in the opposite direction. In the NE¼ sec. 17 a dike occupies the fault. The dike continues northeastward for nearly 4 miles, but, as the Cody shale is the surface formation through most of its extent, data are lacking on the possible continuation of the fault along the dike. The small fault in the SW¼ sec. 17 is thought to have a throw of 130 feet, with the northwest side up in relation to the southeast side.

AGE AND SEQUENCE OF DEFORMATION

The youngest beds that are involved in the intense folding in the region south of Cody belong to the Lance formation. An unconformity separates the Lance from the Fort Union in the region adjoining on the east (Oregon Basin and Meeteetse quadrangles), where large areas of the Fort Union formation remain above the Lance formation.[84] At one place in these quadrangles the relations indicate that the Lance strata dipped 13° before the Fort Union strata were laid down. It seems probable that in the area here described there likewise was some warping after Lance deposition and prior to Fort Union, but, as shown in the region to the east, the principal folding occurred after the Fort Union was laid down. The folding was contemporaneous with or was followed shortly by the forming of most of the faults in the area, and it was completed before the Wasatch deposition. After Wasatch time, however, there was a slight deformation of the Wasatch strata, possibly contemporaneous with the Heart Mountain overthrust. Recent studies by Pierce to the west of the area here described have shown that the volcanic rocks are later than the Heart Mountain overthrust and that the igneous dikes are later than the volcanic rocks.

GEOMORPHOLOGY

GENERAL FEATURES

The region south of Cody lies on the western margin of the Big Horn Basin, which has been regarded as an intermontane valley within the Middle Rocky Mountain province.[85] (See fig. 10.) The land forms of the mapped area, as well as those of most of the western part of the basin, have been developed by steams superposed from drainage channels in existence at the close of Eocene time. The superposition of the major east-flowing streams on the pre-Wasatch structure is strikingly shown, as the structural features have a general north-south alinement. Most of the anticlines and synclines are therefore dissected by streams whose direction of flow is nearly normal to the axes of the structural features. The later erosion of the structural features has given rise to many younger streams, which have eroded the soft shales and left the harder sandstones as hogbacks outlining the anticlines. Near the western margin, where the Heart Mountain overthrust sheet and lava flows of Eocene or early Oligocene age have buried the Wasatch sediments, the stream developmet has been largely due to headward extension of existing drainage.

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[84] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 68, 1926.

[85] Fenneman, N. M., Physiographic divisions of the United States: Assoc. Am. Geographers Annals, vol. 18, No. 4, pp. 333–335, 1928.

A steep escarpment formed in part by the east margin of the volcanic rocks lies along the western and southern margins of the area. Its base ranges in altitude from 6,000 to 8,000 feet, and its top from 9,000 to 10,000 feet. Below and to the east and north of this escarpment there are a few isolated remnants of the highest terrace in the Big Horn Basin—the Cottonwood. Another terrace, just below the Cottonwood, is the Rim, which forms the flat-topped high divide between the Greybull and Shoshone Rivers and caps several high mesas along the Greybull River. Two series of terraces probably of Pleistocene age form long benches along the Shoshone River, but only one terrace, the Sunshine, is distinguished along Greybull River and its tributaries. The terraces and bench surfaces are so widespread and well preserved that they are prominent features of the topography of the area and they contrast markedly with the hogbacks or series of hogbacks that outline each of the anticlines. The hogbacks rise from a few feet to 700 feet or more above the surrounding country. The outward-facing escarpments, also formed by thick Mesaverde sandstones around the Dry Creek, Rawhide, and Sunshine synclines, are prominent features of the landscape.

TERRACES

COTTONWOOD TERRACE

The Cottonwood terrace, the highest and oldest gravel terrace preserved, caps the high hills in sec. 15, T. 49 N., R. 102 W., and in sec. 9, T. 50 N., R. 101 W. The position and altitude of the few remnants of this terrace preserved in the western part of the Big Horn Basin are shown on plate 22 by contour lines. The altitude of the remnant in sec. 15 is about 7,650 feet. The altitude of the base of the volcanic rocks, about 4 miles to the northwest, is about 8,500 feet.

In this area the Cottonwood terrace consists of less than 10 feet of gravels made up almost entirely of angular to subangular lava boulders, with scattered limestone and quartzite boulders, some of them as much as 2½ feet in diameter but averaging about 1 foot. Hewett interpreted these gravels as representing a nearly level surface extending from the vicinity of Greybull River northward to Shoshone River and possibly farther.[86] East of the lava escarpment in the area here described very few points higher than those of the Cottonwood terrace are preserved today.

RIM TERRACE

The next lower terrace, the Rim,[87] lies 150 to 250 feet below the Cottonwood, and few points other than isolated hills of the Cotton-

[86] Hewett, D. F., op. cit., p. 7.
[87] Hewett, D. F., op. cit., pp. 6–8.

wood rise above it. The Rim terrace forms the flat divide, known as the Meeteetse Rim, between the Greybull and Shoshone Rivers in Tps. 49 and 50 N., Rs. 101 and 102 W. It is also present south of Meeteetse Creek and forms the caps of the high mesas on each side of the Pitchfork anticline north of the Greybull River (see pl. 20, *A*). Three small remnants are preserved in the northwestern part of T. 47 N., R. 101 W., and there are small patches along the southeast side of Wood River. The restored level of this terrace is shown by contours on plate 22.

The name Y. U. bench was proposed by Mackin [88] for the terrace along Greybull River, 20 miles east of the area covered by this report, which represents the same stage of erosion as the Rim terrace. The new name was needed to differentiate the terraces formed by major-stream planation from the terraces formed by side-stream planation. The Rim terrace is approximately the equivalent of the Polecat bench terrace, 20 miles northeast of Cody, although it may be slightly younger. Alden [89] correlates the Polecat bench with his No. 1 bench, or the Flaxville terrace of eastern Montana.

As would naturally be expected in a planation surface formed by the meanderings of streams, the Rim terrace has several different levels. The most widely preserved level is indicated on the geologic map (pl. 11) by the symbol Ttr, and higher levels, 40 to 50 feet above the main one, are indicated by the symbol Ttrh.

The gravel deposits of the Rim terrace have a maximum observed thickness of 74 feet in the southern part of sec. 15, T. 48 N., R. 102 W. Along the Meeteetse Rim the thickness commonly ranges from 5 to 30 feet. The surface of the terrace is smooth and is usually covered with a thin layer of soil, silt, and sand that conceals the underlying gravels. Rough field estimates indicate that 50 to 90 percent of the coarse material in the gravel is volcanic and most of the remainder quartzite but that it includes some sandstone, limestone, and chert cobbles or boulders. Boulders as much as 3 feet in diameter were observed at several scattered localities, but their average diameter at most localities was estimated to range from 3 to 6 inches. The following section shows the character and thickness of the material in the gravel of the Rim terrace at an unusually good exposure.

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[88] Mackin, J. H., Erosional history of the Big Horn Basin, Wyo.: Geol. Soc. America Bull., vol. 48, p. 861, 1937.

[89] Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, pl. 1, 1932.

Section of gravel of Rim terrace in SW¼SE¼ sec. 15, T. 48 N., R. 102 W.

	Feet
Gravel-covered slope to top of butte	44
Gravel, mostly volcanic; pebbles in lower 1 foot range from 1 to 3 inches in diameter; overlain by cobbles as much as 1 foot in diameter; beds of silt 2 to 4 inches thick	10
Sand, soft, or silt, dark-buff	10
Gravel, volcanic rock; size range from 1 inch to 2 feet	10
	74

Mesaverde formation.

SUNSHINE TERRACE

The Sunshine terrace, as shown on the map (pl. 11), is restricted to the gravel-covered benches along Greybull River and its tributaries. At the time it was formed, extensive planated surfaces with a thin covering of gravel were cut by many tributary streams. These surfaces are included with the undifferentiated bench surfaces on the map, and in their lower parts grade into the Sunshine terrace.

Hewett chose the name Sunshine for this terrace[90] because of its well-developed remnants along Wood River near Sunshine post office. The most extensive remnant in the area covered by this report is on the north side of Greybull River west of Pitchfork post office. (See pl. 23.)

The Sunshine terrace is 225 to 250 feet above Greybull and Wood Rivers. North of Greybull River, in T. 48 N., R. 102 W., it is about 475 feet below the Rim terrace, whereas on the southeast side of Wood River the interval between the terraces is only about 300 feet. The gradients of Greybull and Wood Rivers over a distance of about 12 miles from their junction are 66 and 71 feet to the mile, respectively.

The gravels of the Sunshine terrace are composed of materials much like those of the Rim terrace above, including a very large proportion of volcanic rocks and smaller proportions of quartzites, coarse-grained igneous rocks, limestones, and sandstones. There is a noticeable difference, however, in the size of the constituents. The pieces that make up the coarse material range in diameter from a quarter of an inch to more than a foot, although there are only a few boulders whose diameter is greater than a foot. Also, the gravels of the Sunshine terrace contain a relatively larger proportion of fine materials, particularly sand. The thickness of the gravels and sands of the Sunshine terrace ranges from a maximum of 20 feet on the streamward side to a minimum of less than a foot on the mountainward side of the terrace.

[90] Hewett, D. F., op. cit., p. 6.

The Sunshine terrace was formed at about the same time as the Powell terrace, along the Shoshone River, but profiles up minor streams suggest that the Sunshine terrace is slightly older. The Sunshine terrace is the same as the Emblem bench of Mackin.[91]

POWELL TERRACE

The Powell[92] terrace occurs only along the valley of the Shoshone River (see pl. 11). It forms the bench that is about 275 feet above that river (see pl. 15, *C*).

Scattered remnants present along the valley of Sulphur Creek were probably formed during the Powell stage. Its approximate equivalent along Greybull River is the Sunshine terrace described above. The Powell terrace is the No. 2 terrace of Alden.[93]

The Powell terrace is covered with a thin veneer of soil and slope wash. The gravel underneath this veneer is composed dominantly of well-rounded volcanic cobbles averaging 3 to 8 inches in diameter. Boulders 18 inches in diameter are common and some are more than 2 feet across. The gravel bed is 55 feet thick as measured at a locality on the north side of the river half a mile west of the railroad station at Cody and 85 feet thick between Marquette Creek and the South Fork of Shoshone River, 3 miles west of the area here considered.

CODY TERRACE

The Cody[94] terrace is present only along Shoshone River at the north boundary of the area. It is really not a single terrace but a series of small benches from 100 to 160 feet above the river. On the geologic map (pl. 11) the highest and most extensive bench in the series is designated the Cody terrace (Qtc) and is the one on which the town of Cody is situated. The lower and less extensive benches below it are grouped together and designated Qtcl. The materials of the Cody terrace are like those of the Powell terrace in composition, but on the whole they are not quite so coarse. The gravel bed is 65 feet thick as measured on the north side of the river, half a mile west of the station at Cody.

UNDIFFERENTIATED BENCH SURFACES

The area shown on the geologic map (pl. 11) as undifferentiated bench surfaces is made up, for the most part, of erosion surfaces formed during the development of the Sunshine terrace. In par-

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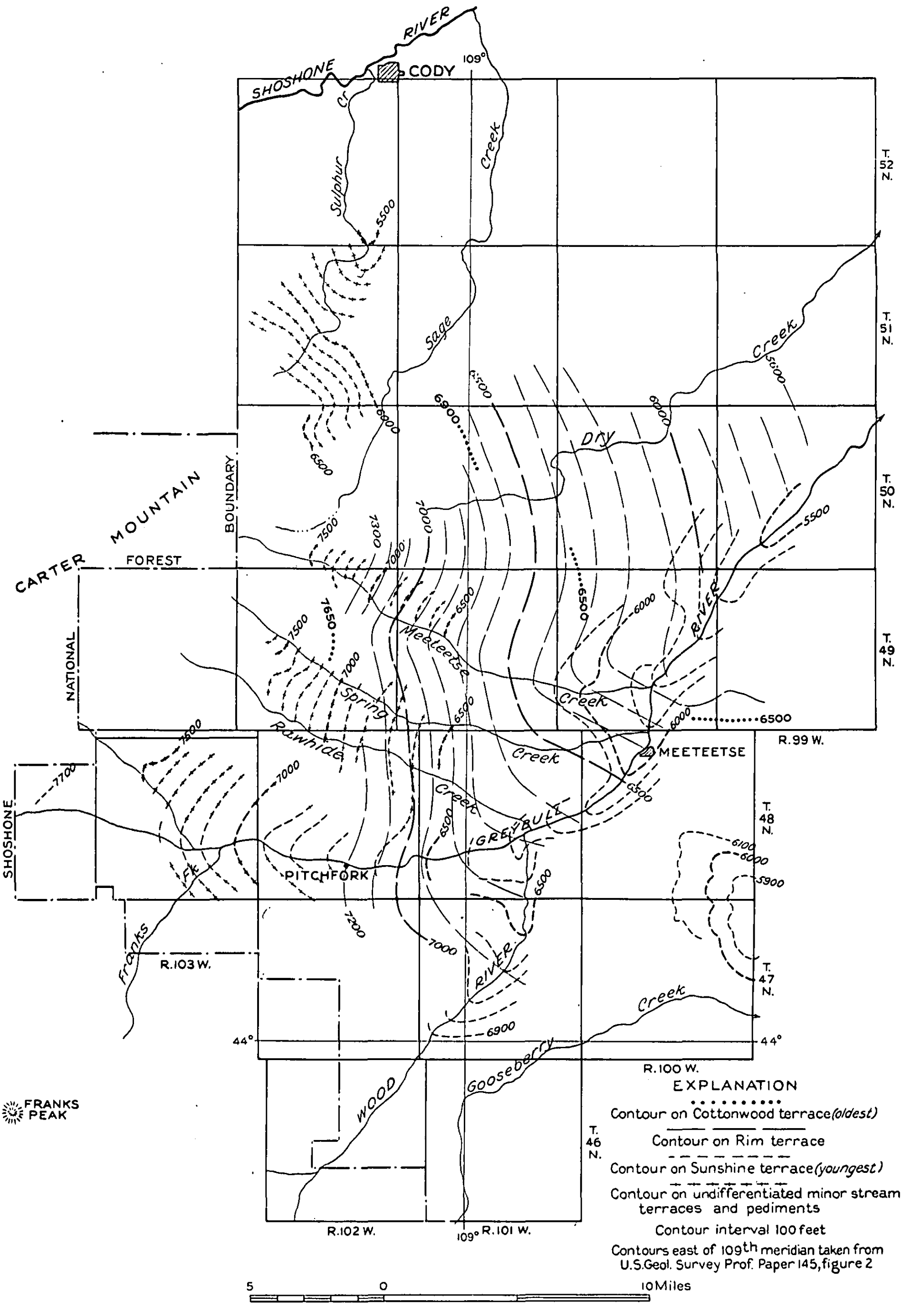
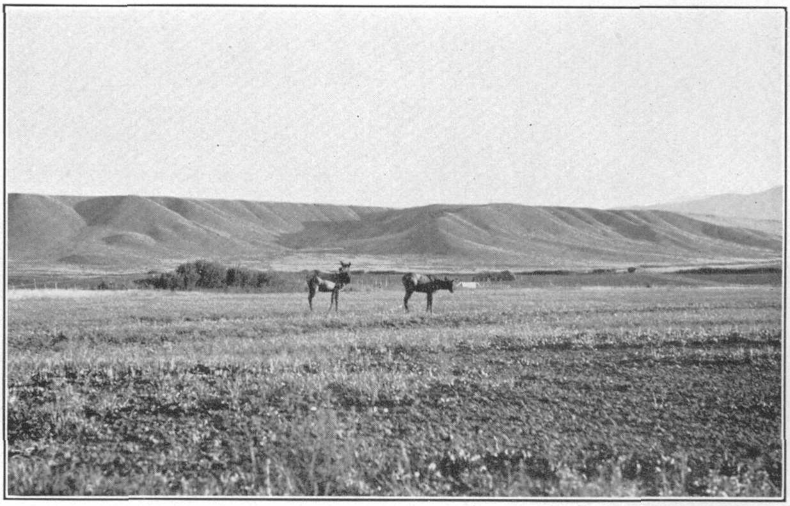
[91] Mackin, J. H., op. cit., p. 861.
[92] Mackin, J. H., op. cit., p. 833.
[93] Alden, W. C., op. cit.
[94] Mackin, J. H., op. cit., p. 833.

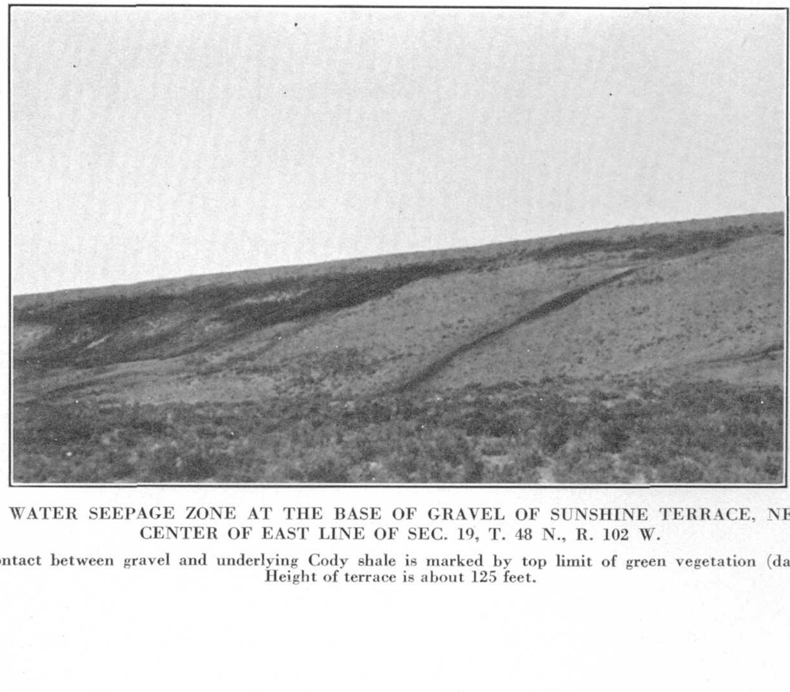


SKETCH MAP SHOWING PARTLY RESTORED CONTOURS ON SURFACES OF COTTONWOOD, RIM, AND SUNSHINE TERRACES.



A, TERRACE IN SEC. 33, T. 48 N., R. 102 W.

Tame elk in foreground.



B. WATER SEEPAGE ZONE AT THE BASE OF GRAVEL OF SUNSHINE TERRACE, NEAR CENTER OF EAST LINE OF SEC. 19, T. 48 N., R. 102 W.

Contact between gravel and underlying Cody shale is marked by top limit of green vegetation (dark). Height of terrace is about 125 feet.

ticular, those along the streams tributary to the Greybull River, such as Meeteetse, Rawhide, Rose, and Rock Creeks, can be traced into the Sunshine terrace. Most of the undifferentiated benches on the south side of the Greybull, also, were formed during the same stage of erosion.

Nearly all the bench surfaces have a veneer of rock debris, the fragments usually subangular and of local origin in the upper or mountainward ends of the surfaces and in the lower ends approaching true stream gravels in both roundness and heterogeneity. Those parts of the surfaces that border the larger creeks are, strictly speaking, terrace deposits, but grade both laterally and upstream into pediment surfaces.

AGE OF TERRACES

Fossils have not been reported from any of the terraces in the Big Horn Basin, consequently no definite age assignment for them is yet possible.

All the terraces are younger than the lavas in the Absaroka region, to the west, which are now placed in late Eocene or early Oligocene time on a basis of the plants collected from the early volcanic rocks along Lamar River. Knowlton [95] studied the early collection from the Lamar River flora and called them lower Neocene (Miocene). However, Read [96] who restudied this flora and also studied other collections, makes the following statement:

The conclusions to be drawn seem obvious. The Lamar River flora contains certain elements which can be accounted for only by regarding the assemblage as somewhat older than Miocene. Such a setting back of the age of the early basic breccias is not out of accord with the views expressed by others. Cockerell, as early as 1909, questioned the Miocene reference of this flora, and remarked "The conclusion seems legitimate that the Yellowstone Intermediate and Lamar floras are Upper Eocene or at least older than Miocene. Were they really Miocene, with so much resemblance to even the basal Eocene, the Florissant flora, to get as far on the side as its lack of affinity would suggest, would have to be projected somewhere into the future."

Jones and Field have arrived at a similar conclusion as to the age of the breccias, employing an entirely different line of reasoning. Their study of the geologic history of the Grand Canyon of the Yellowstone has suggested that the ages of the Tertiary volcanics must be set back to allow time for the complex series of events which have taken place. They state that "The plants from the later or basic breccias are regarded, however, as belonging to the base of the Neocene period. In view of the erosional history of the Park, it is open to question whether even the latest of the breccias are as young as the Neocene."

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[95] Hague, Arnold, U. S. Geol. Survey Geol. Atlas, Absaroka folio (No. 52), p. 5, 1899.

[96] Read, C. B., Fossil floras of Yellowstone National Park, pt. 1, coniferous woods of Lamar River flora: Carnegie Inst. Washington Pub. 416, p. 7, 1933.

Tentatively the view is taken that the Lamar River flora is upper Eocene or lower Oligocene in age, but more conclusive discussion of the subject is reserved for detailed treatment in a future paper.

The Cottonwood terrace, the highest in the area covered by this report, is tentatively correlated with the gravel cap on Tatman Mountain [97] about 30 miles east of the area, to which a probable Oligocene or Miocene age is given by Alden.[98] An Oligocene or Miocene age for the surface upon which these gravels were deposited seems plausible, also, because this surface is only a few hundred feet lower than the nearby surface on which the lavas of Eocene or early Oligocene age flowed.

The gravels of the Rim terrace are correlated by the writers with the Polecat bench 20 miles northeast of Cody, and the gravel of the Polecat bench is in turn correlated by Alden [99] with the Flaxville Plain of northeastern Montana, which Collier and Thom [1] have shown to be Miocene or Pliocene in age.

The Cody terrace has been traced by the writers along the South Fork of the Shoshone River to a point between Ishawooa and Valley where it is overlain by a Wisconsin terminal moraine.[2] It is thus older than the Wisconsin stage of the Pleistocene epoch.

On the basis of these criteria, the Cottonwood terrace might be assigned to Oligocene or Miocene, and the Rim terrace to Miocene or Pliocene. The Sunshine and Powell terraces could be called Pleistocene, and the highest and most extensive bench of the Cody terrace late Pleistocene but pre-Wisconsin. In a recent paper Mackin [3] places the beginning of the degradation of the Big Horn Basin in the middle or late Miocene, a time somewhat later than the Oligocene or Miocene suggested by the present writers. He bases his conclusions in part, however, on the work of Beven and Alden, and on an early paper by Rouse, all of whom regarded the lavas of the Absaroka region as of Miocene age. These lavas are now placed by Read in the Eocene or Oligocene.

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[97] Fisher, C. A., Geology and water resources of the Bighorn Basin: U. S. Geol. Survey Prof. Paper 53, p. 34, 1906.

[98] Alden, W. C., Physiography and glacial geology of eastern Montana and adjacent areas: U. S. Geol. Survey Prof. Paper 174, p. 10, 1932.

[99] Alden, W. C., op. cit., pp. 26–27.

[1] Collier, A. J., and Thom, W. T., Jr., The Flaxville gravel and its relation to other terrace gravels of the northern Great Plains: U. S. Geol. Survey Prof. Paper 108, pp. 179–182, 1918.

[2] Alden, W. C., op. cit., pl. 1, 1932. Rouse, J. T., The physiography and glacial geology of the Valley region, Park County, Wyo.: Jour. Geology, vol. 42, no. 7, pp. 738–752, 1934.

[3] Mackin, J. H., Erosional history of the Big Horn Basin, Wyo.: Geol. Soc. Amer. Bull., vol. 48, pp. 813–894, 1937.

ECONOMIC GEOLOGY

OIL AND GAS

DEVELOPMENT

Sixteen wells have been drilled in the region south of Cody in search of oil or gas. They have been drilled on all the anticlines except Frost Ridge dome. Four wells have encountered oil in commercial quantities in one or more horizons in the Carboniferous formations, but at the time of the field investigation none of them had actually produced oil.

HORSE CENTER ANTICLINE

The area within the lowest closing contour of the Horse Center anticline—the 8,000-foot contour—is mainly in secs. 30 and 31, T. 52 N., R. 101 W., and sec. 6, T. 51 N., R. 101 W. The amount of closure is more than 1,000 feet.

Four wells have been drilled along the crest of the anticline. All of them were drilled through the Chugwater formation, of Triassic age, which is exposed at the surface, and passed into the underlying Carboniferous rocks.

The Oregon-Wyoming Oil & Gas Co.'s well 1, in the SE¼NE¼SW¼ sec. 30, T. 52 N., R. 101 W., was completed March 8, 1929, to a depth of 1,245 feet. It probably entered the Madison limestone at 1,220 feet. The driller's log of this well, together with the writers' interpretation of the formations penetrated, is given on page 160. This company's No. 2 well, in the NE¼NE¼SW¼ of the same section was completed May 16, 1929, to a depth of 864 feet without encountering oil or gas in commercial quantities. The base of the Chugwater was reached at 767 feet, and the bottom of the hole was probably in the Phosphoria formation.

A dry hole was drilled in 1914 to a depth of 823 feet in the NW¼SE¼ sec. 31, T. 52 N., R. 101 W., by the "56" Petroleum Corporation.

The well of the Ydoc Petroleum Exploration Co., in the center of SW¼NE¼ sec. 6, T. 51 N., R. 101 W., was completed to a depth of 930 feet in February 1928. Showings of oil or gas in this well were reported at depths of 415, 666 to 670, 846 to 856, and 915 to 920 feet. It was said that considerable carbon dioxide gas was obtained from the well, but it was never used and the well was plugged several years later. The driller's log and the writer's interpretation of it are given on page 160.

The Madison limestone has not been adequately tested for oil or gas on the Horse Center anticline, but the Carboniferous formations above it, which are productive on other anticlines in this area, have been fully tested without success. The higher formations have been unproductive, and the Madison also may not yield commercial quantities of oil or gas, but there is a possibility that future drilling may reveal additional quantities of carbon dioxide gas.

Record of Oregon-Wyoming Oil & Gas Co.'s well 1 on Horse Center anticline in SE¼NE¼SW¼ sec. 30, T. 52 N., R. 101 W.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Chugwater formation:			Tensleep sandstone—Continued.		
Shale and sandstone, red	560	560	Crevasse	5	932
Red sand	6	566	Lime, gray, very hard	2	934
Phosphoria formation:			Sand, gray, variegated colors	16	950
Lime, light-gray, soft	34	600	Sand, white, soft and flaky	14	964
Lime, dark-gray; some sand	13	613	Amsden formation:		
Lime, light-gray, hard	15	628	Lime, gray, hard	8	972
Shale, dark-gray, very hard	4	632	Sand and lime mixed, cavernous, hard, badly broken up	146	1,018
Sand, brown, well-saturated, but no free oil; formation tight	47	679	Lime, gray, softer	11	1,029
Lime, light-gray, easily drilled	109	788	Limestone, gray, very soft	83	1,112
Tensleep sandstone:			Shale, dark red, very soft; caved very badly	48	1,160
Sand, white; water rose 500 feet	80	868	Limestone, variegated colors	25	1,185
Lime, gray, interspersed with small showing of sand	32	900	Sandstone, reddish-pink, probably Amsden	27	1,212
Sand, light-gray, soft	25	925	Shale, brown, very hard	8	1,220
Gray rock, exceptionally hard	2	927	Madison limestone:		
			Limestone, very hard	25	1,245

Record of the Ydoc Petroleum Exploration Co.'s well 1 on Horse Center anticline in center of SW¼NE¼ sec. 6, T. 51 N., R. 101 W.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Chugwater formation:			Tensleep sandstone—Continued.		
Sandstone and clay shale, red, sandy	342	342	Sand, fine, sharp, gray	2	858
Gypsum, light-pink	14	356	Sand, white, coarse, some lime	2	860
Lime shell	2	358	Sand, fine, gray, cavernous pieces	10	870
Gypsum	19	377	Sand, fine, very coarse pieces, breaking in crevice or seam	10	880
Phosphoria formation:			Amsden formation:		
Lime, tan-colored, bad gas at 415	62	439	Lime, hard gray	6	886
Lime, sandy	56	495	Lime, hard blue-gray, metamorphosed	8	894
Lime shell, hard	5	500	Lime, hard blue-gray, metamorphosed	12	906
Lime, sandy	17	517	Lime, hard blue-gray, like flint sand, and porous rock	4	910
Lime, sandy	8	525	Sand, light-tan; porous rock, colors	3	913
Lime	122	647	Sand, light-gray	2	915
Lime, white, sandy	19	666	Sand, gray; show of gas	5	920
Lime; gas	4	670	Sand, white, some lime	5	925
Lime, sandy	35	705	Sand, blue-gray, very porous; small show of light brown oil	5	930
Lime	10	715			
Very hard shell, white	5	720			
Tensleep sandstone:					
Sand, round white, water	5	725			
Sand, round white, hard	121	846			
Sand, dark, sharp, some lime; gas	10	856			

HALF MOON FAULTED FOLD

The Half Moon fold, which is faulted, has about 600 feet of closure above the 6,000-foot contour that outlines the fold east of the fault. The highest point structurally is near the NE¼SW¼ sec. 23, T. 51 N., R. 102 W. The structural features west of the fault could not be determined in detail from surface observations alone.

Three wells have been drilled on this fold. The Ostland Development Corporation, in December 1927, completed a well in the SW¼SW¼ sec. 23, T. 51 N., R. 102 W., to a depth of 1,745 feet without encountering oil or gas. The driller's log of this well, together with the writers' interpretation of formations encountered, is given below. The Cody Petroleum Co.'s well 1 in the SE¼NW¼ sec. 4, T. 51 N., R. 102 W., was completed to a depth of 4,212 feet in August 1929. The complete log of this well is not available, but parts of the log seen by the writers indicate that the Chugwater was drilled through at a depth of 3,545 feet and that the bottom of the hole was near the base of the Amsden formation. The Flathead Valley B. C. Oil Co. well in the NW¼SE¼ sec. 26, T. 51 N., R. 102 W., was reported to have reached a depth of 250 feet in October 1916,[4] but no further record of this well was found by the writers.

The Ostland Development Corporation well is near the highest point of the fold, but about a quarter of a mile west of the surface trace of the fault. The writers' interpretation of the log indicates that the well did not cross the fault. Perhaps a well drilled on the east side of this fault, in the NE¼SW¼ sec. 23, might reach the possibly productive horizons between the Muddy sand in the Thermopolis shale, and the Madison limestone.

Record of Ostland Development Corporation well 1 on the Half Moon structure in the SW¼SW¼ sec. 23, T. 51 N., R. 102 W.

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Cody shale:			Cloverly formation:		
Shale	60	60	Sand (water)	12	1,482
Frontier and Mowry formations undifferentiated:			Shale, gray	44	1,526
			Sand (water)	30	1,556
Sand and shale	800	860	Morrison formation:		
Thermopolis shale:			Shale, variegated	184	1,740
Shale, dark	260	1,120	Sand	5	1,745
Sand, gray (water)	7	1,127			
Shale, dark	343	1,470			

FROST RIDGE DOME

Frost Ridge dome is a somewhat elongated dome on the southwest limb of the Dry Creek syncline. The lowest closing contour includes parts of secs. 5, 6, 7, and 8, T. 50 N., R. 101 W., but the fold has only about 100 feet of closure on its northwest end.

The dome has not been tested by drilling. The surface rocks are the Meeteetse and Lance formations of Upper Cretaceous age. A

[4] Hewett, D. F., and Lupton, C. T., Anticlines in the southern part of the Big Horn Basin, Wyo.: L. S. Geol. Survey Bull. 656, p. 180, 1917.

depth of about 5,000 feet would be required to test the Frontier formation, which is productive of oil and gas in the Grass Creek and Little Buffalo fields, southeast of the area covered by this report. In view of the small size of the dome and the small amount of closure on its northwest end, it is doubtful whether the structure of the surface beds extends downward to the Frontier or older formations and there forms a trap favorable for the accumulation of oil or gas.

SPRING CREEK ANTICLINE

The Spring Creek anticline has two structural highs. The northern one has about 400 feet of closure, extending from the southwestern part of sec. 22 through sec. 27 to the northeastern corner of sec. 34, T. 50 N., R. 102 W.; it has not been drilled, but inasmuch as a well on the southern part of this anticline obtained oil from several horizons in the Carboniferous formations, the northern high of the anticline may also yield oil.

The lowest closing contour on the southern structural high of the Spring Creek anticline extends from the northeast corner of sec. 3, T. 49 N., R. 102 W., southeastward to the southeast corner of sec. 24 of that township, and has a maximum width of about half a mile in the NE¼ sec. 14. This high is steep, narrow, and long and somewhat asymmetrical. Dips of 50° are present along the east flank, and dips of 70° extend for 2 miles or more along the west flank. Three wells have been drilled on this part of the Spring Creek anticline. The Phoenix Oil Co. No. 1 well in the SE¼NW¼ sec. 11, T. 49 N., R. 102 W., was completed to a depth of 3,175 feet in May 1926, in the Chugwater formation and was abandoned in July 1926. Well 2 of the same company, in the NW¼SE¼SE¼ sec. 11, was located on top of the Rim terrace and was drilled to a depth of 4, 254 feet in 1930, stopping near the top of the Madison limestone. A slight showing of gas was reported from the Muddy sand in the Thermopolis shale between depths of 1,204 and 1,236 feet. Showings of oil were reported from seven horizons in the Carboniferous formations between the depths of 3,657 and 4,250 feet. Initial tests ran 185 barrels of black oil a day, but the well had not been put in commercial production at the time of the field investigation.

The Stancliff well in the SE¼NE¼ sec. 14, T. 49 N., R. 102 W., was drilled to a depth of 510 feet in 1924. It probably did not pass through the Thermopolis shale, which is exposed in the stream bed along the crest of the anticline in sec. 14.

The driller's log of the Phoenix Oil Co.'s well 2, together with the writer's interpretation of the formations encountered, follows.

Record of the Phoenix Oil Co.'s well 2 in the SE¼SE¼ sec. 11, T. 49 N., R. 102 W.

	Thickness (feet)	Depth (feet)
Gravels of Rim terrace:		
Gravel	72	72
Frontier formation:		
Shale, blue	46	118
Lime, gray	6	124
Shale, blue	41	165
Sand, brown, 1 bailer of water per hour	10	175
Shale, gray, upper part blue	45	220
Sand, 3 bailers of water per hour	10	230
Lime, gray	16	246
Sand, hole full of water	9	225
Shale, gray	3	258
Lime, dark	12	270
Water sand	22	292
Shale, sandy	60	352
Lime shell	2	354
Shale, gray, sandy	77	431
Bentonite	5	436
Shale, sandy	12	448
Water sand	35	483
Sand, dark	17	500
Mowry shale:		
Shale, brown	15	515
Shale, gray	17	532
Lime shell, white	1	533
Shale, gray and brown, middle part sandy	179	712
Bentonite	3	715
Shale, black, lower part sandy	27	742
Bentonite	2	744
Shale, hard, gray	56	800
Bentonite	2	802
Shale, gray	103	905
Thermopolis shale:		
Bentonite, broken	10	915
Shale, gray	135	1,050
Bentonite	10	1,060
Shale, gray	105	1,165
Shale, black, muddy	15	1,180
Shale, gray, sandy	22	1,202
Shell, hard	2	1,204
Sand, soft, dry, very slight showing of gas (Muddy sand)	32	1,236
Shale, black	84	1,320
Shale, gray	105	1,425
Cloverly formation:		
Sand and shale	20	1,445
Shale, brown	8	1,453
Shell, hard, sandy	2	1,455
Sand and shale	30	1,485
Sand, 1 bailer of water per hour	5	1,490
Broken and shelly	20	1,510
Sand, 3 bailers of water per hour	5	1,515
Shale, sandy	57	1,572
Morrison formation:		
Shale, pink and red	121	1,693
Shell, very hard	1	1,694
Shale, pink and red, and shells, very cavy	51	1,745
Shell, hard	5	1,750
Shale, pink	18	1,768
Sand, soft, 3 bailers of water per hour	6	1,774
Shale, pink	15	1,789
Shale, sandy, gray	6	1,795
Shale, pink, sandy	20	1,815
Shales, variegated, all colors, very cavy	40	1,855
Sand, hard	9	1,864
Water sand	4	1,868
Shales, variegated	9	1,877
Shale, sandy, light - gray, broken	3	1,880
Shale, gray, lower half sandy	34	1,914
Morrison formation—Continued.		
Sand, hard, sharp pyrites-of-iron shell	6	1,920
Shale, gray and green	25	1,945
Shell	2	1,947
Shale, red and pink	33	1,980
Shale, gray, soft	5	1,985
Sand	5	1,990
Shale, light gray	1	1,991
Shell, hard	3	1,994
Shale, light gray	4	1,998
Sand and sandy shale	7	2,005
Shale, gray and red	5	2,010
Sandstone and shale, gray	53	2,063
Sundance formation:		
Shale, gray, lower half sandy	37	2,100
Sand, gray	55	2,155
Lime, sandy	30	2,185
Sand, gray, muddy	25	2,210
Shale, gray	5	2,215
Sand, gray	10	2,225
Hard	5	2,230
Sand, gray, muddy	20	2,250
Shale, gray, sandy, some lime shells	25	2,275
Shale, light-gray	130	2,405
Lime, gray, sandy	20	2,425
Shale, gray, sandy, showing little pink	15	2,440
Shale, brownish pink	10	2,450
Shale, pink and gray	60	2,510
Shale, gray, with streaks of lime	30	2,540
Shale, gray and pink, cavy	15	2,555
Lime, white, hard	15	2,570
Lime	27	2,597
Chugwater formation:		
Shale, pink and red, with streaks of gray	63	2,660
Sand, red and gray, 700 feet of water raised in hole	25	2,685
Rock, red	95	2,780
Sand, hard	10	2,790
Rock, red, hard	190	2,980
Break making 1 bailer water in 2 hours	5	2,985
Rock, red	140	3,125
Sandy break making little more water	20	3,145
Rock, red, sandy	20	3,165
Shale, gray	5	3,170
Rock, red	330	3,500
Rock, red, some lime	55	3,555
Phosphoria formation:		
Lime, green and greenish gray	30	3,585
Rock, red	5	3,590
Lime, gray, with some shale	40	3,630
Shale, dark blue	5	3,635
Lime, gray, with streaks of shale	22	3,657
Lime, broken, brown, sandy, showing oil	33	3,690
Lime and sand, gray	7	3,697
Sand, brown, with streaks of lime	3	3,700
Lime, gray, sandy	20	3,720
Sand, gray, some lime	5	3,725
Lime, greenish gray, sandy	45	3,770
Shale, gray, sandy	20	3,790
Lime, light gray, sandy	20	3,810
Tensleep sandstone:		
Lime, brown, more sandy, shows oil	5	3,815
Sand, light brown, apparently dry	10	3,825
Sand, brown, dark oil sand	15	3,840
Lime, broken, gray, and oil sand	8	3,848
Oil sand, brown	26	3,874

Record of the Phoenix Oil Co.'s well 2 in the SE¼SE¼ sec. 11, T. 49 N., R. 102 W.—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Tensleep sandstone—Con.			Amsden formation—Con.		
Oil sand, shale, and streaks of lime	11	3,885	Lime, light brown and gray, sandy	9	4,167
Oil sand, brown	92	3,977	Lime, brown and pink, showing bits of brown shale	13	4,180
Sand, brown	28	4,005	Lime, brown, showing chert or quartz	8	4,188
Lime, brown, sandy	5	4,010	Rock, red, mixed colors, and chert, cavy	19	4,207
Sand, very dark brown	3	4,013	Lime, brown	10	4,217
Lime, gray	22	4,035	Shale, brown, cavy	12	4,229
Very dark, showing considerable oil	2	4,037	Rock, red	7	4,236
Amsden formation:			Sand, gray, showing streaks of oil in core	11	4,247
Lime, sandy, showing bits of green at 4,059 feet	70	4,107	Sand, brown, showing oil (core barrel broke, used bit)	3	4,250
Bentonite	2	4,109	Sand, gray	4	4,254
Lime, brown, sandy	41	4,150			
Lime	4	4,154			
Lime, gray, soft	4	4,158			

PITCHFORK ANTICLINE

The Pitchfork anticline has a maximum width of about 1½ miles along the structurally highest part of the anticline in secs. 11 and 14, T. 48 N., R. 102 W., and a closure of about 2,000 feet.

Three wells have been drilled on the anticline. In 1925 the Big Horn Development Co. started a well near the crest, in the NW¼ sec. 14, T. 48 N., R. 102 W. Its total depth was 808 feet. A show of gas was reported from the Cloverly formation at a depth of 780 feet. In January 1928 the California Exploration Co. started its No. 1 well 1,400 feet east of the crest of the anticline, in the NW¼NE¼ sec. 14, T. 48 N., R. 102 W. The well was drilled to a depth of 1,270 feet and encountered water in the Cloverly formation from 1,242 to 1,270 feet. In November 1928 the company started its No. 2 well, which was located 90 feet south of the No. 1 well. The drilling of the No. 2 well was completed in 1930, at a total depth of 3,903 feet. Some of the tools and cable were lost when caving followed shooting of the well, so that its present depth is reported as 3,820 feet. The initial production of oil for a 24-hour period is reported to have been 434 barrels. This well is now shut in and no others have been drilled.

The record of the discovery well on the Pitchfork anticline, as given by the drillers, follows. The interpretation of the formations is by the writers.

Record of the California Exploration Co.'s well 2 on the Pitchfork anticline in NW¼NE¼ sec. 14, T. 48 N., R. 102 W.

	Thickness (feet)	Depth (feet)
Frontier formation:		
Shale	20	20
Bentonite and shells	20	40
Sand, hard, water	10	50
Shells	5	55
Shale	17	72
Shell	5	77
Shale	13	90
Bentonite	6	96
Shale	54	150
Shell	14	164
Sand	32	196
Mowry shale:		
Shale	64	260
Bentonite	3	263
Lime shell	5	268
Shale	85	353
Shell	1	354
Shale	56	410
Shale, dark	30	440
Shale, light	22	462
Shell	3	465
Bentonite	3	468
Shale	112	580
Bentonite	5	585
Thermopolis shale:		
Shale	75	660
Bentonite	5	665
Shale	135	800
Bentonite	2	802
Shale	113	915
Shell	4	919
Shale	28	947
Shale, sandy	3	950
Shell	2	952
Shale	119	1,071
Shell	3	1,074
Shale	53	1,127
Shell	2	1,129
Shale	43	1,172
Shell	3	1,175
Shale, sandy	5	1,180
Cloverly formation:		
Sand, water	62	1,242
Bentonite and shale	21	1,263
Sand	40	1,303
Lime, buff	17	1,320
Shell, hard	3	1,323
Shale, blue	2	1,325
Shale, buff	25	1,350
Shell, hard	2	1,352
Morrison formation:		
Shale, buff	100	1,452
Lime, sandy	3	1,455
Shale, pink	35	1,490
Shell	8	1,498
Sand, water	3	1,501
Shale, pink	9	1,510
Bentonite	5	1,515
Sand	2	1,517
Shale, red	9	1,526
Shell, hard	3	1,529
Shale, red	28	1,557
Shale, pink	15	1,572
Shale, gray	10	1,582
Shell, hard	3	1,585
Lime, sandy	5	1,590
Sand, water	25	1,615
Shell, hard	2	1,617
Shale, green	3	1,620
Shale, green, and shells	14	1,634
Shale, green	6	1,640
Shale, gray	11	1,651
Shale	14	1,665
Shale, sandy	5	1,670
Shale, red	27	1,697
Shale, gray	21	1,718
Morrison formation—Continued.		
Shell, hard	2	1,720
Shell	4	1,724
Shale, gray	11	1,735
Sand	17	1,752
Shale, sandy	26	1,778
Sand, hard	7	1,785
Shell	3	1,788
Shale	2	1,790
Shale, sandy	14	1,804
Sundance formation:		
Lime, blue	6	1,810
Lime, green	50	1,860
Sand	13	1,873
Lime sandy	21	1,894
Sand	4	1,898
Shell	3	1,901
Sand, water at 1,925 feet	99	2,000
Shale, gray	50	2,050
Shale	30	2,080
Shale, gray	48	2,128
Shale, brown	6	2,134
Shale, gray, and shells	20	2,154
Shale, brown	13	2,167
Shale, red	41	2,208
Shale, pink, hard	4	2,212
Shale, red, hard	13	2,225
Shale, blue	5	2,230
Shale, gray	27	2,257
Shale, pink	8	2,265
Shell, hard, pink	15	2,280
Lime, white	8	2,288
Lime, pink	5	2,293
Lime, pink and white	7	2,300
Lime, gray	15	2,315
Chugwater formation:		
Rock, red	185	2,500
Lime, red	40	2,540
Sand, brown	7	2,547
Lime, red, sandy	20	2,567
Lime, red	4	2,571
Rock, red	4	2,575
Sand, red	5	2,580
Rock, red	120	2,700
Lime, hard	10	2,710
Sand, red, 1 barrel of water per hour; exhausted	15	2,725
Rock, red	455	3,180
Lime, hard, red	40	3,220
Rock, red	117	3,337
Phosphoria formation:		
Lime, gray	8	3,345
Shell, hard, light gray	5	3,350
Lime, gray	17	3,367
Lime, blue	3	3,370
Lime, gray	72	3,442
Shell, hard, gray	3	3,445
Lime, gray	2	3,447
Sand, soft, gray	3	3,450
Lime, gray	30	3,480
Slate, black	5	3,485
Lime, gray	8	3,493
Slate, black	3	3,496
Lime, gray	33	3,529
Sand, gray	2	3,531
Lime, gray	34	3,565
Lime, white	15	3,580
Lime, gray	20	3,600
Tensleep sandstone:		
Sand, light-brown, saturated	10	3,610
Lime, light-brown, sandy	37	3,647
Sand, brownish-gray	3	3,650
Sand, gray	35	3,685
Sand, light-gray	15	3,700
Mud, yellow	5	3,705
Sand, gray	2	3,707

Record of the California Exploration Co.'s well 2 on the Pitchfork anticline in NW¼NE¼ sec. 14, T. 48 N., R. 102 W.—Continued

	Thickness (feet)	Depth (feet)		Thickness (feet)	Depth (feet)
Tensleep sandstone—Con.			Amsden formation—Con.		
Mud, yellow	6	3,713	Lime, brownish-gray, sandy	32	3,822
Sand, gray	12	3,725	Sand, gray	18	3,840
Lime, white	10	3,735	Lime, white	2	3,842
Sand, hard, gray	6	3,741	Lime, gray	10	3,852
Shell, hard, sandy	2	3,743	Lime, gray, sandy	4	3,856
Sand, brownish-gray	16	3,759	Sand, white	4	3,860
Amsden formation:			Lime, white	20	3,880
Lime, sandy, brownish-gray	6	3,765	Lime, gray, sandy	10	3,890
Lime, brownish-gray	25	3,790	Lime, gray	13	3,903

FOURBEAR ANTICLINE

The highest point structurally on the Fourbear anticline is about a quarter of a mile south of the California Exploration Co.'s well 2, south of the Greybull River. There the crest of the anticline is more than 400 feet higher than the crest in the region to the south and east. Slight structural saddles in the crest form two smaller structural highs, one southeast of Franks Fork, in lot 39, T. 47 N., R. 103 W., and another in secs. 7, 18, and 17, T. 47 N., R. 102 W., north of the cross fault.

The Kinney No. 1 and California Exploration Co.'s wells 1 and 2 have been drilled in the general area of the structurally highest part of the anticline in T. 48 N., R. 103 W., and the Kinney No. 2 well has been drilled northwest of the high that extends across lot 39, T. 47 N., R. 103 W.

Wells 1 and 2 of the California Exploration Co. were drilled less than 100 feet apart in the NW¼NE¼ sec. 29, T. 48 N., R. 103 W. Well 1 was abandoned at a depth of 3,261 feet because of casing trouble. Well 2 was completed to a depth of 3,350 feet in December 1928. Shows of oil were reported between 2,815 and 2,825 feet and at 2,850 feet, probably in the top of the Tensleep sandstone. Other shows were reported at 3,020 feet and between 3,260 and 3,276 feet, which may be in the Amsden formation. Well 2 has not produced commercially, but tests show a potential production of 250 barrels of black oil a day. The driller's log of this well, with the writers' interpretation of the formations encountered, follows.

Record of the California Exploration Co.'s well 2 on the Fourbear anticline, in NW¼NE¼ sec. 29, T. 48 N., R. 103 W.

	Thickness (feet)	Depth (feet)
Sand	65	65
Thermopolis shale:		
Shale, blue	80	145
Shale, black	140	285
Sand crevice	110	395
Cloverly formation:		
Lime, hard, yellow	31	426
Shale, brown	9	435
Shale, red	5	440
Shale, brown	6	446
Shale, gray	16	462
Shale, brown	10	472
Morrison formation:		
Shale, pinkish-gray	121	593
Lime, hard, gray	3	596
Shale, light-brown	9	605
Shale, red	20	625
Shale, pink	80	705
Shale, gray, sandy	39	744
Sand, gray	34	778
Shale, gray, sandy	27	805
Sand, gray	6	811
Shale, brown	24	835
Shale, gray, sandy	20	855
Shale, brown	150	1,005
Sundance formation:		
Shale, dark gray	30	1,035
Sand, green	145	1,280
Lime, green	60	1,340
Shale, gray	165	1,505
Shale, red	5	1,510
Lime, gray	35	1,545
Sundance formation—Continued.		
Shale, red	30	1,575
Lime, red	30	1,605
Lime, gray	13	1,618
Lime, hard, yellow	52	1,670
Chugwater formation:		
Shale, red	935	2,605
Carboniferous formations, undifferentiated:		
Lime, gray	20	2,625
Lime, greenish-gray, sandy	10	2,635
Lime, gray	75	2,710
Lime, sandy	40	2,750
Sand, gray	30	2,780
Lime, brownish-gray	5	2,785
Lime, dark-gray	10	2,795
Sand, dark-gray; show of oil from 2,815 to 2,835 feet and at 2,850 feet	70	2,865
Lime, gray	90	2,955
Lime, sandy, gray	60	3,015
Sand, hard; oil at 3,020 feet	65	3,080
Sand, brown	40	3,120
Sand, dark brown	10	3,130
Sand, brown	10	3,140
Lime, sandy	60	3,200
Lime, gray, sandy	60	3,260
Lime, gray, sandy; oil	10	3,270
Sand; good oil	8	3,278
Lime, sandy	17	3,295
Lime, pinkish	30	3,325
Sand	25	3,350

The Kinney No. 1 well in the NW¼NW¼ sec. 20, T. 48 N., R. 103 W., on the axis of the anticline and just north of the Greybull River was abandoned in 1920 at a depth of 1,210 feet. The Kinney No. 2 well on Franks Fork in the SE¼SE¼ sec. 33 was abandoned in 1921 at a depth of 1,227 feet. Inasmuch as both of these wells started in alluvium resting on the Mowry shale, they probably penetrated the Cloverly formation. They yielded a little water only.

SOUTH SUNSHINE ANTICLINE

The South Sunshine anticline has a closure of at least 800 feet. The discovery well on this anticline was drilled in 1926 by the Union Oil Co. of California. The well is now controlled by the Continental Oil Co., but it is shut in and no other wells have been drilled. It was drilled with cable tools to a total depth of 2,514 feet. Oil was obtained between 2,480 and 2,514 feet from the Phosphoria (Embar) formation. The initial production for a 24-hour period is reported as 334 barrels. The drillers' log of the well, with the writer's interpretation of the formations penetrated, follows.

Record of the Continental Oil Co.'s Lowrie well 1, on the South Sunshine anticline, in lot 4, sec. 9, T. 46 N., R. 101 W.

	Thickness (feet)	Depth (feet)		Thickness (feet)	depth (feet)
Soil	5	5	Sundance formation—Continued.		
Rock debris	15	20	Shale, gray	65	860
Cloverly formation:			Shale, gray, sandy	15	875
Surface and pink rock	37	57	Shale, gray	13	888
Sandstone and shale, yellow	48	105	Shale, red	49	937
Shale, gray	10	115	Lime, yellow	8	945
Pink rock	8	123	Shale, pink	6	951
Shale, gray	73	196	Lime, white	14	965
Morrison formation:			Shale, white	10	975
Shale, gray	40	236	Shale, red	30	1,005
Lime, pink, hole made 1 bailer of water per hour	24	260	Lime, white	25	1,030
			Shale, pink, limy	5	1,035
Shale, gray	13	273	Lime, white	5	1,040
Shale, pink	22	295	Lime, pink	6	1,046
Shale, gray	46	341	Lime, white	8	1,054
Sand, white	11	352	Lime, pink	14	1,068
Shale, gray, sandy	24	376	Chugwater formation:		
Shale, pink	24	400	Shale, red	200	1,268
Shale, red	15	415	Sand, red	4	1,272
Shale, gray	23	438	Shale, red	1,068	2,340
Shale, pink	42	480	Gypsum, pink	20	2,360
Shale, gray	50	530	Phosphoria formation:		
Sand, gray	5	535	Lime, gray, sandy	40	2,400
Shale, gray	40	575	Lime, hard, blue	68	2,468
Sand, gray	95	670	Lime, gray and brown; show of oil at 2,480 feet	14	2,482
Sundance formation:					
Shale, gray	68	738	Lime, brown, sandy; hole filled up 300 feet with oil in 6 hours	22	2,514
Lime, white	22	760			
Lime, green	35	795			

QUALITY AND PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE OIL

The four anticlines in the region under consideration in which oil has been found in commercial quantity are the Fourbear, Pitchfork, South Sunshine, and Spring Creek anticlines. All of them yielded the so-called black oil, a heavy-gravity crude oil with a high sulphur content, a low gasoline yield, and a high asphalt content.[6]

The oil from the fields on these anticlines has not been marketed. The demand for black oil is small because of the expense involved in refining the crude oil into marketable products by present methods. The estimated potential production of black oils in Wyoming in 1931 was between 36,000 and 46,000 barrels a day for the wells then drilled. The actual production of black oil in 1930 was approximately 6,000 barrels a day.[7]

The following discussion and table are abstracted from the report of Thorne and Murphy.[8]

The "gasoline and naphtha" fractions from the black oil constitute the portion of the crude used in the manufacture of motor fuel. In the four fields in the area, the gasoline and naphtha fractions are deficient in light ends and have a sulphur content ranging from 0.14 to

[6] Thorne, H. M., and Murphy, Walter, A survey of the high-sulphur crude oils (black oils) produced in Wyoming; U. S. Bur. Mines Tech. Paper 538, pp. 1–56, 1932.

[7] Thorne, H. M., and Murphy, Walter, op. cit., p. 1.

[8] Thorne, H. M., and Murphy, Walter, op. cit.

Characteristics of the oil from the Cody-Pitchfork area [1]

Field	Formation	Gravity		Sulphur (percent)	Base of crude	Pour point (°F.)	Color	Gasoline and naphtha (percent)	Kerosene distillate (percent)	Gas oil (percent)	Lubricating distillates (percent)	Residuum (percent)	Road oil (percent)
		Specific	°A. P. I.										
Fourbear [2]	Tensleep or Amsden	0.976	13.5	3.88	Intermediate	45	Brownish black	2.3	2.4	10.6	28.5	55.9	84.4
Pitchfork [2]	Phosphoria and Tensleep	.961	15.7	3.87	do	10	do	6.3	3.3	14.4	22.2	53.6	75.8
South Sunshine [2]	Phosphoria	.947	17.9	3.15	do	10	do	6.2	3.0	15.8	28.1	46.8	74.9
Spring Creek [2]	Phosphoria, Tensleep, and Amsden.	.963	15.4	3.91	do	25	do	5.9	2.9	10.7	30.1	47.7	77.8

[1] Hempel method of analysis.
[2] Samples taken from storage tank.

0.89 percent. These fractions will need blending with light material in order to meet distillation requirements and will require desulphurization treatment in order to meet the sulphur specifications for motor fuel. By cracking, the crudes can be made to yield more gasoline than is shown in the table, but, owing to their high sulphur and carbon-residue contents, cracking offers difficulties of operation that require special equipment. At the Texas Co.'s refinery at Cody, which uses crude oil from the Oregon Basin field, about 15 percent of the crude is converted into gasoline and the remainder into road oil and fuel oil.

As shown in the table, the crude oil contains from 22.2 to 30.1 percent of lubricating oil stocks, which is greater than many of the well-known lubricating oil crudes, but the lubricating oil stocks from these black oils will require extensive and expensive treatment owing to their high sulphur and asphaltic-material content.

The increase in the construction of oiled roads has greatly increased the demand for road oils, so that now road oil is the principal product obtained from black oils. The specifications for road oil as adopted by the different States vary considerably; therefore, the road-oil content of a particular crude oil will depend to a considerable extent on the specifications to be met. To obtain the approximate figures for the road-oil content of the crudes shown in the table, it was assumed that the residue from the crude after the gasoline-and-naphtha, kerosene, and gas-oil fractions had been removed is road oil. The percentage of road oil then is shown by the sum of the lubrication distillates and the residuum. On that basis, the road-oil content of the crude oil from the region south of Cody ranges from 74.9 to 84.4 percent.

Almost any residue obtained from crude oil by topping or cracking processes is suitable for fuel oil unless its flash point is so low that it is dangerous to handle, or unless it contains so much sediment that it clogs in pipes or burners.

COAL

CHARACTERISTICS AND DEVELOPMENT

The coal from the Mesaverde and Meeteetse formations is classed by the Geological Survey as sub-bituminous class B coal. It is pitch black in color, although its streak is dark brown. On weathering it slacks and breaks down into small pieces. The coal beds have not burned along their outcrop, although burning and the formation of clinker are features commonly associated with the coals in the eastern part of the State and in Montana and the Dakotas. In general, the coal in the region south of Cody is impure, and shale partings are common. The impurities in the coal consist of bone, clay or shale, pyrite, and carbonaceous shale.

There are relatively few places in the area where there is clean coal of sufficient thickness to warrant mining under present conditions. Mines have already been opened at those places, and they are worked seasonally when market conditions permit. None of the mines were in operation at the time of the field investigation. The coal produced is used locally.

COAL IN THE MESAVERDE FORMATION

Coal occurs in two zones in the lower part of the Mesaverde. The lower zone was called the Wilson coal group by Hewett and occurs just above the lowest massive sandstone in the Mesaverde, which is about 100 feet thick. The Buffalo group of coal beds, described by Hewett, lies 45 to 100 feet above the Wilson group in this area.

WILSON COAL GROUP

The Wilson coal group is present along the east flank of the Horse Center anticline through the central part of T. 52 N., R. 101 W.,

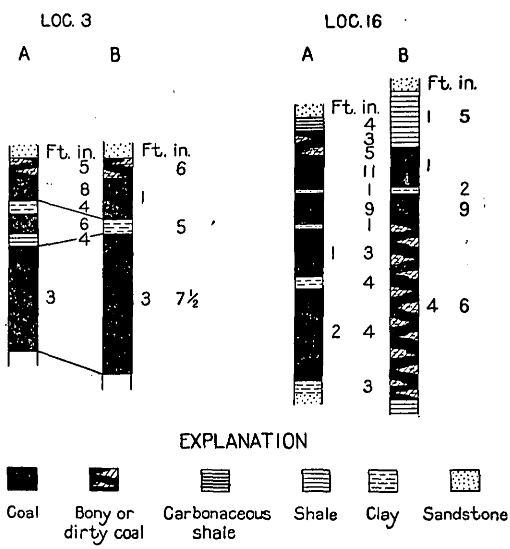


FIGURE 12.—Sections of Wilson coal bed in Mesaverde formation showing variation in coal within short distances.

and the northern part of T. 51 N., R. 101 W. It was not mapped continuously through this area because exposures were poor, but it is probably present. This bed was measured at localities 1, 2, and 3 (see pl. 24) and had a maximum thickness of 5 feet 1½ inches of coal and bony coal with a 5-inch shale parting at locality 3, a small entry mine that is worked during the fall and winter. The rapid lateral change in the bed is well shown at that mine and is illustrated in figure 12 by two sections measured 25 feet apart in the mine entry. Near the opening there are two shale partings 4 inches thick, with 6 inches of coal between them. Within 25 feet they come together to form one shale parting 5 inches thick, and the coal thickens both above and below this parting. The Schwab mine, at locality 2, in the NW¼ sec. 21, T. 52 N., R. 101 W. (see pl. 24), was described by Woodruff,[9] who shows a section of the coal bed very similar to that measured by the writers. This mine was described earlier by Fisher [10] as the Burns and Rogers mine. The section measured by Fisher is similar to the sections measured by Woodruff and the writers.

The Wilson coal bed also extends intermittently from the eastern border of the area in sec. 33, T. 51 N., R. 101 W., northwest to sec. 13, T. 51 N., R. 102 W., and from there almost directly south to the Meeteetse Rim in sec. 25, T. 50 N., R. 102 W. Sections of the bed were measured at localities 4, 5, 6, 15, 16, and 19. Bony coal with a maximum thickness of 5 feet 6 inches was observed at locality 6, and coal with a maximum thickness of 5 feet 11 inches, separated by three shale partings, making a total thickness of 6 inches for the bed, was observed at locality 16. Many prospects have been opened on this bed in T. 51 N., R. 101 W., between the Frost Ranch and the east border of the area. The coal has been mined sporadically at the Orr mine, described by Woodruff,[11] for more than 30 years.

This coal bed also crops out along Meeteetse Creek and Horse Creek in the northern part of T. 49 N., R. 101 W. Sections were measured at localities 22, 23, 24, and 25, with a maximum observed thickness of 3 feet 5 inches of coal and bony coal at locality 22. Fisher [12] reported two benches of coal, each 3 feet thick, with a light bluish-gray slate parting at the Horse Creek mine (Orr mine in Fisher's report) in the NW¼NE¼ sec. 7, T. 49 N., R. 101 W. Woodruff [13] later reported two benches of coal in this mine (Orr's Horse Creek mine in Woodruff's report), the upper bench 22 inches thick and the lower one 26 inches thick.

The Wilson coal crops out on both the northeast and southwest limbs of the Rawhide syncline, in the northwestern part of T. 48 N., R. 101 W., the northeast corner of T. 48 N., R. 102 W., and the southwest corner of T. 49 N., R. 101 W. Outcrop measurements were made at localities 27, 28, 29, 31, 32, 33, and 35, as shown on plate 24. The maximum measured thickness is 2 feet 3 inches. The coal is

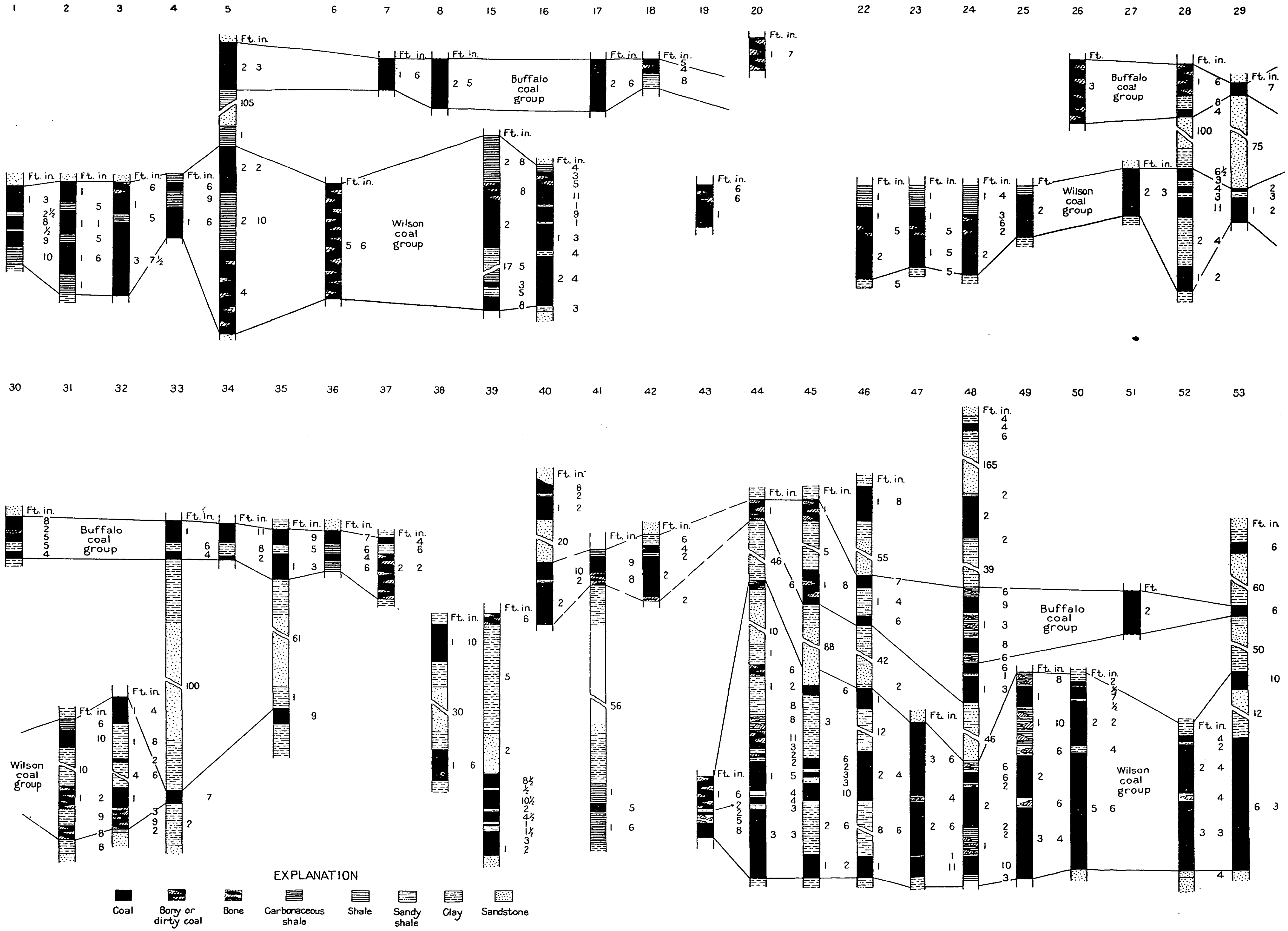
[9] Woodruff, E. G., Coal fields of the southwest side of the Big Horn Basin, Wyo.: U. S. Geol. Survey Bull. 341, p. 209, pl. 11 (locality 4), 1909.

[10] Fisher, C. A., Coal of the Bighorn Basin in northwest Wyoming: U. S. Geol. Survey Bull. 225, p. 348, 1904.

[11] Woodruff, op. cit., p. 210.

[12] Fisher, C. A., op. cit., p. 350.

[13] Woodruff, E. G., op. cit., p. 211.



SECTIONS OF COAL BEDS IN MESAVERDE FORMATION.

lenticular and is usually either impure or contains one or more partings. No mines have been opened on the coal in this syncline.

The Sunshine syncline is encircled by the outcrop of the Wilson coal group. On the northeast flank of the syncline sections were measured at localities 43, 44, and 45. There the coal has a southwest dip of 42° to 62°. Near the center of T. 48 N., R. 102 W., there is a faulted area which contains some coal. The coal is not thick, its areal extent is small, and the faulting and fracturing will make mining difficult. Sections were measured at localities 38 and 39; at locality 38 the coal bed is vertical. The thickest coal bed in the Wilson group occurs on the west and south sides of the Sunshine syncline, as shown by the sections measured at localities 46, 47, 48, 49, 50, 52, and 53. The maximum measured thickness is at locality 50, where there is 8 feet 5 inches of coal with two half-inch partings and one 4-inch parting. The coal has been mined at localities 50 and 52.

BUFFALO COAL GROUP

The Buffalo group of coal beds, named by Hewett,[14] crops out in much the same area as the underlying Wilson coal group. The Buffalo group is 40 to 90 feet above the Wilson group in the southern part of the area and about 100 feet above the Wilson group in the northern part of the area. The Buffalo group is more lenticular than the lower group and consists, in the main, of coal beds less than 2½ feet thick that are dirty or bony at many localities. As a result, the Buffalo group has been prospected far less than the underlying Wilson group.

The Buffalo group of coal beds was not observed on the east flank of Horse Center anticline in Tps. 51 and 52 N., R. 101 W. It does crop out, however, along Cedar Ridge in T. 51 N., R. 101 W., where it follows closely the outcrop of the Wilson group. Sections were measured at localities 5, 7, and 8, and a maximum thickness of 2 feet 5 inches was found at locality 8, as shown on plate 24. This coal group crops out also in the east tier of sections of T. 50 N., R. 102 W., from the vicinity of the Orr mine southward to the Meeteetse Rim. Sections were measured showing 2 feet 6 inches of coal at locality 17 and 9 inches of coal and bony coal at locality 18. The coal bed cropping out at locality 20 seems to be a local one 200 feet or more above the horizon of the Buffalo group. No coals of the Buffalo group were observed along Horse and Meeteetse Creeks in the part of T. 49 N., R. 101 W., included in the region south of Cody, but 3 feet of bony coal

[14] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 95, 1926.

was measured at locality 26 in the NW¼ sec. 27, just outside the region.

The Buffalo coal group is present in the Rawhide syncline. Its outcrop is closely parallel to the outcrop of the Wilson group, which underlies it at an interval of 60 to 100 feet. The coal is not of economic importance, however, owing to the thinness of the bed and the impurities and partings that it contains. Sections showing the general character and thickness of the bed were measured at localities 28, 29, 30, 33, 34, 35, 36, and 37 and are shown graphically on plate 24.

The Buffalo coal group does not contain coal of economic importance in the Sunshine syncline. Only rarely does the bed attain a thickness of 2 feet. Its outcrop roughly parallels the outcrop of the Wilson coal, which is 42 to 88 feet below it. Sections were measured at localities 40, 41, 42, 44, 45, 46, 48, 51, and 53.

The Buffalo coal has not been mined in either the Rawhide or Sunshine synclines.

COAL IN THE MEETEETSE FORMATION

Coal beds which exceed a foot in thickness occur in the upper part of the Meeteetse formation. Although these coals locally attain a thickness of 5 feet as shown at locality 9, figure 13, the beds are lenticular and discontinuous. It was impracticable to try to map each bed, but the zone containing the coal, which occurs on a steep westward-facing escarpment in T. 50 N., R. 101 W., is shown by a line on the geologic map (pl. 11). The coals may extend north and south of the ends of this line, but their outcrops are poor and they could not be traced in the grass-covered slopes. Detailed sections of the coal beds that were measured are shown in figure 13. The thickest bed found measured 5 feet and was 392 feet below the top of the Meeteetse formation at locality 9. Most of the remaining coal beds are less than 100 feet below the top of the formation. A bed 4 feet thick, near the top of the formation, was measured at localities 10 and 11, and two beds 3 feet thick and 14 feet apart were measured at locality 9. Additional beds were measured at localities 12, 13, and 14. A coal bed in the Meeteetse formation at locality 21 was described by Fisher,[15] whose measured section is plotted in figure 13. At the time the section was measured the bed was exposed at the Conie mine, which is in an area covered with gravel debris from the gravel of the Rim terrace. Several years later Woodruff [16] reported that the mine was abandoned. The entry of the abandoned mine was not found in the course of the present examination. The formational boundaries cannot be located

[15] Fisher, C. A., Coal of the Bighorn Basin in northwest Wyoming: U. S. Geol. Survey Bull. 225, p. 349–350, 1904.

[16] Woodruff, E. G., Coal fields of the southwest side of the Bighorn Basin, Wyo.: U. S. Geol. Survey Bull. 341, p. 211, 1909.

accurately in the immediate vicinity of the old mine, but the coal bed probably is near the top of the Meeteetse formation.

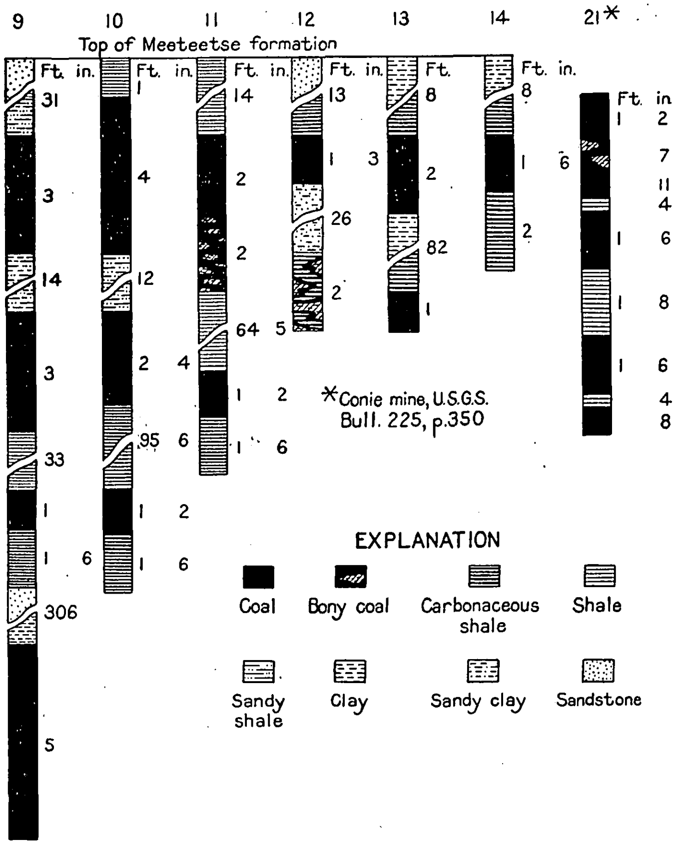


FIGURE 13.—Sections of coal beds in upper part of Meeteetse formation, T. 50 N., R. 101 W.

BENTONITE

The area covered by this report contains a number of bentonite beds and is therefore a field for exploration and possible development. Bentonite beds are common through a stratigraphic range of 1,500 feet, including the Frontier, Mowry, and Thermopolis formations. The beds in the Frontier and Mowry formations are the most promising for commercial development because in general they are the thickest—some of them 2½ to 6 feet thick. As noted on page 124, there are usually two bentonite zones in the Frontier, one from 85 to 140 feet below the top of the formation and the other from 90 to 140 feet above the base. The middle half of the Frontier apparently does not contain any persistent beds of bentonite.

The greatest number of bentonite beds occurs in the Mowry and

Thermopolis shales. In measured sections of the two formations a total of 44 beds was noted, with a combined total thickness of about 80 feet. Hewett[17] records 32 beds of bentonite in the Thermopolis shale along Shoshone River so that with the 27 beds noted in the Mowry the total number in the two formations may be about 60. A bentonite bed in the Mowry is mined about 4 miles northwest of Cody.

Pure bentonite is a white to pale greenish-yellow clay that is practically free from grit. Its absorbent quality is unusual, for it can absorb three times its weight of water and swells to six or ten times its original volume. When fresh it breaks with a conchoidal fracture, but on exposure it loses this property and when dry has either a fluffy granular appearance or assumes a crinkled coral-like surface. When wet it becomes plastic and slippery, a characteristic which no doubt has led to such names as "mineral soap" and "soap clay." In some places where the bentonite remains wet most of the time, "soap holes" form that may become encrusted with a thin hard dry layer at the top and form a dangerous mire particularly for livestock.

Bentonite is composed chiefly of the mineral montmorillonite. It seems to be the consensus of opinion of those who have studied them that bentonites are devitrified and partly decomposed volcanic ash deposits. Bentonite beds encountered in drilling operations often cause considerable trouble because the bentonite swells when wet and forms a sticky mass that flows into the hole and causes its sides to swell, heave, and cave. Bentonite swells much less in salt solutions than in water, however—a fact that can be utilized to advantage when difficulty is encountered in drilling through it.

Bentonite was probably first used by the Indians and early settlers in the West for washing blankets. The first commercial shipment of this clay was in 1888, and in 1898 it was named bentonite from its occurrence in the unit then called the Fort Benton formation (Benton shale of present usage). The interest shown in bentonite was considerable at first, then died down for a period but revived as investigations revealed new uses for it in industry. These uses are varied and numerous, as shown by the following list: Absorbent in the refining of petroleum; a seal for walls and a medium for maintaining suspension in oil-well drilling mud; water softener; sealing agent for dams and porous rock; filler in paper, oilcloth, phonograph records, and similar products; constituent in the manufacture of soap, cosmetics, coatings for metals, molded electrical insulators, pencil leads and crayons, cold-water paints, calcimines, enamels, and inks; constituent in stove, shoe, and other polishes; adulterant in candy; suspension agent in ceramic glazes; absorbent for de-inking printed

[17] Hewett, D. F., Geology and oil and coal resources of the Oregon Basin, Meeteetse, and Grass Creek Basin quadrangles, Wyo.: U. S. Geol. Survey Prof. Paper 145, p. 56, 1926.

paper; dusting agent in grinding materials; base for salves and ointments, and diluent for drugs.

As beds of bentonite are numerous in the region south of Cody, it seems advisable, before commercial production is undertaken, to call attention to factors indicated in the following quotation:[18]

> Prospectors and others who become interested in the production of bentonite should make a careful investigation of the commercial possibilities of the deposit in question before investing heavily. Such a study should include the possibility of marketing the product, the specifications demanded, the price obtainable, the cost of mining, treating, and shipping to market, the size of the deposit, and the nature of the crude bentonite. One should also realize that most consumers desire a homogeneous product that will remain uniform over a period of years and that deposits containing bentonite which will do this are not common; that most crude bentonites contain appreciable quantities of objectional impurities such as sand, gypsum, carbonaceous matter, or soluble salts that must be removed at considerable expense by washing; and that the purified bentonites from different deposits and even from different levels or parts of the same deposit may have very different properties, such as variation in color, colloid content, and ease of hydration. In general, consumers want a clean, homogeneous, finely divided substance.

SULPHUR

Surficial hot-spring deposits of native crystalline sulphur are present near the base of Cedar Mountain, extending from Shoshone River southward to Sulphur Creek[19] through secs. 3 and 10 and tracts 64 and 78, T. 52 N., R. 102 W. The sulphur occurs as veins in the travertine overlying the Cody and Powell terraces, as disseminated deposits in sandstone and as cavity fillings in the Phosphoria formation. Most of the production has been from the Phosphoria formation. The earliest production reported from this area was that of 1906 by the Bighorn Sulphur Co. After a few years this activity ceased and was not revived until 1916. The stimulus furnished by the World War initiated a revival of activities, and production was reported during 1916 and 1917 by the Midwest Sulphur Co., the Cody Sulphur Co.,[20] and the Yellowstone Sulphur Co.[21] Production from these deposits has not been reported since 1917.

[18] Davis, C. W., and Vacher, H. C., Bentonite: its properties, mining, preparation, and utilization: U. S. Bur. Mines Tech. Paper 438, p. 29, 1928.

[19] Woodruff, E. G., Sulphur deposits at Cody, Wyo.: U. S. Geol. Survey Bull. 340, pp. 451–456, 1908.

[20] Smith, P. S., Sulphur, pyrite, and sulphuric acid: Mineral Resources, U. S., 1916, pt. 2, p. 416, 1919.

[21] Smith, P. S., Sulphur, pyrites, and sulphuric acid: Mineral Resources, U. S., 1917, pt. 2, p. 19, 1920.

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