Professional Paper No. 53

Series { B, Descriptive Geology, 91
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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

GEOLOGY AND WATER RESOURCES

OF THE

BIGHORN BASIN, WYOMING

BY

CASSIUS A. FISHER

WASHINGTON
GOVERNMENT PRINTING OFFICE
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ILLUSTRATIONS.

GEOLOGY AND WATER RESOURCES OF THE BIGHORN BASIN, WYOMING.

By Cassius A. Fisher.

INTRODUCTION.

This paper is the result of field work done during the seasons of 1904 and 1905 It is designed mainly to furnish information regarding geologic structure and. the prospects for underground water. The description of the formations of the Bighorn Mountain area is chiefly the work of N. H. Darton, under whose direction the exploration was made.

A general account of the surface waters is given, including a statement of their present and proposed uses for irrigation, and the economic products of a geologic nature are also described. The region considered comprises the Bighorn basin, a part of the Clark Fork basin, and the slopes of the adjoining mountain ranges, the entire area comprising 8,500 square miles. As shown on fig. 1, it is situated mainly in Bighorn County, in the northwestern part of Wyoming, and includes the greater portion of the area lying between meridians 107° 15′ and 109° 15′ and parallels 43° 40′ and 45°. It is bounded on the north by Montana, on the east by the Bighorn Mountains, on the south by Bighorn and Owl Creek mountains, and on the west by Shoshone, Absaroka, and Beartooth mountains.

TOPOGRAPHY.

GENERAL RELATIONS.

The area presents a great variety of topographic forms. Its salient feature is a broad structural valley bordered on nearly all sides by high mountain ranges. Along the outer portions of the valley there are a number of secondary ridges of moderate prominence, extending in a direction nearly parallel to the trend of the higher mountain ranges. The interior of the valley is characterized by high bad-lands slopes, which terminate in irregular ridges and sharp peaks or are capped by older gravel terraces. The streams crossing the basin flow in deep but broad, sloping valleys, bordered by terraces rising to adjoining highlands.

RELIEF.

There is considerable range of altitude in the area. The highest point in the district is the Washakie Needles, very prominent peaks in the southern part of the Shoshone Mountains, which rise to an altitude of 12,496 feet. The lowest point is at the upper end of Bighorn Canyon, where the altitude is less than 3,600 feet above sea level. The average altitude for the interior of the basin is 5,000 feet.

Bighorn Mountains.—The high western slopes of the Bighorn Mountains extend diagonally across the eastern side of the district from southeast to northwest. In

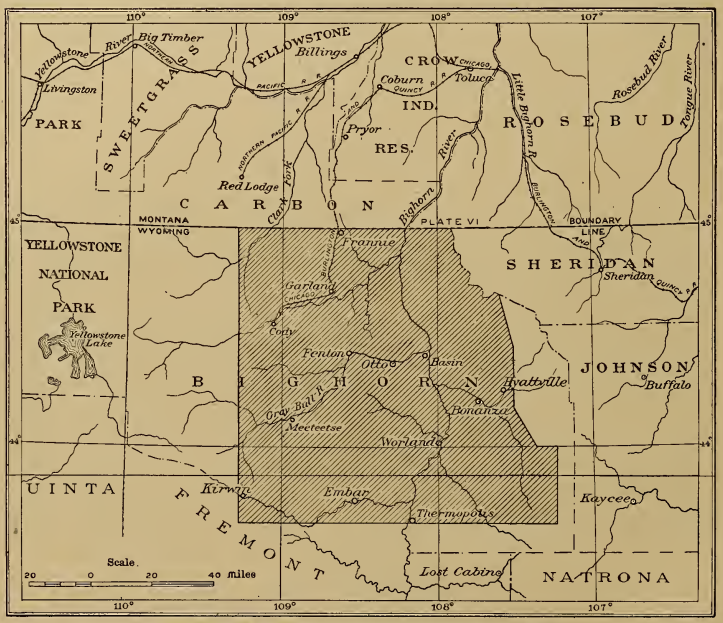


FIG. 1.—Map of part of Wyoming and Montana, showing area described.

the northern part of the basin the slopes are 6 to 10 miles wide and extend from a point about 6 miles southeast of Shell post-office nearly to Medicine Mountain, where, owing to a decrease in dip, the high mountain front merges into a broad, sloping plateau that lies between the outer edge of the front range and the summit of the main uplift. The mountains generally rise abruptly from the plains to an altitude of about 8,000 feet and then more gradually toward the summit line or divide of the range, which reaches, in places, an altitude of about 10,000 feet. All the larger streams have their sources near the tops of the mountains and have cut

A. CODY, FROM THE SOUTHEAST.

B. GRAY BULL RIVER ABOVE PITCHFORK RANCH, WYO.

deep canyons in the mountain front, while at its northern end the high, sloping plateau is deeply trenched by Bighorn River and Devil Canyon. There are a number of prominent peaks along the summit of the Bighorn Mountains, including Hunt, Little Bald, Bald, Medicine, and Duncom mountains, all of which rise to an altitude of about 10,000 feet.

From the summit of the high divide between Shell and Paintrock creeks southward the western side of the Bighorn Mountains is characterized by long, gradual slopes, generally deeply cut by the numerous mountain streams which traverse them. Extending along the base of the mountains from northwest to southeast are a number of minor folds, some of which give rise to prominent topographic ridges.

Bridger and Owl Creek mountains.—The Bighorn basin is bounded on the south by the Bridger and Owl Creek mountains. Both ranges belong to the same general uplift, which in reality is a prolongation of the Bighorn Mountains westward. The uplift ranges in altitude from 7,000 to 9,500 feet. Near the center from east to west it is crossed by Bighorn River, which cuts a narrow gorge having a depth of 2,250 feet in the axis of the range. The uplift is characterized on the north by long, gradual slopes and on the south by steep ascents, which are considerably faulted. Only the lower portion of the northern slope of that part of the uplift lying west of Bighorn River is included in the area to which this report relates. Along the northern side of Owl Creek Mountains, in the vicinity of Thermopolis, there are a number of small anticlines, giving rise to prominent topographic ridges.

Absaroka and Beartooth mountains.—The eastern side of the Absaroka and Beartooth mountains forms a narrow strip along the western margin of the district, extending from Black Mountain northward to the Montana line. The highest portion of this front range is Black Mountain, which has an altitude of about 8,600 feet above sea level. Across Shoshone River, in the vicinity of Cody, there is an anticlinal spur extending from the Absaroka Mountains, which comprises the Rattlesnake and Cedar Mountain uplift. The highest portion of this spur is near the north end of Rattlesnake Mountain. The uplift has been deeply trenched at the south end by Shoshone River, which has there formed a canyon that now separates Cedar and Rattlesnake mountains. Heart Mountain, an isolated butte in the northwestern part of the basin, is a very prominent topographic feature, rising to an altitude of nearly 8,000 feet. A view of Cody, in the Shoshone Valley, with Heart, Rattlesnake, and Cedar mountains in the distance, is shown on Pl. I, *A*. McCulloch Peak is a prominent eminence southeast of Heart Mountain, on the opposite side of Shoshone River. Its altitude is about 6,000 feet. Between Heart Mountain and McCulloch Peak and the main uplift west of these high points are several low ridges, due to minor folding, and along the base of the mountains lie a number of hogback ridges.

Shoshone Mountains.—From Shoshone River southward the basin is bordered by the Shoshone Mountains. This range, in appearance, is that of a high, deeply dissected plateau, presenting a confused mass of castellated peaks and ridges and traversed by many deeply cut canyons. This configuration is maintained to the eastern mountain front, which, in the region north of Gray Bull River, is bordered by a broad belt of low foothills. To the south of this stream the transition between

mountain and plain is more gradual, and between Sunshine post-office and Dent's ranch many of the prominent mountainous ridges extend far out into the basin province.

Sheep Mountain region.—Several high ridges extend across the eastern side of the basin from the mouth of Shell Creek to Shoshone River, the most prominent of which are Sheep and Little Sheep mountains. Sheep Mountain has an altitude of about 5,000 feet, rising 800 to 900 feet above the surrounding country. It is deeply cut by Bighorn River in Black Canyon. Little Sheep Mountain has an altitude of about 5,000 feet, and, as it is bordered on the north and the east by lowlands, is a prominent topographic feature.

Bighorn basin region.—Between Clark Fork and Bighorn River there is a ridge extending from the vicinity of Heart Mountain northeastward to the western end of Pryor Mountain; the lowest point in this ridge, which is at the head of Big Sand Coulee, has an altitude of 4,800 feet. At the southwest end of the ridge the divide is very narrow, but to the northeast it is continued as a broad plateau which constitutes one of the most prominent topographic features of the northern part of the Bighorn basin. On either side of Clark Fork the surface rises gradually toward the surrounding highlands. To the west of Clark Fork, between the valley and the high mountains, there are a number of prominent hills, some of which have an altitude of nearly 7,000 feet. On the northern side of Sage Creek, from Frannie to beyond Cowley, the surface rises gradually toward the hogback ridges bordering the base of Pryor Mountain. Between Cowley and Garland there is a series of low, irregular, sandstone hills separated by wide, shallow valleys leading to Shoshone River. West of Garland, between Shoshone River and the base of the high plateau to the north, there is a broad, level area, comprising about 100 square miles, known as Garland Flats.

The region between Shoshone River and Dry Creek is made up of gradual slopes, traversed by high ridges and deep ravines. The divide between these two streams usually presents a high escarpment to the north and long, gradual slopes to the south. In its westward extension it terminates in McCulloch Peak. Beyond Dry Creek, which flows through a wide, open valley, there is a high terrace, more or less dissected by ravines on either side, which continues to the Gray Bull Valley. Northwest of Wise there is a high plateau sloping eastward, known as Meeteetse rim, which rises to an altitude of over 7,000 feet. It is about 3 miles wide and occupies the area between Meeteetse Creek and the head of Sage Creek. In its eastward extension it spreads out considerably and is traversed by numerous deep ravines. A very prominent ridge occurs between the headwaters of Dry and Sage creeks, which is locally known as Frost Ridge. It has an altitude of about 7,000 feet and continues from Frost ranch southeastward for about 6 miles.

The Gray Bull River Valley below Fourbear post-office is relatively wide, but in the vicinity of Pitchfork ranch it narrows rapidly and is bordered on either side by high bluffs of Cretaceous formations. Below Fenton the bluffs recede and the valley again widens to 5 or 6 miles and maintains this width nearly to the mouth of the river.

The topographic features of that portion of the basin lying between Gray Bull and Bighorn rivers are mainly those of a badlands district. Broadly viewed, the surface is a plain rising from east to west, which has been much dissected by large,

intermittent streams and their numerous tributaries. A number of high buttes still remain in the interior of the basin. Tatman Mountain, Squaw Buttes, and Ilo Ridge are among the most prominent, all of which rise to an altitude of about 6,000 feet. To the west the surface rapidly rises, and a number of very prominent ridges occur between the headwaters of Owl, Cottonwood, Grass, and Gooseberry creeks and Wood River.

The region lying east of Bighorn River, which comprises the southeastern part of the basin, is mainly a badlands district. It consists of long, gradual slopes terminating in irregular ridges and sharp peaks. Along the high divide between No Wood and No Water creeks are a number of isolated peaks which have altitudes of 5,800 to 6,000 feet. On the west side of this divide, near the head of the east fork of No Water Creek, there is an area of very rugged topography, known as the Honeycombs.

DRAINAGE.

Bighorn River.—The principal stream of the district is Bighorn River. It enters the area at Thermopolis and flows in a northerly direction across the region, passing into Bighorn Canyon near the Montana line. Its largest tributaries from the west are Shoshone and Gray Bull rivers and Gooseberry, Meeyero, and Owl creeks, and from the east No Wood and Shell creeks. A number of small streams of moderate flow enter the river in the northern part of the basin. These are Bear, Crystal, Five Springs, Willow, and Cottonwood creeks from the east and Crooked Creek from the west. There are several intermittent streams with large drainage areas in the central portion of the basin, which, during the flood season, carry a large volume of water. The largest of these are Dry, Dry Cottonwood, Kirby, and No Water. Measurements of the flow of Bighorn River have been taken at Thermopolis and Basin, and the results of these observations are given in the following table:

Discharge measurements of Bighorn River at Thermopolis, Wyo.

[Made by A. J. Parshall.]

1899.	Second-feet.
July 28	4,867
August 7	4,204
August 16	2,673
September 14	1,162
1900.	
May 28	8,500
May 29	10,527
May 30	12,187
September 13	945
September 18	672
1902.	
June 11	9,080
June 14	8,391
June 16	6,334
1903.	
March 27	621
May 23	1,953
May 25	1,709
1903.	Second-feet.
June 20	9,280
June 21	8,444
June 22	7,442
July 18	3,882
July 20	4,024
1904.	
March 25	290
June 19	12,940
June 22	14,240
July 11	7,117
July 12	7,467
July 17	6,130
July 28	5,008
August 3	3,941
August 11	2,878
August 26	2,084
November 24	438

Shoshone River.—Shoshone River, the largest tributary of Bighorn River, flows diagonally across the northern portion of the Bighorn basin. It is formed by the North Fork and the South Fork of the Shoshone, which have their confluence just above Shoshone Canyon. This river was formerly called Stinkingwater River, a name derived from the distinctly sulphurous odors which its waters emit, especially in the vicinity of Cody, where there are a number of hot mineral springs (Pl. XVI, *A*, p. 60). The principal tributaries of Shoshone River are, from the south, Carter, Diamond, Sulphur, Sage, Whistle, and Coon creeks, and from the north, Trail, Dry, Cottonwood, Eaglenest, Alkali, and Sage creeks. Nearly all these streams are dry for a portion of the year. Discharge measurements of Shoshone River near Cody, Wyo. (see Pl. II, *A*), have been made as follows:

Discharge measurements of Shoshone River near Cody, Wyo.

1902.	Second-feet.	1903.	Second-feet.
April 26	538	June 24	4,212
June 7	4,352	July 14	3,829
July 17	2,812	July 15	3,299
July 31	2,039	July 25	3,087
December 8	270	October 31	450
1903.		1904.	
March 20	263	March 29	253
April 21	633	April 30	1,536
April 25	1,399	May 22	6,200
May 19	1,374	June 17	6,330
May 20	1,263	June 20	9,116
June 6	2,624	August 27	1,186
June 11	5,502	September 9	885
June 16	7,297	October 8	413
June 17	8,885	December 22	321
June 18	8,840		

Hydrographer, A. J. Parshall, except for the following dates: June 6, 11, and October 31, 1903, and May 22, June 17, 20, August 27, October 8, and December 22, 1904, J. Ahern; April 30, 1904, W. E. Young.

Gray Bull River.—This stream rises in the Shoshone Mountains and flows northeastward across the central part of the basin, joining Bighorn River near Coburn post-office. As the stream has its source high on the slopes of a snowy range, it carries a large amount of water, especially in midsummer. At Meeteetse its flow is estimated as follows:

Estimated monthly discharge of Gray Bull River at Meeteetse, Wyo., 1897.

	Second-feet (mean).		Second-feet (mean).
June 14–30	943	October	[a] 100
July	513	November	[a] 100
August	299	December	[a] 100
September	104		

[a] Approximate.

The largest tributary is Wood River, which rises high on the slopes of the southern part of the Shoshone Mountains at altitudes ranging from 10,000 to 12,000 feet, where there is much snow and a moderately high rainfall. In consequence this stream carries a good volume of water. From the north, Gray Bull River

A. SHOSHONE RIVER AT CODY, WYO.

B. SHOSHONE DAM SITE.

Upper end of Shoshone Canyon

receives small flows from Rawhide, Spring, and Meeteetse creeks, and from the south, from Timber and Franks creeks.

Clark Fork.—This stream crosses the extreme northwest corner of the district. It rises high in the slopes of the Absaroka Mountains to the west and carries a large volume of water, especially during the early summer months. From the south, its principal tributaries are Pat O'Harra, Paint, and Newmeyers creeks and from the west, Little Rocky, Bennett, and Line Creeks. All these streams have a vigorous flow derived from springs on the mountain slopes.

Other important streams.—Owl Creek, which flows along the base of the Owl Creek Mountains and joins Bighorn River below Thermopolis, carries only a moderate volume of water, which probably does not exceed 20 second-feet. It is formed by North Fork and South Fork of Owl Creek, which have their confluence near Embar ranch.

In the southwestern part of the basin along the base of the Shoshone Mountains several streams have their sources. Gooseberry Creek, the largest of these, flows across the southern part of the basin and joins Bighorn River above Olwen post-office. It carries considerable water in its upper course, and a small amount goes through to Bighorn River at all seasons of the year. Middle and Enos creeks, two small running streams, join Gooseberry Creek in the vicinity of Dickie ranch.

Meeyero Creek, which drains the district between Gooseberry and Owl creeks, is formed by Grass and Cottonwood creeks, at a point about 6 miles east of Morrison ranch, and joins Bighorn River near Winchester post-office. Cottonwood and Grass creeks are fed by springs at the base of the mountains and have small flows which continue throughout the year, but below their junction the water sinks, and the lower part of Meeyero Creek is usually dry in the late summer months.

No Wood Creek flows in a northwesterly direction along the west side of the Bighorn Mountains and receives several vigorous mountain streams, most of which rise in springs in the higher slopes of the Bighorn Mountains east of the area here described. The principal affluents are Paintrock and Tensleep creeks, and above these are Spring, Otter, and Little Canyon creeks. All of these are flowing streams, which add materially to the volume of No Wood Creek. Messrs. Elwood Mead and C. T. Johnston made a discharge measurement of No Wood Creek at Morgan's ranch, 4 miles above its mouth, August 21, 1897, which showed a flow of 109 second-feet.

Shell Creek, one of the largest branches of Bighorn River in the northeastern part of the area, rises in the Bighorn Mountains near the base of Cloud Peak, in a region of perpetual snow. It has an average fall of 20 feet a mile in the lowlands west of the mountains and carries a large amount of water. Trapper, Horse, and Beaver creeks are its principal tributaries.

Dry Cottonwood Creek is the largest intermittent stream in the central part of the Bighorn basin. It rises in the high hills near Meeteetse and joins the Bighorn at Worland. The area drained by this stream is about 450 square miles, lying between Gray Bull River and Gooseberry Creek. As this stream has its source on the west side of the basin, where there is a relatively large rainfall, it carries considerable flood water. Dry Creek, another important intermittent tributary, crosses the north-central part of the basin, rising near Meeteetse rim and joining Bighorn River at Coburn post-office. This stream also has a large watershed.

The southeastern part of the Bighorn basin is drained by Kirby and No Water creeks, but these streams do not rise high on the slopes of the adjoining mountains, where they can receive water from melting snows, and in consequence are flowing streams for part of the year only. The region which they drain is used mainly for grazing.

OUTLINE OF THE GEOLOGY.

STRATIGRAPHY.

The formations appearing at the surface within the area to which this report relates consist of both igneous and sedimentary rocks. They are representatives of the pre-Cambrian, Cambrian, Ordovician, Carboniferous, Triassic, Jurassic, Cretaceous, Tertiary, and Quaternary systems. The distribution of the various formations, except the Quaternary, is shown on the geologic map (Pl. III, pocket), and their structural relations are indicated in the cross sections (Pl. IV). The data for the geologic map of the area included in R. 102 and 103 W., T. 43 and 44 N., have been taken from the report on the geology of the Owl Creek Mountains by Mr. N. H. Darton.[a]

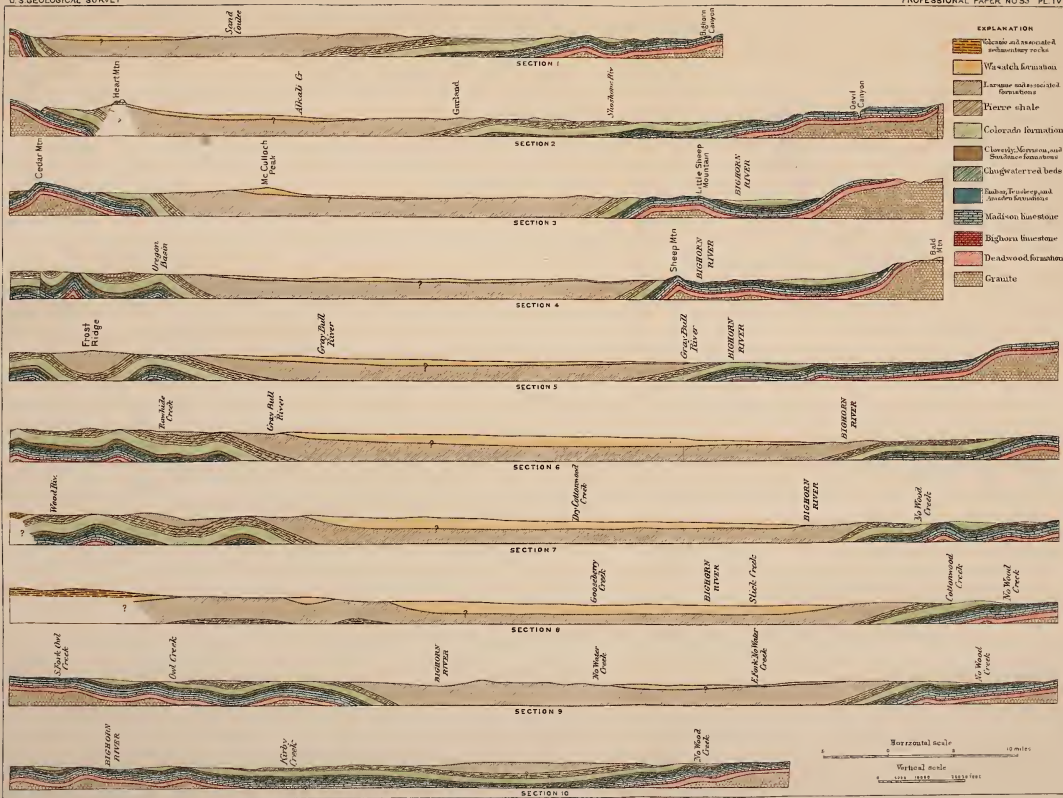
The following table shows the order, age, and characteristic features of the formations (Pl. V):

Table of geologic formations in the Bighorn basin.[b]

System.	Formation.	Principal characters.	Thickness.
			Feet.
Quaternary	Alluvium	Sand, loam, and gravel	20–40
	Hot spring deposits	Light-colored calcareous rock	20
	Later terrace gravels	Gravel and sand; dark color due to large amount of volcanic material.	20–30
	Early terrace gravels	Sand, gravel, and sandy clay; dark pebbles predominate in gravel.	20–60
	Volcanic rocks	Mainly volcanic breccia with basalt flows, intrusive dikes, and associated sedimentary rocks.	.....
Tertiary	Wasatch	Sand, clay, and conglomerate	2,000–3,000
	Laramie and associated formations.	Alternating layers of sandstone and shale, containing coal, greenish-gray sandstones at base.	5,000–7,000
	Pierre shale	Dark sandy shales containing concretions of iron	1,200–2,000
Cretaceous	Colorado formation	Dark gray to black shales, with sandstone, clay, and concretionary layers.	1,400–2,000
	Cloverly formation	Buff sandstones, alternating with massive red to purple shales.	200–300
	Morrison	Pale grayish-green sandstones and shales	130–400
Jurassic	Sundance	Greenish-gray shales and sandstones, with layers of limestone.	200–350
Triassic (?)	Chugwater formation	Massive red sandstone and shale, with layers of limestone and gypsum.	600–800
Carboniferous	Embar formation	Massive gray limestone	80–200
	Tensleep sandstone	Massive gray sandstone, containing layers of limestone	30–250
	Amsden formation	Red sandy shales and sandstones, with layers of limestone and chert.	100–200
	Madison limestone	Gray massive limestones	700–1,000
Ordovician	Bighorn limestone	Siliceous gray limestone, very hard and massive	200–300
Cambrian	Deadwood formation	Sandstone, shale, conglomerate, and limestone	700–1,500
Pre-Cambrian	.....	Granite	.....

[a] Geology of the Owl Creek Mountains, etc., U. S. Senate Doc. No. 119, 59th Cong., 1st session.

[b] Many of the names given in this table have been proposed by N. H. Darton for the Bighorn Mountain region. They are defined in a Comparison of the stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range: Bull. Geol. Soc. America, vol. 15, 1904, pp. 379–448, pls. 23–34.



CROSS SECTIONS OF THE BIGHORN BASIN, WYOMING, BY C. A. FISHER

PRE-CAMBRIAN ROCKS.

GRANITE.

General statement.—The underlying formation of the Bighorn uplift is a massive granite which has been raised several thousand feet above its original position. In the northern part of the Bighorn Mountains the overlying sedimentary rocks conceal the greater part of the granite, but it appears in irregular areas in several portions of the district. The most extensive exposures are about Bald Mountain, in the anticline extending from Red Gulch to a point west of Medicine Mountain, in the valley of Porcupine Creek, in Cookstove basin, and in the deeper portions of the canyons of Shell Creek. The rock is generally very massive and is of pre-Cambrian age. Granite is also exposed in Shoshone Canyon and on the north slope of the Owl Creek Mountains.

Granites of the Bighorn Mountain region.—The granites of the northwestern portion of the Bighorn Mountains are mainly a coarse-grained red variety, but there are a few small areas of a fine-grained gray granite.

The so-called red granite has a light-grayish appearance at a distance, but when viewed at close range is seen to be characterized by a more or less pronounced reddish tinge, due to the abundance of pink feldspar in it. The rock often presents a well-defined system of joints. and weathers into bold, rounded forms. Its surface is usually rough, owing to differential weathering, and the large feldspar phenocrysts often have sufficient prominence to give it a porphyritic appearance. The principal constituents are feldspar, quartz, and mica, occurring in varying proportions.

The gray granites of the district are generally uniform in color and texture and in the kind, amount, and distribution of their component minerals. There are, however, local areas where the ferromagnesian minerals predominate, giving the rock a very dark appearance. The gray granite presents in some localities a well-defined system of joints, the rock weathering into angular blocks or slabs, making the topography very rugged. To the unaided eye this rock is of dark-gray color, of medium to fine texture, and is marked occasionally by lines of secondary movement. The principal constituents are feldspar, quartz, and biotite.

Dikes of the Bighorn Mountain region.—Several dikes of diabase and peridotite cut the granite area described above. They vary in width from 2 to 25 feet and usually extend transversely or at a wide angle to the major axis of the main uplift. These dikes, owing to the greater hardness of the rock, offer greater resistance to atmospheric agencies than the softer granites into which they have been intruded, and consequently stand out in more or less prominent ridges that extend across the granitic areas. The rock weathers into cubes 2 to 6 inches square, the ultimate product of decomposition being a reddish-brown residual soil which in color presents a striking contrast to that derived from the lighter colored country rock. There are several of these dikes in the vicinity of Bald Mountain and on Porcupine and South Beaver creeks. In the granite flats west of Bald Mountain there is a branch dike extending north-northwest. It passes east of Medicine Mountain under the Deadwood sandstone for about a mile and appears to be continued due northward by one of the dikes crossing Porcupine Creek, its entire length being at least 5 miles. Small

dikes, or chimneys, of diabase appear in the vicinity of Fortunatus Mill, especially to the southwest. They are from 10 to 20 feet in diameter and of circular or elliptical outline. These smaller masses are of variable character and some of them exhibit considerable mineralization. The distribution of the dikes is not shown on the geologic map.

A microscopic examination of the diabase shows that the constituent minerals are feldspar, augite, and quartz, with biotite, magnetite, chlorite, and apatite occurring in smaller amounts.

Granite and diabase of Rattlesnake Mountain.—A small area of granite is exposed in Shoshone Canyon between Rattlesnake and Cedar mountains. The rock is moderately coarse grained and massive and appears to have been subjected to considerable pressure, for in places it is schistose. It has a well-defined system of joints, and weathers into bold, rounded forms. The granite is cut by dikes and sills of a quartz-bearing diabase. No microscopic examination of the granite of this locality has been made. One of the diabase dikes is shown in Pl. VI, *B*, p. 12.

Granite of Owl Creek Mountains.—The granites of the north slope of the Owl Creek Mountains, a small area of which is exposed within the district, appear to have no essential variation from those above described.

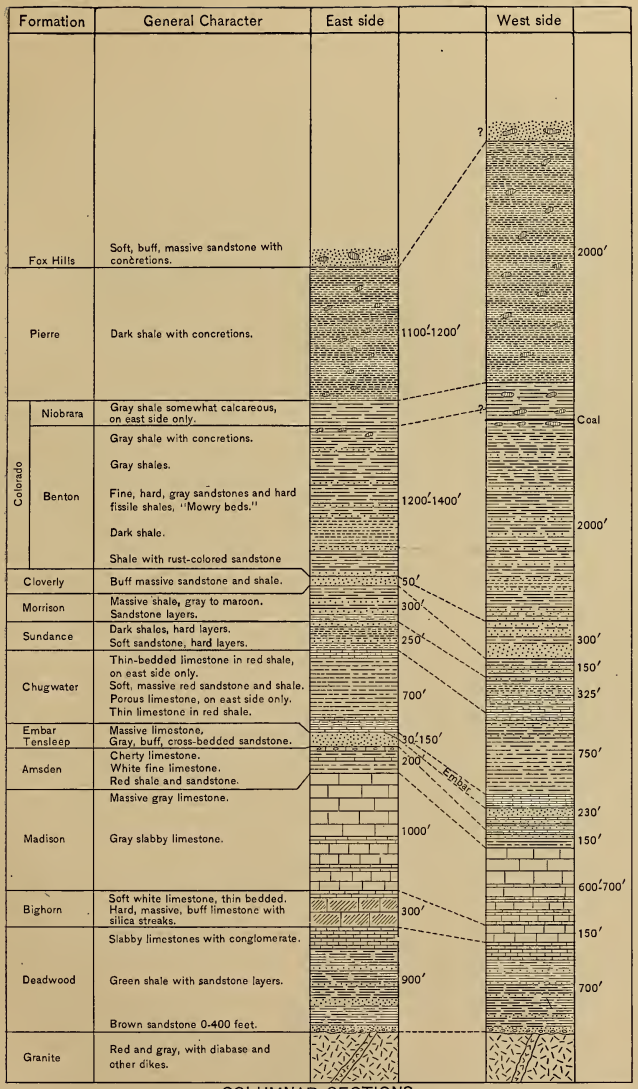
CAMBRIAN SYSTEM.

DEADWOOD FORMATION.

General relations.—The oldest sedimentary formation outcropping within the area is a series of beds of sandstone, shale, limestone, and conglomerate of middle Cambrian age that have a thickness ranging from 700 to 1,500 feet. To these beds, in the Bighorn Mountain province, Mr. Darton has applied the name Deadwood formation. The basal member is a sandstone, somewhat conglomeratic, lying on the granite. Its thickness varies from 10 to 30 feet. Next above this is a series of greenish-gray shales with layers of sandstone and sandy shale, having in all a thickness of about 300 feet. This member is succeeded by a sandstone 25 to 40 feet thick, which in turn is overlain by several hundred feet of shale containing thin-bedded conglomeratic sandstones and limestones. Overlying these beds are alternating layers of limestone and limestone conglomerate made up of flat limestone pebbles. The pebbles are mostly green in color, but on freshly broken surfaces are gray to pale pink. These limestones and conglomerates have a thickness of about 200 feet and are sometimes capped by a layer of white sandstone, which is regarded as the base of the Bighorn formation.

Fossils have been observed at various horizons, chiefly in the limestones a short distance above the middle of the formation, in the sandstones next below, and in the basal sandstones. The prominent forms are *Dicellomus politus* and *Ptychoparia owenia*, the latter occurring mainly in the basal sandstone.

Absaroka Mountain region.—In Shoshone Canyon on the western side of the district the entire succession of beds comprising the Deadwood formation is exposed. The limits of the formation here are well defined, but the thickness is somewhat diminished. At the top there is a thin-bedded limestone alternating with layers of green shale and flat-pebble conglomerate; below this occur sandstone and shale in



COLUMNAR SECTIONS
EAST AND WEST SIDES BIGHORN BASIN

By C. A. FISHER

Scale

0 500 1000 2000 feet

1905

alternate succession, and at the base is a coarse conglomeratic sandstone about 50 feet thick lying unconformably on the granite. The formation has a thickness of about 700 feet and is overlain by the massive limestones of the Bighorn formation. It is exposed also along the crest of Rattlesnake Mountain.

Bighorn Mountain region.—The higher portion of the northern part of the Bighorn Mountain Range consists of sandstones and shales of the Deadwood formation. These rocks have a thickness of about 900 feet and, owing to the large amount of soft material, are weathered into long, gradual slopes. This feature is well illustrated in Bald Mountain, which rises as a huge, rounded mound about 800 feet above a floor of granite. Little Bald Mountain is similar in shape, but somewhat smaller. In Medicine, Duncom, and Hunt mountains there are long slopes of Deadwood shales capped by the harder Bighorn limestone. The Deadwood beds are also extensively exhibited in the valleys of Cedar and Shell creeks. While the total thickness of the formation is generally as much as 900 feet, it appears to be somewhat less than this about Medicine Mountain; but, on the other hand, it thickens locally to nearly 1,500 feet in the lower portion of Shell Creek Canyon. Owing mainly to its hardness the basal sandstone is in most places a prominent feature. It is a reddish rock, coarse grained, often conglomeratic at base, massively bedded and in part cross-bedded, with a thickness varying from 20 to 50 feet. It lies on a smooth surface of granite, planed by early Cambrian erosion. This smooth surface is noticeable around Bald Mountain, especially in places where the sandstone has been recently removed. In the vicinity of Fortunatus Mill and the old Bald Mountain settlement the basal Deadwood conglomerates occupy the surface and are in places disintegrated into beds of bowlders and gravel which carry small values in free gold. In portions of the region about Bald Mountain the basal sandstone is a 4-foot layer of deep-red, coarse-grained, often pebbly sandstone. It is overlain by a 5-foot bed of red-brown conglomerate composed of quartz pebbles and from 5 to 10 feet of pale buff sandstone containing red streaks. In the region along Shell Creek the shales usually lie directly on the granite. Some of the sandy layers of the formation contain a green, granular mineral (glauconite). Toward the top of the formation there is about 200 feet of limestone which breaks easily into slabs and is gray to pinkish in color. This contains layers of limestone conglomerate characteristic of the horizon. This rock consists of flat to subangular limestone pebbles intermingled with broken and distorted layers of limestone, with a matrix of fine limestone and shale material. Most of the pebbles are so thickly covered with grains of glauconite that they have a greenish color, but like the associated beds are gray or pinkish on freshly broken surfaces. They are intraformational conglomerates.

On many of the steep slopes of the Deadwood formation there are extensive landslides which have on their surfaces large blocks of Bighorn limestone. These slides are caused by the softness of the Deadwood shale, which, when saturated with water, is unable to bear a heavy load. They occur along the canyons of Shell and Cedar creeks, in the Bighorn Mountains, as well as on both sides of Shoshone Canyon, in the region to the west.

Owl Creek Mountain region.—The Deadwood formation outcrops in 3 small areas along the southern margin of the district in the vicinity of Anchor, but the beds here present no unusual features.

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ORDOVICIAN SYSTEM.

BIGHORN LIMESTONE.

General relations.—The Bighorn formation is one of the most prominent members of the great limestone series constituting the front ranges of the Bighorn, Absaroka, and Owl Creek mountains. It has a thickness of about 250 feet and outcrops everywhere in a prominent escarpment overlooking the softer shales of the Deadwood formation. The distribution of the formation is shown on the geologic map. It consists mainly of massive limestones, generally of light-gray to buff color, containing a reticulating network of silica which causes the limestone on weathering to assume a pitted or honeycombed appearance. The formation does not contain a large number of fossils, but those which have been found are of late and early Ordovician age.

Absaroka Mountain region.—The Bighorn limestone is exposed in all the deep canyons cut by the larger streams on the western side of the district in the front range of the Absaroka Mountains and on the west face of the higher portion of Rattlesnake Mountain. In Shoshone Canyon the formation is about 150 feet thick, presenting high, straight escarpments above the slopes of softer Deadwood shales on either side of Shoshone River. The limestone at this place has its usual massive character, but the characteristic reticulation appearing on the weathered surfaces of the rock is not so pronounced. The upper portion of the formation consists of thin-bedded limestone. There is no notable unconformity between these and the limestones of the Madison formation. The Bighorn limestone outcrops in the canyons of Clark Fork and Pat O'Harra, Little Rocky, Bennett, and Line creeks in the region west of the area to which this report relates. Whether the beds lying immediately above the typical Bighorn limestone in Shoshone Canyon include sediments of Silurian and Devonian age was not ascertained, for no fossils were observed in them. In the Crandall quadrangle, northwest of the Bighorn area, the Jefferson and Three Forks limestones, described by Mr. Hague, lie between the Cambrian and Carboniferous rocks. The Jefferson limestone probably includes the Bighorn limestone, and possibly higher beds also. The Three Forks limestone is of Devonian age.

Bighorn Mountain region.—In the northern portion of the Bighorn Mountains the Bighorn limestone is the most conspicuous sedimentary formation. Here also it is a hard, massive limestone which outcrops in thick ledges lying on long slopes of Deadwood rocks. Its thickness averages 300 feet, including an upper portion of 100 feet of soft, thin-bedded limestone, which is regarded as a part of the formation mainly because of its Ordovician age. The principal exposures of the Bighorn limestone form cliffs on the higher slopes of the mountains, capping some of the prominent ridges north of Bald Mountain and bordering the sides of the valleys of Shell, West Pass, and Porcupine creeks. In Hunt Mountain this limestone presents a high, straight escarpment facing the west, which can be seen far out in the Bighorn basin. The formation is cut by faults on either side of South Beaver Creek and for some distance north of Devil Canyon. In the mouths of the canyons of Cottonwood, Five Springs, and Horse creeks small exposures occur.

The limestone constituting the greater part of the Bighorn formation is usually of light-buff color, weathering somewhat darker, and containing the coarse matted

A. CHARACTERISTIC WEATHERING OF BIGHORN LIMESTONE AND UPPER PART OF MADISON LIMESTONE.

North face of Shoshone Canyon.

B. DIABASE DIKE CUTTING GRANITE.

network of irregular masses of silica referred to above. This and the massive bedding are characteristic of the limestone throughout the Bighorn Range. Owing to the softness of the underlying Deadwood shale and the hard, massive nature of the Bighorn limestone, their exposure gives rise to high cliffs, having a talus of large blocks of limestone on the slopes below. In the canyons are close, high walls where streams cross the formation and high, vertical cliffs where the rock rises in the slopes. In its upper portion the formation consists of limestone that is softer and purer than that below; the bedding is thinner, the color is a lighter gray, and the rock in part is very compact or fine grained. There is considerable variation in the local features of the formation, and the thickness varies from 75 to 100 feet. In many places the upper member includes a bed of hard, massive limestone, with a network of siliceous material similar to the lower member, but not so pronounced in character and only about 30 feet thick; some beds of shale and limestone are also included. At the top the formation is not easily separated from the Carboniferous limestone. While the total thickness of the Bighorn formation averages 300 feet, it appears to be more than this in the lower part of Shell Creek Canyon, where two beds of massive, siliceous limestone occur in the upper portion, separated by slabby limestones. This upper portion is here separated from the basal by white, fine-grained limestone.

The greater part of the Bighorn limestone yields but few fossils. The lower massive member contains chiefly fragments of maclurinas and coral. In the lower portion of the upper limestone there is a horizon of corals consisting largely of *Halysites catenulatus*, while toward the top fossils of Richmond fauna occur in moderate numbers at localities to the east. The coral-bearing limestones underlie the higher massive bed of siliceous limestone, and the corals are often numerous and of large size. At a point east of Bald Mountain some beds of reddish shaly sandstone lie between the coral-bearing limestones and the great massive limestones below. Fossils were collected by Mr. Darton in the Bighorn limestone on top of Medicine Mountain from beds about 100 feet above the base of the formation. The following are the forms from this locality, as determined by Mr. E. O. Ulrich: *Streptelasma* sp. undet.; *Protarea* n. sp. (massive); *Plectorthis plicatella* (?); *Dinorthis pectinella*(?); *D. subquadrata*(?); *Rhynchotrema capax*(?) var.; *Oxydiscus*, sp. undet.; *Liospira*, sp. undet.; *Trochonema* sp. undet. (near *T. robbinsi*); *Holopea excelsa*(?); and *Huronia* sp. undet.—a lower Galena-Trenton fauna as nearly as can be ascertained. From the upper beds of the formation, at a point about 3 miles east of Bald Mountain cabins, the following fossils were collected: *Streptelasma* n. sp. with trilobite calyx; *Calapoecia* sp. undet.; *Favosites* sp. undet.; *Stromatocerium* (?) n. sp.; *Dalmanella testudinaria* var.; *Leptaena unicostata*, and *Rhynchotrema capax*.

CARBONIFEROUS SYSTEM.

MADISON FORMATION.

General relations.—The Madison formation constitutes the greater part of the high, anticlinal front range of the Bighorn, Absaroka, and Owl Creek mountains. It has a total thickness varying from 600 to 1,000 feet, and consists mainly of massive gray limestone. In the upper part there is a pure limestone which weathers into

castellated forms (see Pl. VI, *A*). In the lower portion some of the beds are very sandy. The formation contains a Mississippian fauna.

Absaroka Mountain region.—The Madison limestone is exposed in Shoshone Canyon, on the west side of the Bighorn basin, and high on the slopes of Rattlesnake, Black, and Heart mountains. In Shoshone Canyon the formation consists of a lower member, a massive, dark-gray limestone containing thin-bedded layers, and an upper member which is a lighter gray and somewhat softer limestone. Its total thickness ranges from 600 to 700 feet, and it yields fossils in moderate abundance. At Heart Mountain about 400 feet of limestone are exposed in the side of an isolated knob which rises to an altitude of nearly 8,000 feet. A large area is exposed on the higher slopes of Black Mountain, where it is deeply trenched by numerous small canyons. In the exposures on Clark Fork the formation consists of an upper and lower members, separated by thin-bedded limestones alternating with red shale.

Bighorn Mountain region.—Across the northeastern part of the basin, from near the mouth of Shell Creek to Lovell, extend a number of anticlines, the most conspicuous of which comprise Sheep and Little Sheep mountains. Bighorn River crosses both of these mountains, flowing through deep canyons. In these canyons and along the crests of the uplifts are exposures of Madison limestone.

Along the west side of the Bighorn Mountains, from Trapper Creek to the upper end of Bighorn Canyon, the limestone rises in rugged slopes 1,000 to 2,000 feet in height. It is deeply trenched by many canyons, of which the deepest are those of Shell and Horse creeks, where there are excellent exposures of all the beds. In the northeastern part of the district, between Bighorn River and the high mountain summits, the beds lie nearly horizontal in an area of approximately 40 square miles. Along Shell Creek the formation has been widely and deeply eroded and its edge rises in high cliffs on the southern side of the valley of that stream. From these cliffs a thick sheet of the limestone slopes gently down to the south and west, where it is deeply cut by White and Trapper creeks. The Madison limestone in this region consists of the usual two members, the lower one a somewhat massively bedded limestone in part of dark-gray color, and the upper about 200 feet thick, of softer, purer, and more massive rock, which weathers into the characteristic pinnacled forms. The base of the formation is not distinct, and, although between this and the succeeding Bighorn formation there is a hiatus representing Silurian and Devonian times, no unconformity is noticeable.

On the northern side of Shell Creek Canyon the following fossils were collected by Mr. Darton from the middle of the Madison formation: *Rhipidomella michelini, Spirifer centronatus, Seminula humilis, Eumetria verneuiliana, Orthotetes inæqualis, Syringothyris carteri* (?), and *Camerotoechia herrickana,* constituting a Madison limestone fauna, of Mississippian age.

Owl Creek Mountain region.—Exposures of Madison limestone occur along the northern side of the Owl Creek Mountains in the southwestern part of the district, but here the thickness is very much diminished, being represented by less than 600 feet of beds. In other respects the formation shows no material change.

A. MASSIVE BEDS OF MADISON LIMESTONE OVERLAIN BY SOFTER AMSDEN SHALES.

Upper end of Shoshone Canyon above dam site.

B. TYPICAL AMSDEN FORMATION.

Western slope of Bighorn Mountains.

AMSDEN FORMATION.

General relations.—Overlying the Madison limestone and generally extending far up the outer slopes of the mountains, are limestones, shales, and cherts, constituting the Amsden formation. This has an average thickness of 150 feet; its lower portion consists of bright-red shale, 60 to 80 feet thick, often containing layers of limestone, and its upper portion of a thin-bedded sandy limestone, in part containing extensive deposits of chert. Fossils are not abundant, but some that have been collected by Mr. Darton from upper beds on the eastern side of the district are of Pennsylvanian age.

Absaroka Mountain region.—The Amsden outcrop extends nearly halfway across the district along the front range of the Absaroka Mountains. It occupies a wide area on the higher slopes of the Rattlesnake and Cedar Mountain Range. In the vicinity of Black Mountain the dips are steep and the formation does not extend far up the slopes, but farther north and west, in the low, sloping plateau, it is extensively exposed. On the south side of Clark Fork Canyon, where the beds dip steeply, the formation is composed of a basal member of red sandy shale 75 feet thick, overlain by a series of alternating beds of gray sandstone, chert, and fine-grained slabby limestone.

In Shoshone Canyon (Pl. VII, *A*) the formation contains the usual red sandy layer at the base, followed in ascending order by harder beds of sandstone, quartzite, limestone, and chert. The following section was measured on the northern side of Shoshone Canyon:

Section of Amsden formation on north side of Shoshone Canyon, Wyoming.

	Feet.
Tensleep sandstone	--
Gray compact limestone	20
Dark-red sandstone, very hard	3
Light-gray limestone, very compact, containing layers of chert	20
Alternating layers of light-colored limestone and deep-red sandy shale	20
Red sandy shale containing few sandstone layers	60
Madison limestone.	
	123

Bighorn Mountain region.—On the eastern side of the basin the Amsden formation is about 200 feet thick. Where the dips are steep the outcrop zone is narrow, but, in other places, as on the sloping plateaus on both sides of Horse Creek, it is broader and extends nearly to the main divide. From Cottonwood Creek northward it underlies a number of plateaus, forming wide benches on the mountain slopes, but here it is largely covered by later formations. It is deeply dissected by Devil Canyon and the valleys of Deer and Trout creeks. The lower member of the Amsden formation consists of the usual bright-red sandy shale overlying the Madison limestone, which last is often deeply stained by the red shales. In the basal shale of the Amsden there is a fine-grained, light-colored limestone about 10 feet thick, and above the shale are sandy limestones, containing in places extensive deposits of chert, which weather out and accumulate on the surface (Pl. VII, *B*). The thickness of the

formation averages 200 feet, but is much less than this in some localities. At Shell Creek Canyon the following section was measured:

Section of Amsden formation on Shell Creek east of Shell, Wyo.

	Feet.
Pink sandstone overlain by flesh-colored massive sandstone of Tensleep formation	4
Light-red to maroon sandy shales	40
Gray sandy limestones, thin-bedded at top and containing much chert	20
Red shale	75
Hard, fine-grained, flesh-colored limestone	10
Red shale lying on blue-gray Madison limestone	25
	174

Near the base of the formation in this locality there are some very peculiar concretions, composed of masses of silica, suggesting a coral in appearance. They vary in diameter from 6 inches to 2 feet.

Owl Creek Mountain region.—The Amsden formation is exposed on the northern slopes of the Owl Creek Mountains in the southwestern part of the district, where it exhibits the usual stratigraphic sequence. The thickness here is about 200 feet and the shales at the base have the characteristic bright-red color.

TENSLEEP SANDSTONE.

General relations.—The Tensleep sandstone, which overlies the Amsden formation, is prominent among the formations flanking the front range of the Bighorn, Absaroka, and Owl Creek mountains. It is also exposed in the Sheep Mountain uplift, on the eastern side of the basin, and in the high anticline southeast of Hyattville. Its thickness varies from 30 to 230 feet. The formation is composed of massive, cross-bedded sandstone alternating with beds of limestone.

Absaroka Mountain region.—The formation is extensively exposed on the slopes of Rattlesnake and Cedar mountains. It outcrops along the base of Black Mountain and extends far up the slopes of the inclined plateau to the north. From the vicinity of Clark Fork Canyon to the Montana line it appears in a narrow zone. In the region of Rattlesnake Mountain the sandstone is a massive, cross-bedded, light-colored rock, 150 feet thick, the upper portion of which is sometimes quartzitic. On the northern side of Shoshone Canyon, a short distance above its mouth, a section of the Tensleep sandstone, including the overlying limestones, was measured.

Bighorn Mountain region.—Along the base of the Bighorn Mountains, on the east side of the basin, the Tensleep sandstone usually gives rise to a ridge of moderate prominence on the lower slopes. The formation is only about 30 feet thick in the northern part of the area, but its thickness increases rapidly southward, and in Horse Creek Canyon is 150 feet. Generally the thickness varies from 100 to 125 feet. Small outliers of the formation lie high on the divide on both sides of Bear Creek; also along the road east of Cloverly, on the divide north of the mouth of Shell Creek Canyon and on the divide south of White Creek. The predominant rock is white to buff sandstone, in thick massive beds, which are cross-bedded and often weathered into very irregular forms (Pl. VIII, *A*, *B*). Where the formation

A

B

TENSLEEP SANDSTONE.

A. Western slope of Bighorn Mountains. *B*. No Wood Canyon, Bighorn basin, Wyoming.

is thick, the basal member usually consists of 50 feet or more of soft buff sandstone not clearly separable from the underlying Amsden formation, which usually occurs in thinner beds. The upper sandstone frequently contains a few thin limestone layers, which in other districts in the Bighorn Mountains have yielded Pennsylvanian fossils.

Owl Creek Mountain region.—To the southward the Tensleep sandstone is exposed only in a few small areas within the district considered in this paper. The beds in these localities exhibit no unusual features.

EMBAR FORMATION.

General relations.—Overlying the Tensleep formation, on the slopes of the Owl Creek Mountains, are massive limestone and cherts, to which Mr. N. H. Darton has applied the name Embar formation, from Embar post-office, at which the beds are typically developed. The formation has a thickness of between 200 and 250 feet, and usually gives rise to long dip slopes. It is widely exposed all along the northern side of the Owl Creek Mountains, and in the vicinity of Thermopolis extends far up the slopes. Where the formation is typical, the basal member usually consists of 50 feet or more of alternating layers of light-buff limestone and sandstone. Above this there is a dark-gray fossiliferous sandstone 4 to 6 feet thick, overlain by about 90 feet of cherty limestone. Next above there is 30 to 50 feet of limestone, massive in character, capped by about 50 feet of compact sandstone, merging in color from a gray at the top to a brownish-gray or yellowish near the base. In the vicinity of Anchor the top member of the formation is 20 feet thick, resting on the massive limestone. The formation is extensively exposed throughout the Owl Creek uplift, but only a few small areas occur within the southern part of the district to which this report relates. They are found generally on anticlinal ridges branching from the main uplift. One of these occurs east of Anchor, where it is crossed by South Fork of Owl Creek, in a deep gorge, and another is southeast of Embar. The formation also appears in the more elevated portion of the anticline which passes through Thermopolis.

Large numbers of fossils occur in the Embar limestone in the walls of Bighorn Canyon south of Thermopolis. A collection was made at this locality by Mr. N. H. Darton, from which one mollusk has been identified by Dr. G. H. Girty as *Spiriferina pulchra*. This form is believed to characterize a horizon just below the so-called Permo-Carboniferous of the Wasatch Mountain region.

Rattlesnake and Cedar mountains.—On the flanks of Rattlesnake and Cedar mountains, immediately overlying the Tensleep sandstone, there is exposed a succession of limestone, chert, and sandstone about 80 feet thick, which is believed to be the equivalent of the Embar formation. A section of these beds on the northern side of Shoshone Canyon is as follows:

Section of Embar formation in Shoshone Canyon, Wyoming.

Chugwater formation.	Feet.
Gray compact fossiliferous limestone	15
Alternating layers of cherty limestone and sandstone	65
Tensleep sandstone.	

The top limestone of this formation contains fossils which are believed to be of Pennsylvanian age. The fossils collected from the limestone at the head of a small tributary of Sulphur Creek, on the eastern side of Cedar Mountain, have been identified by Doctor Girty as follows:

Fossils from east side of Cedar Mountain, Wyoming.

Fenestella (?) sp.	Fragments of pelecypods.
Orthothetes n. sp.	Laevidentalium canna.

From the same horizon, on the western end of a prominent red hill on the southern side of Trail Creek, the following fossils were collected:

Fossils from Trail Creek, Wyoming.

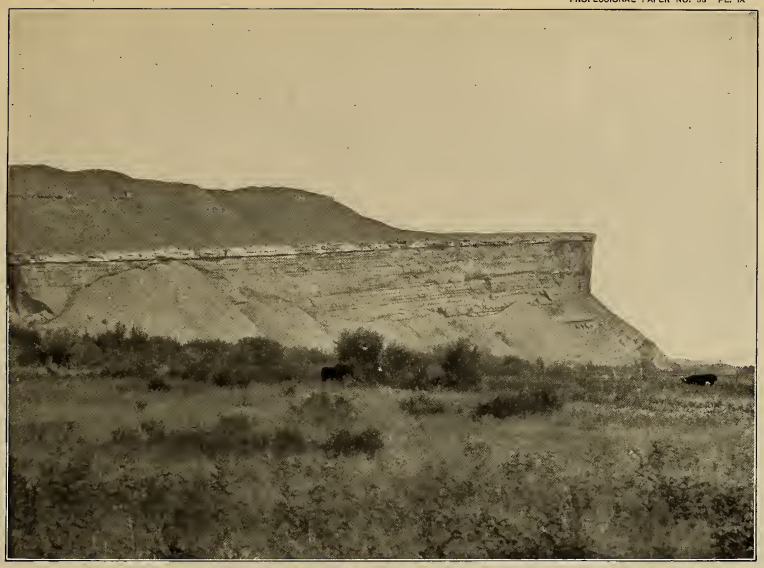
Enchostoma n. sp.	Nucula (?) sp.
Myalina (?) sp.	Fragments of pelecypods.
Myalina cf. M. perattenuata.	Laevidentalium canna.
Leda sp.	

TRIASSIC SYSTEM. (?)

CHUGWATER FORMATION.

General relations.—The Chugwater formation, which comprises the red beds of the northern Front Range of the Rocky Mountains, is extensively exposed throughout the Bighorn basin. The formation varies in thickness from 600 to 800 feet, and consists mainly of soft, massive, red sandstones with layers of gypsum and limestone. In different parts of the basin it shows considerable variation in character. Along the eastern side of the area there are generally two limestone beds, near the base, which are underlain by about 100 feet of red sandy shale, containing deposits of gypsum. The upper limestone is overlain by several hundred feet of soft red sandstone, usually outcropping in a line of prominent cliffs (Pl. IX, *A*, *B*). Above these sandstones there are about 100 feet of red sandy shale, which contains a layer of hard, thin-bedded, light-colored limestone at or near its base. Higher up are some beds of gypsum and at the top several layers of thin-bedded white limestone. Along the Absaroka front range, in the western part of the area, the formation presents a somewhat different stratigraphic succession. The basal member, about 30 feet thick, consists mainly of beds of light-gray, thin-bedded sandstone alternating with layers of limestone, the whole resting with apparent conformity on the massive limestones that comprise the upper part of the Tensleep formation. This member is overlain by 500 to 600 feet of soft, massive, red sandstones, capped by 20 to 30 feet of white gypsum. Above the gypsum there is a 12-foot layer of red sandy shale containing thin seams of gypsum which comprise the uppermost member of the formation.

Distribution.—The Chugwater formation occurs in extensive outcrops, especially along the eastern side of the basin. From the southern margin of the district to beyond Shell the outcrop has an average width of about 4 miles. Between Horse Creek Canyon and Cottonwood Creek, where there are steep dips, it occurs in a narrow zone along the base of the mountains. From Cottonwood Creek to the



A

B

CHUGWATER RED BEDS.

A. Characteristic long cliff in eastern part of Bighorn basin. *B*. Perpendicular wall near Shell, Wyo.

Montana line the dips decrease and the outcrop spreads out over a wide area, in which the formation caps several small plateaus and extends eastward far up the slopes of the mountains. The Sheep Mountain uplift exposes about 80 square miles of red beds on either side of Bighorn River from near the mouth of Shell Creek to the vicinity of Lovell. Along the western side of the basin the zone of outcrop is generally narrow, but it is present on both sides of Rattlesnake and Cedar mountains and along the base of the Absaroka and Beartooth ranges. In the southern part of the district the Chugwater red beds occupy an extensive area in the central part of the Thermopolis anticline and an area of equal size between Embar and Anchor.

Local stratigraphy.—Though the Chugwater formation is generally well exposed, it is often difficult to obtain a complete section at one locality. The following measurements of the lower part of the formation were obtained on Shell Creek east of Shell, Wyo.:

Section of lower part of Chugwater formation east of Shell, Wyo.

	Feet.
Limestone, weathering porous, lying beneath about 600 feet of red shale and sandstone	4
Red shale	25
Thin-bedded purplish limestone	6
Red shale	25
Gypsum	12
Purplish sandy shale	4
Red shale resting on 75 feet of Tensleep sandstone	20
	96

In Red Gulch, east of Cloverly, the lower members of the Chugwater formation are as follows:

Section of lower part of Chugwater formation in Red Gulch, Wyoming.

	Feet.
Limestone, weathering porous, overlain by about 500 feet of red shales and sandstone	20
Green shale	15
Limestone, weathering porous	6
Green shale	10
Limestone, weathering porous	4
Red shale	35
Thin-bedded purplish limestone	10
Red shale with gypsum on Tensleep sandstone	125
	225

At the mouth of Crooked Creek the lower beds of the Chugwater formation are as follows:

Section of lower part of Chugwater formation on Crooked Creek, Wyoming.

	Feet.
Alternating layers of white compact limestone and gray limestone, weathering porous	30
Red and green clays	2
Alternating layers of light-gray limestone and green clay	8
Red sandy shale, green near top	35
Gray limestone	½
Gray sandstone	1
Dark-red sandy shale on Tensleep sandstone	6
	82½

Near Alkali Creek, northwest of Cloverly, Wyo., a complete section of the Chugwater formation was measured:

Section of Chugwater formation northwest of Cloverly, Wyo.

	Feet.
Dark-red shales overlain by gray shales containing Jurassic fossils	60
White limestone with red shale partings	10
Red shale	20
Thin-bedded, fine-grained light-colored limestone	10
Red shale	60
Red sandy shale	50
Red sandstones, some red shale	224+
Green shale	20
Massive limestone, weathering porous	50
Red shale, not well exposed	40
Thin-bedded purplish limestone	6
Red shale, not well exposed, resting on Tensleep sandstone	80
	630

On the south side of Clark Fork Canyon, in the northwestern portion of the area, the formation has a thickness of about 750 feet. Here the limestone members appear to be absent, with the exception of a few thin layers at the base. The order of the beds is as follows:

Section of Chugwater formation on the south side of Clark Fork Canyon, Wyoming.

	Feet.
White massive gypsum overlain by Sundance beds	25
Soft, red, massive sandstone containing layers of gypsum	725
Greenish sandy shale containing thin limestone layers on Tensleep sandstone	10+
	760

About 6 miles northwest of Thermopolis, on the north side of Owl Creek, the following section of Chugwater formation was taken:

Section of Chugwater formation near Watson's ranch on Embar road just north of Owl Creek, Wyoming.

	Feet.
Red beds with an occasional greenish sandy layer	210
Gray massive sandstone	40
Red beds	20
Gray massive sandstone	10
Red shale with few sandstone layers	120
Gray, thin-bedded, porous limestone intercalated with red shale	35
Alternating layers of drab fissile limestone and red thin-bedded shale	35
Deep maroon shale with spongy, angular, calcite concretions	9
	479

Age of the formation.—The age of the Chugwater formation is not definitely known. Along the western side of the basin no fossils have been observed in the beds, and those that have been collected farther east, from the limestones in the lower part, do not furnish satisfactory evidence. The forms are not sufficiently complete or distinctive to be classed as Permian or Triassic. On Beaver Creek, northeast of Cloverly, the basal limestones contain pelecypod shells in great abundance, but they are generally too much deformed by compression to be determined. They resemble the genus *Schizodus* of the Carboniferous, one specimen being similar to *S. wheeleri* and another similar to *S. symmetricus*. The shells were diminutive, and it is possible that they are some other genus of Mesozoic age. A few fossils were obtained near Kane, but they are so small and so poorly preserved that it is not possible to determine their generic characters or relations. One shell, according to Doctor Girty, closely resembles *Myalina swallowi* of the Upper Carboniferous, but this fossil may possibly be a *Pteria* or *Bakewellia* or a Mesozoic *Mytilus* or *Modiola*. Another species suggested, by its form, *Astartella*, possibly *A. gurleyi*. All these suggestions are based on features which might also be interpreted as those of Mesozoic forms, but Doctor Girty and Mr. Schuchert are inclined to believe that they are Permian. As to the age of the overlying red sandstones of the Chugwater formation, there is no definite information; they may belong to the Permian or they may represent deposits of Triassic times.

JURASSIC SYSTEM.

SUNDANCE FORMATION.

General relations.—The marine Jurassic deposits of the Bighorn Mountains, to which the Black Hills name, Sundance, has been applied by Mr. Darton, reach a considerable thickness and carry an abundant fauna in the Bighorn basin area. The formation retains a moderately uniform thickness throughout the district, but shows variation in stratigraphy. It consists of sandstone, limestone, and shales. The shales usually predominate and have a greenish-gray color.

The formation generally outcrops in a narrow zone flanking the base of the uplifts on the eastern, western, and southern sides, but along Shell and Trapper creeks, on the eastern side of Bighorn River from Bear Creek to beyond Alkali Creek, on each side of Crooked Creek, and at the southern end of Rattlesnake Mountain, owing to low dips, the outcrop widens greatly. In the southeastern part of the district, from Hyattville to Redbanks, the zone of outcrop averages a mile in width.

Absaroka Mountain region.—Along the base of the Absaroka and Beartooth mountains the Sundance formation has a thickness of about 350 feet. Its base comprises a succession of light-gray to white thin-bedded limestone alternating with red and green sandy shale, having a total thickness of about 65 feet. Next above are 50 to 70 feet of dark-red sandy shale, overlain by about 150 feet of greenish fossiliferous shale containing layers of massive gray sandstone. Above this member, at the top of the formation, is a greenish, sandy shale with at least two and sometimes more layers of dark greenish-gray, fossiliferous sandstone. The following

section of the Sundance formation was measured on Trail Creek, 8 miles northwest of Cody, Wyo.:

Section of Sundance formation on Trail Creek, Wyoming.

Morrison shales.	Feet.	Samples.
Massive gray sandstone	6	
Gray sandstone, fossiliferous	1	1
Soft, gray sandstone	6	
Hard, gray sandstone, very fossiliferous	1	2
Greenish sandy shale	30	
Hard, thin-bedded, gray sandstone, containing fossils in upper part	6	3
Dark-gray limestone, fossiliferous	1	4
Greenish sandy shale; belemnites throughout	50	5
Greenish-gray massive sandstone	4	
Gray calcareous sandstone	6	6
Light-green shale, fossiliferous	6	7
Dark-green sandy shale	20	
Green sandy shale, containing fossils	60	8
Greenish gray sandy shale, capped by a layer of fossiliferous limestone	6	9
Red sandy shale, containing a thin band of oolitic fossiliferous limestone	2	10
Compact gray limestone	1	
Alternating layers of red and gray sandy shale, containing thin layers of gypsum	50	
Gypsum	1	
Gray thin-bedded limestone, weathering white	1	
Gypsum, containing layers of red shale near top	6	
Green shale, capped by a thin layer of fossiliferous limestone	2½	11
Gypsum	3½	
Compact gray limestone, oolitic, fossiliferous	1½	12
Green shale with bands of oolitic limestone	2	
Green shale	4	
Thin-bedded, gray limestone	1	
Green shale	1	
Gypsum	4	
Green sandy shale, capped by a thin layer of dark-gray limestone	12	
Gray thin-bedded limestone, fossiliferous	3	13
Green sandy shale with a fossiliferous limestone layer at base	2½	14
Green sandy shale, containing red layers	3	
Alternating layers of green shale and white gypsum	4	
Dark-green fissile shale	5	
Thin-bedded, light-colored limestone, fossiliferous	1½	15
Alternating layers of red and green shale	1½	
Dark rust-colored limestone, fossiliferous		16
Alternating layers of red and green sandy shale	1½	
Gray limestone, containing fossils		17
Green shale, containing thin layers of light-gray limestone resting on Chugwater	3½	
	322	

The fossils from this locality have been examined by Mr. T. W. Stanton, and his report is here given. "The marine Jurassic fossils from Trail Creek, collected from many beds in a local section, all belong to one fauna, which is the same that occurs in Yellowstone National Park and the Black Hills." The fossils are listed below:

Fossils from Sundance formation on Trail Creek, Wyoming.

Lot 1. Pentacrinus asteriscus M. & H.
Ostrea.
Eumicrotis curta Hall.
Lot 2. Ostrea sp.
Pleuronya (?) sp. cf. P. subellipticus M. & H.
Belemnites densus M. & H.
Lot 3. Ostrea sp.
Belemnites densus M. & H.
Lot 4. Camptonectes.
Ostrea.
Belemnites densus M. & H.
Lot 5. Ostrea.
Camptonectes bellistriatus.
Belemnites.
Lot 6. Ostrea sp.
Eumicrotis curta Hall.
Lot 7. Belemnites densus M. & H.
Lot 8. Pentacrinus asteriscus M. & H.
Serpula sp.
Gryphæa calceola var. nebrascensis M. & H.
Lot 9. Pentacrinus asteriscus M. & H.
Ostrea strigilcula White.
Camptonectes sp.
Lyosoma powelli White
Lot 10. Oolite; no determinable fossils.
Lot 11. Nerinea sp.
Neritina (?) sp.
Two to three undetermined bivalves.
Lot 12. Modiola sp.
Cyprina (?) sp.
Lot 13. Trigonia americana Meek.
Trigonia montanaensis Meek.
Trigonia conradi M. & H.
Astarte sp.

Undetermined small bivalves.
Lot 14. Modiola sp. cf. M. pertenuis M. & H.
Lot 15. Modiola sp.
Trigonia conradi M. & H.
Trigonia elegantissima Meek.
Nucula sp.
Several undetermined bivalves.
Lot 16. Ostrea strigilcula White.
Modiola sp.
Camptonectes.
Several undetermined small bivalves.
Lot 17. Gryphæa calceola var. nebrascensis M. & H.
Trigonia elegantissima Meek. Abundant.
Astarte meeki Stanton.
Tancredia sp.
Modiola sp.

Bighorn Mountain region.—In the vicinity of the Bighorn and Sheep Mountain uplifts the Sundance formation is of variable constitution, changing so often that no two sections are closely alike. Soft greenish-gray sandstones predominate in its lower portion, and there is the usual thick mass of green shales above. Several hard sandstone and impure limestone layers occur at intervals, outcropping as prominent ledges, which generally are highly fossiliferous. Some typical sections follow:

Section of Sundance formation on west side of mouth of Trapper Creek, south of Shell, Wyo.

	Feet.
Alternating brown sandstone and green shale	20
Dark-brown fossiliferous sandstone, hard, thin-bedded	12
Dark-green fossiliferous shale with thin-bedded sandstone at base	115
Light-green sandy shale	50
Light-colored sandy clay	3
Dark-maroon sandy clay	2
Green sandy shale with numerous small oysters	20
Gray sandstone	1
Green shale on red beds	20
	243

Section of Sundance formation on Alkali Creek, Wyoming.

Morrison.	Feet.
Green shale	25
Green thin-bedded sandstone	5
Brown fossiliferous sandstone	6
Green shale with belemnites and oysters	115
Thin-bedded gray limestone	16
Green shale on red beds	75
	242

Section of Sundance formation on Horse Creek, 5 miles north of Shell, Wyo.

Morrison shales.	Feet.
Brown sandstone, hard at base, soft at top, very fossiliferous	25
Soft greenish-brown sandstone	25
Green shale, many fossils, belemnites at base, large oysters above	50
Dark-brown and light-gray sandstones alternating, no fossils	20
Light-gray sandstone	25
Green shales, very fossiliferous	38
Brown sandstone, fossiliferous	1½
Light-brown sandstone, fossiliferous	2
Green shale, fossiliferous, on maroon shale of Chugwater	12
	198½

The fossils collected at this last locality have been examined by Mr. T. W. Stanton, who reports the following forms:

Fossils from Sundance formation, Horse Creek, Wyoming.

Lots 1–2. Ostrea strigilecula White.
Lot 3. Dosinia jurassica Whitfield?
Lot 4. Gryphæa calceola var. nebrascensis M. & H.
Lot 5. Ostrea engelmanni Meek.
Belemnites densus M. & H.
Lots 6–7. Ostrea sp.
Eumicrotis curta Hall.

In the southern part of the district, along the base of the Owl Creek Mountains, the formation has a thickness of about 194 feet. A section taken on Owl Creek near Watson's ranch is given below:

Section of Sundance formation near Watson's ranch on Embar road just north of Owl Creek, Wyoming.

	Feet.
Green sandy shale	2
Fine-grained, hard, buff limestone. This limestone breaks at right angles to the bedding plane in a singular way, so as to give the ledge the appearance of being frost-cracked or minutely spalled	2
Thin-bedded greenish-gray sandstone	4
Green sandy shale	20
Alternating layers of greenish-gray sandstone and soft greenish sands	30
Green sandy clay with many belemnites and a few oysters	40
Gray calcareous sandstone	2
Green sandy clay	20
Gray sandstone	4
Alternating layers of green, soft, sandy shales and hard, greenish fossiliferous sandstone	70
	194

CRETACEOUS SYSTEM.

MORRISON FORMATION.

General relations.—The Morrison formation is extensively developed along the eastern, western, and southern sides of the Bighorn basin and shows considerable change in character throughout the area. It is composed of soft sandy shales and clays alternating with layers of massive sandstones, all of fresh-water origin. The clays have the characteristic joint-clay structure, and the sandstones are fine-grained. The prevailing color is pale green with shades of red, maroon, and purple, and in the upper part of the formation the clays are very dark. The thickness varies from 130 to 382 feet. The formation is generally exposed in a narrow band on the inner rim of a low ridge formed by the harder overlying sandstones of the Cloverly. Along the base of the Bighorn Mountains, from the Montana line southward nearly to the head of Beaver Creek, the dips are steep, and the outcrop is relatively narrow, but south of Beaver Creek, owing to decreased dips, it is much wider. Around the Sheep Mountain uplift the outcrop zone is generally narrow. Farther west, on both sides of Rattlesnake Mountain and along the front of the Absaroka and Beartooth ranges, the outcrop rarely exceeds one-fourth mile in width.

Absaroka and Owl Creek mountain region.—Along the western side of the basin the Morrison formation is about 150 feet thick. It consists of alternating layers of gray fine-grained sandstone and dark-gray sandy shale. Near the base there is often a thin bed of gray limestone. In one locality near the southern end of the Cedar Mountain anticline a deposit of gypsum 8 feet thick was observed near the top of the formation. Three typical sections along the western and southern sides of the Bighorn basin are as follows:

Section of Morrison formation on Trail Creek, northwest of Cody, Wyo.

Cloverly formation.	Feet.
Green, sandy shales alternating with green clay containing thin layers of gray limestone throughout	100
Massive, fine-grained, gray sandstone lying on Sundance formation	30
	130

Generalized section of Morrison formation south of Clark Fork Canyon, Wyoming.

Cloverly formation.	Feet.
Massive greenish-gray sandstone	80
Greenish clay	60
Dark-gray limestone	1
Dark-gray sandy shale lying on Sundance formation	20
	161

Section of Morrison formation near Watson's ranch on Embar road just north of Owl Creek, Wyoming.

	Feet.
Massive gray sandstone	10
Concealed material, evidently soft and sandy	125
	135

Bighorn Mountain region.—In the Bighorn Mountain region the Morrison formation consists of clay, fine sandstone, and sandy shale. The colors of the shale vary from gray and greenish-gray to maroon and purple, with some dark layers, especially toward the top. The sandstones are mostly of light-gray color and often contain large fossil saurian bones. South of Shell and southeast of Cloverly there is a massive light-colored sandstone near the base. South of Shell this bed is 20 feet thick and moderately hard, and is separated from the Sundance formation by reddish shale and overlain by massive, greenish, sandy clay. Southeast of Shell the sandstone is of light-buff color, is 40 feet thick, moderately coarse grained, and has lenses of conglomerate near the top. In places the sandstone is bright red, resembling some of the sandy members of the Cloverly formation. A typical section of the formation on Alkali Creek follows:

Section of Morrison formation on Alkali Creek, Wyoming.

	Feet.
Pale-green massive shale overlain by Cloverly sandstone	50
Thin-bedded gray sandstone, brown on surface	15
Pale-green massive shale	5
Blue-black shale	10
Maroon massive shale	10
Variegated massive shale	45
Thin-bedded gray sandstone	6
Variegated massive shale, drab, purple, and maroon	65
Pale-green to white sandstone	6
Pale-green and maroon massive shale	85
Pale-green massive sandstone	45
Red sandy shale lying on Sundance formation	40
	382

CLOVERLY FORMATION.

General relations.—Overlying the Morrison formation in this region are sandstones for which Mr. Darton has proposed the name Cloverly formation, from the extensive exposures in the vicinity of Cloverly. The formation consists of alternating layers of sandstone and sandy clays, which are generally highly colored; buff, light green, maroon, and bright red prevail. The materials comprising the formation are very changeable. In places the sandstones are locally hard and have resisted erosion so as to stand out in typical hogback ridges; in other localities the entire succession is so soft that it weathers in low slopes and can be traced only by the bright colors which some of the members exhibit. In some localities it is possible to recognize a basal coarse-grained sandstone lying unconformably upon the Morrison shales, not unlike the Lakota sandstone of the Black Hills region, and above this a highly colored shale, overlain in turn by a massive sandstone resembling the Dakota. The basal sandstone of the succession is often very coarse-grained and pebbly and is very different in character from the underlying fine-grained sediments of the upper part of the Morrison formation. Frequently the contact between the formations is marked by an unconformity showing distinct channeling.

The sandstone of the Cloverly formation is from 10 to 50 feet thick, and the thickness of the formation varies from 100 to 300 feet. Coaly shale and coal some-

times occur associated with the basal sandstones. The area of Cloverly outcrop in the district is about equivalent to that of the underlying Morrison formation.

Absaroka Mountain region.—West of Rattlesnake and Cedar mountains the dips are steep and the Cloverly formation outcrops as a very narrow zone, rarely exceeding one-eighth mile in width. Along the eastern side of Rattlesnake Mountain it caps the prominent ridge between Trail and Dry creeks, and at the southern end of this ridge it extends across a saddle, through which Dry Creek passes, and joins the area exposed by the low anticline on Cottonwood Creek. Along the base of the Absaroka Range the Cloverly formation occupies a narrow but continuous zone, extending from Black Mountain to the Montana line. In the vicinity of Clark Fork Canyon its thickness is about 300 feet.

South of Cody the Cloverly formation consists of a basal coarse-grained sandstone, often pebbly, about 50 feet thick. It is overlain by softer gray sandstones of undetermined thickness. Above this occurs a layer of highly colored clay, which contains near the middle a band of dark shale. Overlying the clay is a top sandstone member, which is succeeded by the rust-colored sandstone of the base of the Colorado formation.

Bighorn Mountain region.—Along the base of the Bighorn and Pryor mountains and around the rim of the Sheep Mountain uplift the outcrop of the Cloverly is generally narrow, but widens somewhat on the high ridge east of Frannie, along the upper part of Alkali Creek and in the vicinity of Cloverly. South of Shell Creek the formation rises with the upward pitch of the syncline southwest of Shell and outcrops in an irregular zone extending east and west for several miles. In the anticline east of Sheldon's ranch it appears on the northern side of Shell Creek for a short distance, pitching down to the north under the basal shales of the Colorado formation. Along the foot of the mountain north of Cloverly it dips steeply for some distance, but on Alkali Creek and about Cloverly and farther south it dips very gently to the west. In the lower portion of Beaver Creek Valley the rocks are covered by alluvium, except for a small sandstone outcrop on the eastern side near the mouth of the creek. There are extensive and characteristic exposures in the vicinity of Cloverly, the type locality. Here the rocks are usually gray to buff sandstone below and massive shale or hard sandy clay above, their thickness varying from 50 to 150 feet. East and north of Cloverly the formation consists of sandstone which outcrops extensively in cliffs. It is a buff-colored rock in massive beds, mostly of moderately coarse-grained material. It is here 50 to 125 feet thick. West of Cloverly the middle and lower portions of this sandstone change to a maroon color, and some clay is intermixed with the sand.

Section of Cloverly formation 1½ miles west of Cloverly, Wyo.

	Feet.
Light-buff sandstone overlain by Colorado formation	10
Tan-colored sandstone	10
Maroon clay	4
Reddish, tan-colored sandy clay	10
Drab sandy clay	10
Deep-maroon sandy clay	20
Hard, tan-colored sandstone	3
Deep-maroon to purple variegated clay	12

	Feet.
Lenses of maroon sandstone	3
Deep-maroon sandy clay	20
Olive-green, soft, cross-bedded sandstone, with hard layers lying on maroon and drab-gray Morrison shale	10
	122

Owl Creek Mountain region.—Along the base of the Owl Creek Mountains the Cloverly formation is extensively exposed, and a small outcrop occurs at the base of the Shoshone Mountains on Gooseberry Creek near the southern end of a small anticline east of Sunshine post-office. It outcrops in a zone of varying width around the base of the larger anticline at Thermopolis and in a similar way encircles a smaller anticline lying to the east in range 93. It occupies the central portion of a small uplift which lies mainly on the east side of Bighorn River, opposite the mouth of Owl Creek, and other exposures occur along the southern margin of the district in ranges 95, 96, and 97. In ranges 98 and 99, township 43, the outcrop is narrow, owing to steep dips, and to the west, near the head of a small branch of Cottonwood Creek, it disappears under the volcanic rocks. On the western rim of the Thermopolis anticline, near Watson's ranch, the Cloverly formation has a thickness of 225 feet and exhibits the following members:

Section of Cloverly formation near Watson's ranch on Embar road, just north of Owl Creek, Wyoming.

	Feet.
Gray massive sandstone of uneven hardness	100
Concealed in part, but at another exposure consists of maroon sandy shale at base, merging upward to a dull greenish gray, with an occasional harder layer of sandstone	100
Brown massive sandstone with thin-bedded layers	25
	225

COLORADO FORMATION.

General relations.—The Colorado formation is well developed in the Bighorn basin, being represented by beds ranging from 1,400 to 2,000 feet in thickness, but the Greenhorn limestone, which is so prominent in the vicinity of the Black Hills and along the Rocky Mountain Front Range, does not appear. The Colorado formation is exposed in a wide area in the northeastern portion of the basin, and from Shell Creek southward its outcrop varies from 4 to 6 miles in width. It is exposed in a wide area on both sides of Rattlesnake Mountain, but farther north, along the base of the Absaroka and Beartooth ranges, the beds dip steeply and the outcrop is very narrow. Small areas of the formation are exposed along the axes of anticlines east of Sage Creek, at intervals along the base of the Shoshone Mountains from Fourbear to the Antler ranch, on the divide between Rawhide Creek and Gray Bull River north of Pitchfork ranch, and on Wood River and Gooseberry Creek near Sunshine post-office. In the Owl Creek Mountain Region it occupies an area 3 to 6 miles wide, extending along the base of the mountains from a point west of Embar to the middle of range 92. South of Cottonwood Creek there is an anticline exposing 5 or 6 square miles of Colorado formation. For further details concerning the distribution of the formation see the geologic map. (Pl. III, pocket.)

Pryor Mountain region.—On the southern side of Pryor Mountain, 5 miles north of Cowley, the Colorado formation consists of a basal member of rusty brown sandy shales, 200 feet thick, overlain by 500 feet of very black shale, in the upper part of which occur several horizons of a light-colored clay known as bentonite. Immediately above this there are about 150 feet of hard, lighter gray shale and sandstone, constituting the Mowry beds. Next above are about 300 feet of light-gray shales alternating with sandy beds. These shales are capped by 60 feet of gray, coarse-grained, cross-bedded sandstone, often water bearing, which in turn is overlain by shales 200 feet thick, containing concretionary bands and constituting the uppermost member of the formation.

Absaroka Mountain region.—Along the western side of the Bighorn basin the Colorado formation is represented by about 2,000 feet of beds, of which the lower 100 feet consist of rusty brown sandstone, alternating with gray sandy shale. This basal member is usually overlain by 200 to 300 feet of very black shale, in the middle of which occurs a brown sandstone 20 to 30 feet thick. Above the shale are several hundred feet of lighter colored fissile shale, alternating with massive beds of gray sandstone that contains in its upper portion a thin deposit of coal. Above this there are 200 to 300 feet of dark shale with iron concretions, forming the uppermost member of the formation. The sandstones of the Colorado formation are sometimes coarse grained and in one locality, on Cottonwood Creek south of Heart Mountain, were observed to contain thin layers of pebbly conglomerate.

Bighorn Mountain region.—On the lower lands bordering the Bighorn Mountains from Shell Creek northward there is a wide area of Colorado shales in a shallow syncline or basin whose western side rises in Sheep Mountain. In the vicinity of Cloverly the Colorado shales are about 1,200 feet thick. The predominating rock is black fissile shale, with thin sandstone alternations.

The salient features of the formation west of Cloverly are as follows: At the base, lying on buff sandstone of the Cloverly formation, are about 100 feet of dark-gray to black shale, with thin brown sandstone layers, weathering to a rusty color. The shales usually begin abruptly on top of the Cloverly formation, but apparently there is no unconformity. Concretions of globular shape, averaging an inch in diameter, occur in a few feet of the lower shales, about 60 feet above the base. The concretions have a radiating structure and consist mainly of phosphate of lime, having the crystalline form of marcasite, the mineral of which the concretion originally consisted. Overlying this basal rusty succession are about 200 feet of black fissile shale, capped by 25 feet of hard sandy shale containing layers of thin-bedded dark sandstone, which represents the Mowry beds of the eastern side of the Bighorn Mountains.

These beds contain many fish scales and weather to a light-gray color. They merge upward into 30 feet of dark shale, overlain by alternating shale and sandstone, capping a high ridge. The sandstone layers are from 6 inches to 3 feet thick and are of dark-gray color. This succession may represent the upper part of the Mowry beds. At its top there is a bed of light-colored sandstone about 10 feet thick. Above this there are several hundred feet of dark-colored soft shale containing a few black concretions and in its upper portion several sandstone layers. At the top there are 100 feet of sandy buff-colored shales, with brown concretions, containing *Metoicoceras*

gibbosus, M. whitei Hyatt, and *Inoceramus fragilis*. This is believed to be the top of the formation.

The calcareous shales and impure chalks which characterize the upper member of the Colorado formation elsewhere have not been distinctly recognized in the Bighorn basin. Along the base of the Bighorn Mountains light-gray shales, sometimes calcareous, lie immediately below the Pierre shale and may represent deposits of Niobrara age; but no fossils have been found in these beds. On the western side of the basin, in the vicinity of Cody, black shales, underlying the Pierre shales, contain fossils belonging to a horizon near the top of the Colorado formation. The following forms, identified by Mr. T. W. Stanton, were collected from the southern bank of Shoshone River 1 mile northeast of Cody:

Fossils from the south bank of Shoshone River, Wyoming.

Inoceramus acutilineata Stanton (?).	Corbula.
Inoceramus sp.	Turritella.
Crassatella.	Baculites asper Morton (?).
Cardium.	Baculites cf. B. anceps Lam.
Pholadomya papyracea M. & H.	Scaphites ventricosus M. & H.

Sandstone dikes.—A number of sandstone dikes cut the Colorado shales along the lowlands bordering the Bighorn Mountains. These are formed of sand that has been forced up, while wet, from underlying sandstones, through crevices in the overlying shales, probably by the pressure of a heavy load of overlying strata. These dikes vary from 6 to 10 feet in width and are composed of material similar to the Cloverly sandstone. They can sometimes be traced for a mile, generally in a direction at right angles to the trend of the mountains. A small dike of this character occurs on the divide between Bear and Alkali creeks, about 6 miles west-northwest of Cloverly, and others traverse the shales a short distance west of the northern end of Sheep Mountain.

PIERRE SHALE.

Character and thickness.—In the Bighorn basin this formation is represented by lead-gray sandy shales containing occasional concretions, which are often fossiliferous. The shales are ferruginous and on weathering generally assume a yellowish color. Along the eastern side of the basin the formation is probably less than 1,000 feet thick, while at Cody and in the vicinity of Heart Mountain a thickness of 2,000 feet was measured. The shales of the Pierre formation are soft and weather uniformly, often giving rise to strike valleys between the high sandstone ridges of the underlying and overlying formations. A number of topographic depressions in the Laramie and associated formations, which are due to eroded anticlines, expose Pierre shale in their central portions.

Distribution.—The Pierre shale spreads out over a wide district along Sage and Dry creeks, in the neighborhood of Cowley, but to the south, on the west side of Sheep Mountain, owing to steeper dips, it outcrops as a narrow band, continuing thus to Basin. East of Basin a broad, shallow syncline, 8 to 10 miles wide, in Pierre shale, extends nearly to Bonanza, and from here to the southeast corner of the basin the outcrop zone varies in width from 2 to 4 miles. On the head of No Water and Kirby

creeks the dips are low, and the formation covers a considerable area, which narrows somewhat along the northern side of the Thermopolis anticline. From Watson's ranch on Owl Creek, northwest to beyond Cottonwood Creek, a number of gentle folds in the beds occur, materially increasing the surface area of the formation. Between Cottonwood Creek and Gray Bull River a number of anticlines expose Pierre shale in their central parts, and from Sunshine post-office to Cedar Mountain it occupies an area from 4 to 10 miles wide, lying at the base of the Shoshone Range. South of Oregon basin there is an area of Pierre shale comprising several square miles, but from Wiley's ranch northward to the Montana line the outcrop zone rarely exceeds a mile in width.

LARAMIE AND ASSOCIATED FORMATIONS.

General statement.—The Laramie and succeeding formations in the Bighorn basin have a thickness varying from 5,000 to 7,000 feet, consisting of sandstones, shales, and clays, with seams of coal and coaly shales. The group is extensively exposed throughout the northeastern portion of the Bighorn basin. Along the western side of Bighorn River, from Basin nearly to the head of Little Dry Creek, it is partly covered by the overlying Wasatch beds, but from the latter point northwestward to the Montana line its outcrop gradually widens. Southward from Basin the dips are moderately steep, and the formations occupy an area 3 to 5 miles wide, which continues to Bud Kimball Draw. Across the southeast corner of the basin the area expands somewhat, and to the west, across the southern side of the district, it averages about 6 miles. In the southwestern part of the basin this group is exposed over an area 10 to 12 miles wide, which in some places is covered by the Wasatch and in others sufficiently eroded to expose the underlying Pierre. In the vicinity of Sunshine post-office there is an outlier of so-called Laramie covering several square miles.

On both sides of Sage Creek east of Cody there is an extensive outcrop of Laramie, etc., due to a low, broad, anticlinal fold, which passes through Oregon basin. North of Shoshone River the outcrop occupies a relatively broad area, which is greatly contracted in its northern extension, owing to an increase in dips and a decrease in the thickness of the beds. On Line Creek the entire series apparently has a thickness of less than 1,200 feet.

Stratigraphy.—The sandstones of the group are generally gray, but a variable amount of iron gives rise to local coloring. Throughout the lower portion the sandstones are usually fine grained and massive and the beds are from 1 to 75 feet thick, but 25 to 30 feet is a most common measure. Where shaly intercalations predominate the sandstone generally exhibits considerable variation in character. Sandstone concretions frequently occur which vary in size from 1 to 10 feet in diameter; their form is usually elongated, with rounded edges, although spherical and lens-shaped concretions abound. In the upper part of the group the sandstones are coarse grained, containing numerous cross-bedded, pebbly, conglomerate layers, some of which attain considerable thickness. At the base of the upper half there is a conglomeratic horizon, which, owing to its increased hardness, gives rise to a hogback ridge. This ridge crosses Shoshone River near the mouth of Sage Creek. From this horizon to the base of the overlying Wasatch formation the conglomeratic

layers recur in the sandstones at frequent intervals. The intercalated shales are mainly gray, but often contain a sufficient amount of carbonized wood particles to impart to the beds a lignitic character.

Age of the formations.—As to the age of the formations comprising this group there is some uncertainty, for no distinctive fossils were found, and the stratigraphic relations to other regions were not determined. Along the eastern side of the Bighorn Mountains the sandstone at the base of this group, which has been designated the Parkman formation, contains fossils characteristic of the Fox Hills sandstone, but in the Bighorn basin from the supposed equivalents of these beds fossils appear to be absent. Its stratigraphic position indicates that the entire succession probably represents the Fox Hills or Parkman and Laramie formations and possibly in its upper portions the Fort Union beds. The Livingston formation, which is extensively developed in Montana, may also be represented in the upper beds.

Supposed Fox Hills sandstone.—The Fox Hills sandstone has not been definitely recognized in the western portion of the Bighorn basin. At the base of the Laramie formation is a succession about 300 feet thick of massive gray to buff sandstone, with several layers of harder, rust-colored, concretionary sandstone. Lithologically these beds resemble the Fox Hills or Parkman sandstone on the eastern side of the Bighorn Mountains. On Polecat Creek, about 5 miles northeast of Garland, the following fossils were collected from sandstones overlying the Pierre shale:

Fossils from Polecat Creek, Wyoming.

Cardium speciosum M. & H.	Baculites sp., imperfect casts.
Mactra sp., small casts.	Tooth of shark.

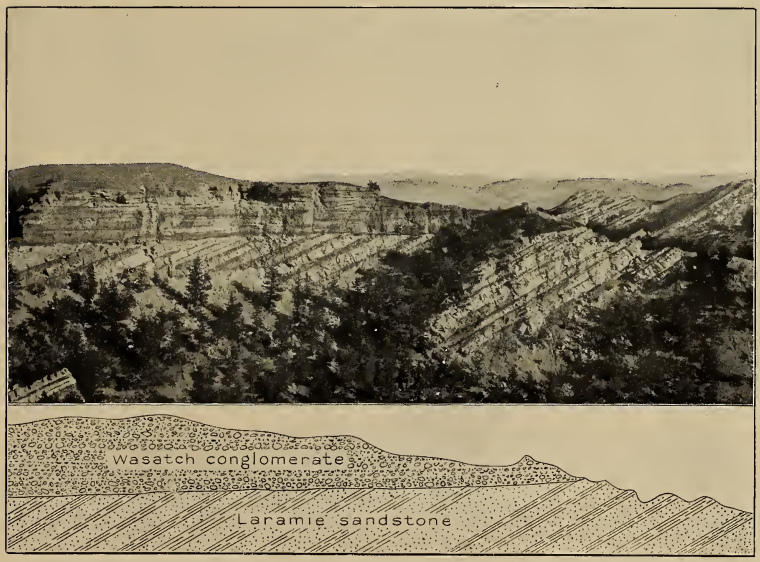
The above species have a considerable vertical range and, according to Mr. Stanton, may occur in the Judith River beds as well as in the Fox Hills. On the geologic map these sandstones are included with the overlying Laramie and associated formations.

TERTIARY SYSTEM.

VOLCANIC AND ASSOCIATED SEDIMENTARY ROCKS.

The Tertiary deposits of the Shoshone Mountains have not been studied in detail in connection with the present investigation. The rocks consist largely of volcanic breccias and lava flows interbedded with sandstones and shales which have a thickness of many thousand feet. They overlap unconformably all the older rocks, outcropping along the western side of the Bighorn basin, as shown in the cross sections (Pl. IV, p. 8). On the northern side of the Middle Fork of Owl Creek, near its head, fossil leaves were discovered by Mr. N. H. Darton, which have been identified by Mr. Knowlton, as follows:

A. SHOSHONE RIVER IN VICINITY OF CORBETT, WYO.



B. BASAL WASATCH CONGLOMERATE LYING UNCONFORMABLY ON LARAMIE SANDSTONE.

At head of Dry Cottonwood Creek.

Fossils from Middle Fork of Owl Creek, Wyoming.

Equisetum sp., one fragment.
Lygodium kaulfusii Herr (L. neuropteroides Lesq.). Abundant.
Populus cuneata Newberry. Abundant.
Populus glandulifera Herr. Abundant.
Populus zaddachi Herr. Abundant.
Quercus olafseni Herr. Two examples.
Platanus sp.? Several fragments of large leaves.
Aralia whitneyi Lesquereux. Several fragments.
Aralia notata Lesquereux. Several fragments.
Aralia, cf. A. radiata Ward. Two examples.
Sapindus obtusifolius Lesquereux. Two or three examples.
Cinchonidium, cf. C. ovata Lesquereux. Two or three examples.
Carpites sp.
From a slightly higher horizon the following forms were obtained:
Fragments of the rays of a large palm.
Ficus sp.?
Acer, cf. A. bolanderi Lesquereux. One small leaf.

WASATCH FORMATION.

Character and thickness.—The Wasatch formation consists of alternating layers of sandstone and clay, with an occasional bed of conglomerate. The sandstone predominates, mostly as a soft, fine-grained, massive rock in beds which vary in thickness from 10 to 40 feet. The thicker sandstone members occur near the base of the formation, while those higher up are not only thinner, but less pure, approaching sandy clays. The prevailing color is gray, although rust-colored bands are not infrequent. The clays are sandy and contain numerous small concretions, which are sometimes fossiliferous. They are generally gray, but strata of red, maroon, and green abound, giving to the whole a banded appearance. Red colors predominate, and often serve as a means of distinguishing the formation from the underlying Cretaceous sandstone. The lower part of the Wasatch is conglomeratic, comprising 400 to 600 feet of alternating layers of conglomerate and red clay. The conglomerate is composed of pebbles derived mainly from Paleozoic sediments, with only a small percentage of pre-Cambrian material. The formation has a thickness of 1,500 to 2,500 feet and lies unconformably upon the preceding Cretaceous deposits (Pl. X, *B*).

Distribution.—The Wasatch has a more extensive outcrop than any other formation in the district, occupying a broad area in the central part of the basin, which narrows rapidly to the northwest. It constitutes the prominent McCulloch Peak, extends entirely around the base of Heart Mountain, occupies the low divide between Bighorn and Clark Fork basins, and gives rise to a number of prominent peaks along the base of the Beartooth Mountains from Clark Fork to the Montana line. It continues from Gray Bull south to beyond Bighorn River in the region of the Honeycombs. Along Dry Creek, Shoshone River, and Clark Fork the formation is covered by broad areas of Quaternary deposits.

The Wasatch beds contain an abundant mammalian fauna. The fossils are generally found in the clays, although their occurrence in the sandstones is not uncommon. The best collecting grounds observed were on the badlands slopes northeast of McCulloch Peak, but fossils were found all along the divide between Shoshone River and Dry Creek. These deposits have been studied jointly by Messrs. Osborn and Wortman with reference to their fossil mammalia, and they have been found to be the same as those that characterize the Wasatch formation in regions southwest of this area.

Capping some of the highest areas in the central part of the Bighorn basin, especially that part lying south of Gray Bull River, are brown, leaf-bearing, sandy shales and gray sandstones, which have a total thickness of about 600 feet. Thin coal seams sometimes occur in these beds, and in one locality on the southern side of Tatman Mountain some prospecting has been done in a seam which has a thickness of about 18 inches. A number of fossils were collected from the sandstones of this formation in the vicinity of Squaw Buttes. These have been examined by Dr. T. W. Stanton, who makes the following report:

> The small collection contains many internal casts of fresh-water fossils belonging to the genera *Unio*, *Viviparus*, and *Goniobasis*. Of the last named there are imprints of the exterior which permit identification with *G. tenera* Hall, an Eocene species. The *Unio* has about the size and proportions of *U. haydeni* Meek and the *Viviparus* resembles *V. wyomingensis* Meek, but in neither case can specific identification be positively made with such material, as there are Laramie species so closely resembling these that they could not be discriminated from the casts alone. I think that the horizon is Eocene, but I am unable to determine from these fossils whether it is Wasatch or Bridger.

These beds are extensively exhibited in Tatman Mountain and Squaw Buttes. They have been represented with the Wasatch on the geologic map.

QUATERNARY SYSTEM.

General statement.—During the Quaternary period erosion preponderated throughout this general region, especially in the higher mountainous portion. Most of the products of this erosion, however, have been carried away, but some materials remain, derived chiefly from the high mountains in the western part of the area. The deposits are confined mainly to the northern part of the Bighorn basin, where they occur as extensive gravel terraces capping the high divides and bordering the larger streams. Deposits of three different periods are recognized, early and late terrace gravels and alluvium.

Early terrace gravels.—The early terrace deposits cap the high plateaus between the larger streams in the central portion of the basin. The most extensive of these terraces are on the high plateau northeast of Ralston, on the highland between Dry Creek and Gray Bull River, extending from the western end of Meeteetse rim nearly to Bighorn River and capping Tatman Mountain. They are composed of alternating layers of gravel, sand, and silt, having a thickness of 30 to 40 feet, and in places are underlain by light-colored sandy clays, which may be of Tertiary age.

Later terrace gravels.—The later terrace gravels (Pl. XVI, *A*, p. 60) border all the larger and many of the smaller streams, especially in the northern part of the district. The most extensive of these deposits lie along the northern side of Shoshone River from Garland to Eaglenest. Between Ralston and Corbett they occupy a width of about 2 miles along the western side of the river, and from there to Shoshone Canyon they occur in terraces on both sides of the river. Later terrace gravels of no great extent occur along Bighorn River and its principal tributaries to the south, No Wood and Owl creeks, and remnants of these deposits occur on Tensleep, Paintrock, and Shell creeks. Along Clark Fork and Pat O'Harra Creek there are extensive areas of the later terrace gravels. The material in the vicinity of Clark consists mainly of coarse gravel and bowlders, with a small amount of sand and silt.

Alluvium.—The alluvial deposits of the Bighorn basin exhibit some diversity of character, especially along the smaller streams. The alluvium along Bighorn River is of varying width, rarely exceeding 1 mile, and extends nearly across the area described in this paper. There are places throughout its course where the river flows through deep, narrow gorges in which no alluvium has been deposited. These are in Black, Sheep, and Bighorn canyons. The alluvial material is light gray, very sandy, and has a thickness of 25 to 40 feet. Shoshone River has considerable fall between Shoshone Canyon and the Garland bridge, and is in consequence a cutting rather than a depositing stream, but below this point the fall diminishes and the stream is bordered on both sides by wide alluvial flats. Here the material consists of a fine gray sand mixed with decayed vegetation and usually containing a large amount of black magnetic sand. Dry Creek Valley has a light-colored sandy wash, derived chiefly from the soft sands and clays of the Wasatch formation.

Gray Bull River and its principal tributary, Wood River, are bordered by narrow alluvial deposits, which generally contain more or less coarse material brought down by the mountain streams during the flood seasons. Below Fenton the alluvial flat widens considerably and continues thus to a point below Otto, beyond which it extends as a relatively narrow band to Bighorn River.

Most of the streams in the northwestern part of the basin, including Clark Fork, have narrow alluvial deposits. Along this river the material is coarse and contains bowlders suggestive of sediments derived from a glacier. The alluvium of the smaller streams is of local origin, and varies in character with the formations which the streams traverse. Newmeyer and Paint creek deposits contain much detritus derived from the Chugwater red beds on the higher slopes to the west. The alluvial materials on Pat O'Harra Creek, below the mouth of Skull Creek, have a dull-gray color and consist largely of wash from the Colorado and Pierre shales and from the more sandy cretaceous beds overlying them in the vicinity of Heart Mountain. On Trail Creek northwest of Cody the alluvium is composed mainly of red wash from the Chugwater formation.

The streams in the higher portion of the Bighorn Mountains flow in deep canyons or narrow valleys, where the conditions are unfavorable for the deposition of alluvium. In the lower lands farther west, which are underlain by shales and soft sandstones, wide valleys have been cut by the streams and the alluvial deposits are more extensive. The principal areas of alluvium lie along Shell Creek, occupying a belt about 1 mile wide. The deposit is from 10 to 40 feet thick. Along Beaver Creek lie narrower alluvial flats which, below the mouth of Red Gulch, attain a width of about a quarter of a mile. In its course through the red beds Trapper Creek traverses a narrow alluvial valley which joins that of Shell Creek above Shell. Along Beaver Creek and in the valley south and east of Shell the deposits contain much red detritus derived from the Chugwater red beds. In their lower courses Paintrock and Tensleep creeks have narrow alluvial valleys, which are very fertile.

Alluvial deposits of a more or less local nature occur on Dry, Dry Cottonwood, Gooseberry, Meeyero, and Owl creeks, and along the eastern side of Bighorn River on Kirby, No Water, and No Wood creeks. The alluvium of the streams draining the central portion of the basin shows some local variation, but is generally light colored and sandy, being derived chiefly from the soft sands and clays of the Wasatch.

and underlying Cretaceous formations. No Wood Creek in its upper course contains much red wash derived from the Chugwater red beds, through which it flows for several miles.

STRUCTURAL GEOLOGY.

General features.—The mountain ranges inclosing the Bighorn basin are primarily anticlinal uplifts more or less modified by erosion. In the Absaroka, Beartooth, and Shoshone ranges the erosion has been followed by the deposition of immense sheets of volcanic breccia, which are now deeply cut by the present streams. The Bighorn basin is essentially a broad structural valley which has been formed between two large anticlinal folds, the Bighorn Mountains on the east and south and the Beartooth, Absaroka, and Shoshone mountains on the west. Across the northern end of this valley, from Heart to Pryor mountains, extends a low anticlinal fold that separates the Bighorn and Clark Fork basins, and a number of minor flexures parallel to the larger uplifts occur along the outer rim of the inclosed valley. The details of the structure of the Bighorn basin are shown in Pl. XI.

Structure of the Bighorn uplift.[a]—The Bighorn Mountains form a great anticline that is due to an uplift measuring many thousand feet, which begins in south-central Montana and extends southeastward and southward about 125 miles, into central Wyoming. It lifts a thick series of Paleozoic and Mesozoic formations high above the plains and, owing to the deep erosion of its crest, presents a central nucleus of pre-Cambrian granites from which sedimentary rocks dip at varying angles on each side. The most elevated portion of the uplift is in latitude 44° 30′, where one of the granite summits, Cloud Peak, has an altitude of 13,165 feet, rising about 9,000 feet above the adjoining plains. The greatest vertical displacement of the strata, as indicated by the height at which the granite floor is now found, amounts to about 18,000 feet. For the greater part of its course, the anticline is relatively simple in shape, but there are numerous local variations in the steepness of its sides and the shape of its top, owing to the presence of extensive faults. In general, its eastern side is much steeper than the western, especially in the central portion of the uplift. In its northern part both sides are relatively steep and the top is remarkably flat. In the highest portion of the uplift, which is probably near Cloud Peak, the sedimentary rocks have been removed over a considerable area, and we can only conjecture the form which the flexure would have if the eroded portions of the granite and the overlying sedimentary beds were restored. In this region there is apparently a long, uniform rise from the west, a similarly gentle grade downward to the east for some distance, and then the steep dips which are now found in the foothills on that side. The main uplift bears a number of subordinate flexures, the most notable one being east of Bald Mountain. It is an anticline rising about 2,500 feet on the northeastward dipping limb of the main anticline. A diagram of the structure of the Bighorn Mountains[b] and their southern extension, the Owl Creek Range,[c] has been published by Mr. N. H. Darton.

[a] This description of the structure of the Bighorn uplift is taken from the Bald Mountain folio, now in press, by Mr. N. H. Darton.

[b] Geology and water resources of the Bighorn Mountains: Prof. Paper U. S. Geol. Survey No. 51.

[c] Geology of the Owl Creek Mountains, Wyoming: Senate Doc. No. 119, 59th Congress, 1st session.

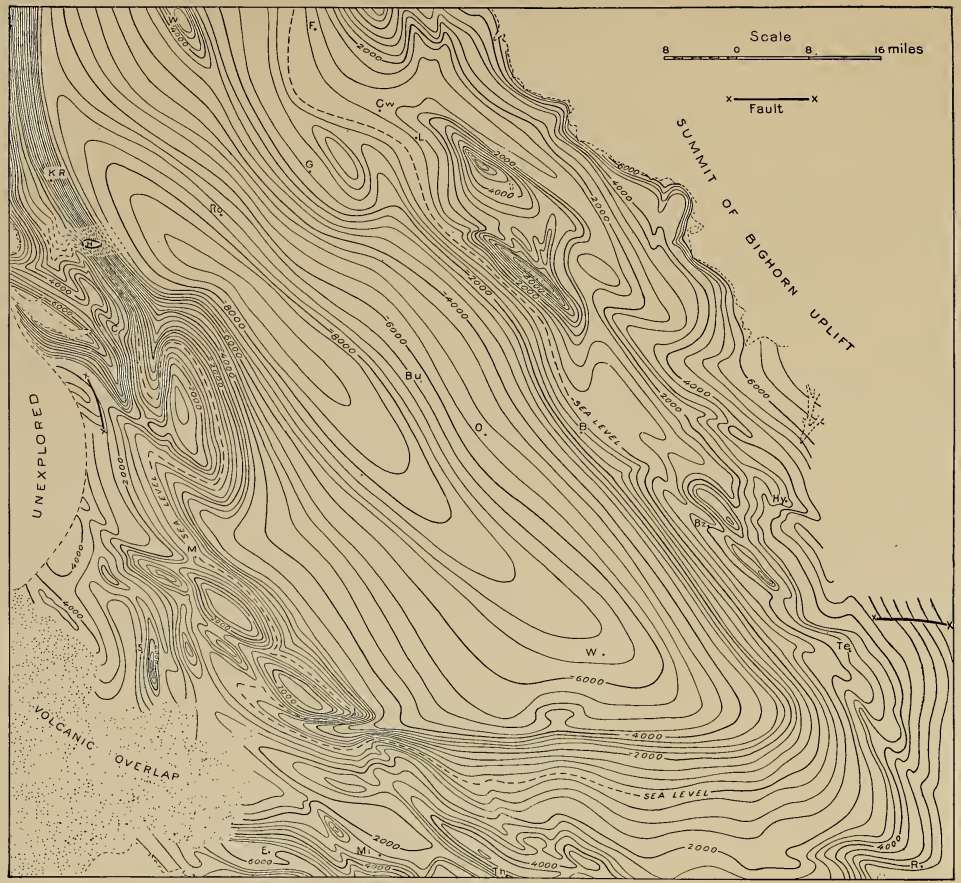


DIAGRAM OF STRUCTURE OF THE BIGHORN BASIN, WYOMING.

Structure of the Absaroka Mountains.—The Absaroka Mountains comprise that part of the western Rocky Mountain Front Range lying between Clark Fork and Shoshone River. This range extends in a north-south direction for a distance of about 80 miles, and has an average width of 50 miles. Only the eastern portion is included within the area to which this paper relates. The structure of the Absaroka Range is complex, but in general it is a broad anticlinal fold having a pre-Cambrian granite core, which to the east is bordered by a thick series of Paleozoic and Mesozoic formations dipping eastward with steep angles toward the Bighorn basin. These dips decrease rapidly toward the lower lands. Between Clark Fork and Shoshone River two important folds extend from the main range. The larger, comprising Rattlesnake and Cedar mountains, diverges at an angle of about 20°, and the smaller, which constitutes Black Mountain, at a somewhat greater angle.

The Rattlesnake Mountain uplift is a moderately broad anticlinal fold, with gradual slopes on the east and steep dips on the west. It lifts the Paleozoic strata about 8,000 feet above the horizon. In the deep canyon of Shoshone River the structure of the uplift is exposed down to and into the crystalline rocks. The structure of the Rattlesnake Mountain uplift is shown in the cross sections on Pl. IV, p. 8. South of Shoshone River the anticlinal bends sharply to the east, and, owing to rapidly decreasing dips, soon drops into a low arch which disappears near Frost ranch, on Sage Creek. The smaller fold projects from the main range at an angle of about 40°, and gives rise to Black Mountain. On the southern side of this mountain, at the head of Pat O'Harra Creek, the Tensleep sandstone and overlying Chugwater formation dip steeply to the southwest into a narrow syncline separating Black and Rattlesnake mountains. Across the northeast side of Black Mountain there is a bold escarpment of Carboniferous limestone overlooking the steeply dipping Tensleep and Chugwater formations. About 6 miles east of Black Mountain, along the axis of the smaller fold, stands the high, isolated peak of Heart Mountain. This mountain is capped by Madison limestone, which rises as a huge block 500 to 600 feet above the slopes of the softer Cretaceous and Tertiary formations. The limestones dip to the northeast at an angle of about 15°. The highly colored shales of the Wasatch formation surround the base of the limestone cliffs and lie unconformably upon the steeply dipping beds of the underlying Cretaceous deposits. The dip of the Wasatch beds here is somewhat obscure, but they appear to lie horizontal or possibly to be slightly inclined to the east. North and east of Heart Mountain the Wasatch beds lie against the base of the limestone cliffs. About 2 miles northwest of the peak the relation of the Wasatch shales to the underlying Cretaceous beds is well exposed. Here the latter dips at an angle of 45° to 60°, and across the upturned ends of these beds lie Wasatch shales, which dip eastward at a low angle. On the western side of Heart Mountain the dip and strike of the Cretaceous beds are unchanged from Pat O'Harra Creek to Shoshone River. The underground structural relations of Heart Mountain are somewhat obscure, but the uplift is probably due to a circular fault, which raised the Madison limestone several thousand feet above its original position. Between Heart and Rattlesnake mountains minor flexures appear, the largest exposing a small area of the Sundance formation along the western side of Cottonwood Creek. South of Shoshone River and east of Sage

Creek there is a broad anticline extending southward, in which the lowest formation exposed is the Colorado.

Structure of the Shoshone Mountains.—The Shoshone Mountains comprise the rugged mountainous district lying to the west of the Bighorn basin and extending from Shoshone River southward to Wind River. Carter Mountain, a prominent ridge at the northern end of the range, forms a high divide between South Fork of Shoshone and Gray Bull rivers. Only the eastern part of the Shoshone Range is included in the area described. The Shoshone Mountains were formed by an uplift which raised a thick series of Paleozoic and Mesozoic formations high above the plains, followed by deep erosion of its crest, and later deposition of a thick mass of volcanic and associated sedimentary rocks, which still retain their horizontal position. The most elevated part of the range in this district is the southern end, where a lofty peak, Washakie Needles, reaches an altitude of 12,496 feet, rising about 1,000 feet above the adjoining area.

Structure of Sheep Mountain.—Across the eastern part of the basin there are a number of minor flexures, of which the most prominent are those comprising the Sheep Mountain uplift. This uplift is composed mainly of two anticlinal ridges marked by Sheep Mountain along the western side in the southern part of the uplift and Little Sheep Mountain along the eastern side toward the northern end. These ridges trend N. 50° W.; they are nearly parallel, and the distance between their axes is about 5 miles. Sheep Mountain extends from near the mouth of Shell Creek to Dry Creek. It is due to a narrow anticline uplifted about 600 to 700 feet, exposing the Madison limestone along the crest of the ridge and in the walls of Black Canyon. Little Sheep Mountain begins near Shoshone River and continues southward to beyond Bighorn River, where the flexure becomes less prominent. About 2 miles east of Crystal there is an anticline exposing Chugwater beds on both sides of Alkali Creek. In its southern extension this anticline apparently joins Sheep Mountain south of Bear Creek. Farther south, along this line of uplift, there are a number of small anticlines, two near Bonanza, which expose the Sundance formation in their crest, and one on the western side of No Wood Creek below Bigtrails, which coalesces with the main uplift at its southern end. At the southeast corner of the area there is a sharp anticline through which No Wood Creek has cut a narrow, steep-sided canyon, exposing Madison limestone in its crest.

To the north, in a direct line with Little Sheep Mountain, the southern extension of the Pryor Mountain uplift occurs. The lowest beds exposed by this uplift within the area considered in this paper is the Chugwater formation. Farther out in the basin there are a few smaller folds, one east of Garland, which exposes the Pierre shale, and another east of Windsor. Northwest of Frannie there is a small anticline that exposes the sandstone of the upper Colorado formation.

Structure of the west side of the basin.—Extending southward from the Oregon basin there is a low, broad anticline, exposing an area of Colorado formation. Farther south this anticline coalesces with the southern extension of the Rattlesnake Mountain anticline. To the west there is a broad syncline, the western limb of which lies along Sage Creek Valley. To the north this syncline passes between the southern extension of the Rattlesnake uplift and a fault which, along its upthrow side, exposes

a narrow ridge of sandstone belonging to the upper part of the Colorado formation. The position of this fault is shown on the geologic map.

To the south, in the vicinity of Meeteetse, the region is one of greater structural complexity. A series of anticlines with corresponding synclines crosses the region with a south-southeast trend from Meeteetse to the base of the Shoshone Mountains.

Beginning at the base of the Shoshone Range the first fold, which is small and unimportant in the present consideration, crosses Gray Bull River about 2 miles above the mouth of Rock Creek. This fold is exposed in the Colorado shale. To the east, along Gray Bull River for a distance of 6 to 8 miles, the surface is occupied by Pierre shale. The Laramie formation is first encountered below the Frank ranch, where a bold escarpment of sandstone faces the west. From here the Laramie, etc., extends eastward for about 3 miles in a synclinal trough, followed to the east by an eroded anticline exposing Pierre and Colorado beds. These flexures have a northern extension of 4 to 5 miles, and to the south continue to Gooseberry Creek. Still farther east, near the mouth of Rawhide Creek, there is a low syncline and anticline and to the south toward Gooseberry Creek a number of folds occur. Upper Buffalo basin, the most prominent of these, exposes a large area of Pierre in its central portions. Two small anticlines which expose Pierre shale cross Gooseberry Creek near Renner's ranch. From the eastern slope of the low anticline at the mouth of Rawhide Creek the beds extend eastward with a low, uniform dip, passing beneath the Wasatch beds toward the center of the Bighorn basin.

South of Dickie's ranch there is an anticline which presents a deep topographic depression, locally known as the "Upper Grass Creek basin." The center of this fold is occupied by Pierre shale encircled by a high wall of the overlying formation. On the south side of Grass Creek the beds dip steeply to the center of a narrow syncline in Wasatch, which extends to the west.

Structure of the Thermopolis anticline.—This anticline extends from the middle of R. 93, T. 43, west-northwest to the divide between Owl and Cottonwood creeks. A small area of Embar limestone is exposed on the crest of the fold near Thermopolis, surrounded by several square miles of Chugwater red beds. To the northwest the beds dip rapidly downward, carrying the Sundance, Morrison, and Cloverly formations beneath the surface a short distance beyond Owl Creek.

HISTORICAL GEOLOGY.

General statement.—The geologic history of the Bighorn basin, as recorded in the various rocks outcropping around its outer portion, extends from Middle Cambrian time to the present. All the more important changes in physical geography which took place in the adjoining Bighorn and Rocky Mountain province, from the earliest Cambrian submergence to near the close of Eocene times, are recorded in the rocks of this region. These rocks comprise sedimentary strata several thousand feet in thickness which were originally a part of a much larger area now bordering the Rocky Mountain Front Range. Near the close of the epoch of early Tertiary mountain development, which resulted in the elevation of the Rocky Mountain Range and the Bighorn, Prior, and Owl Creek mountains, the district now comprising the Bighorn basin became surrounded on all sides by high mountain barriers. The elevation

of these inclosing ranges probably was greater than it is at present, for subsequent erosion has removed from their summits the softer sedimentary rocks and some of the granitic nucleus.

The sedimentary rocks of the Bighorn basin consist mainly of sandstone, limestone, shale, sand, and gravel, all more or less variable in composition and appearance. The principal materials of which the sedimentary rocks are composed were originally sand, gravel, or calcareous mud derived from the decomposition of older rocks, or chemical precipitates from sea waters.

Cambrian times.—The lowest sediments of this period are of middle Cambrian age. They are such as characterize shore deposits along a land surface of crystalline rocks. Numerous exposures occur in which sediments containing much local material can now be seen abutting against the crystalline rocks that formed these shores. During the early part of this period the Bighorn Mountains were probably an island and the Rocky Mountain Front Range a highland rising out of the Cambrian sea. After the earliest shore-line conditions a submergence followed and finer deposits of mud were laid down, which are now represented by shales and limestones in the upper part of the Cambrian. The limestone conglomerates of the Deadwood formation indicate shallow-water conditions, and the sandstone overlying the formation probably marks the beginning of emergence which progressed through the early portion of Ordovician time.

Ordovician period.—Later in the early part of Ordovician time there was a submergence of this entire region, and extensive deposition of lime carbonate which at first was mixed with a large amount of silica. The shores of this Ordovician sea were probably distant, some of them being in the Laramie Range to the south.

Silurian-Devonian times.—Throughout the eastern portion of the district there is no geologic record from the close of Ordovician to early Carboniferous times, but to the northwest, in the Absaroka Mountains, deposits occur which are believed to represent these periods. The absence of Silurian and Devonian sediments in the Bighorn Mountains and adjoining region is difficult to account for. It may have been due to an extensive but shallow sea or land so low as to leave no noticeable evidence of erosion.

Carboniferous conditions.—During the subsidence which took place in early Carboniferous times, resulting in the establishment of relatively deep water and marine conditions throughout the Rocky Mountain province, calcareous sediments were laid down which are now represented by 600 to 1,000 feet of limestone, known as the Madison limestone. This formation contains no coarse sediments, a fact that suggests that possibly there were no crystalline land surfaces exposed in this region during its deposition. In regions to the south, however, limestones believed by some to be the stratigraphic equivalent of the Madison were deposited on crystalline rocks. Following the deposition of these limestones there was a change in conditions, during which beds of red shale of wide extent, followed by cherty limestone, pure limestones, and, in some places, beds of sand, were deposited, which now represent the Amsden formation. Toward the close of Carboniferous times there was an uplift, and a period of shallow water with strong currents ensued, during which time there were deposited several hundred feet of sandstone, which now constitute the Tensleep formation. At the close of this period marine conditions

prevailed and limestones were deposited, followed by the deposition, in a widespread saline lake, of 700 to 800 feet of red shale containing gypsum, which now constitute the Chugwater red beds. These thick red shales and associated beds of gypsum were probably the product of an arid climate. The red color is not due to surface oxidation, but extends through the entire thickness, as has often been shown by deep borings, and is therefore the original color of the sediments. During the deposition of these red muds there were doubtless periods when, owing to evaporation, the waters became highly concentrated, and more or less gypsum was precipitated throughout the sediments, which later segregated into massive beds of gypsum as we now find them. Most of the red deposits were laid down in shallow water, so that subsidence must have kept pace with deposition while they were accumulating.

During the early part of the red-beds deposition there was an interruption which was widespread in the shale sedimentation, and a succession of relatively pure, thin-bedded limestones were laid down. In some locations outside of this area the supposed equivalents of these limestones are of Permian age, but further than this there is no satisfactory evidence as to the age of the red shales. They probably represent not only Permian, but a part of Triassic, times.

Between the red shales of the Chugwater formation and the overlying Sundance there is in this region no suggestion of an unconformity, but in most localities there is evidence of uplift and erosion of the red beds in an interval prior to the deposition of the Sundance formation.

Jurassic sea.—Throughout the Jurassic period shallow and deep marine waters alternated. The sediments are mainly fine grained, such as characterize waters without strong currents. Three principal events are recorded in the rocks of the formation—first, a period of shallow waters, during which sandy shales, in part ripple marked were laid down, followed by deeper water conditions, resulting in the deposition of limestones bearing an extensive marine fauna, with a return to shallow waters near the close, now indicated by sandy sediments.

Cretaceous period.—In the Cretaceous period deposits that vary greatly in character, but that are generally of uniform type over wide areas, accumulated. The deposits at first were such as are characteristic of shallow seas and estuaries that lie along a coastal plain, passing into sediments derived from marine waters, and toward the close changing to fresh-water materials, mainly sand and clay with marsh vegetation. The earliest Cretaceous deposits constitute the Morrison formation. This is a widespread deposit of material which is generally fine grained, consisting of clay and sand, with local beds of coarse sand deposited by streams. During this period large saurians were more or less abundant, as is indicated by the remains now found in the sandstones. The fine-grained sediments of the Morrison are succeeded by coarse, pebbly sandstones of the lower part of the Cloverly formation. Overlying the pebbly sandstones there are highly-colored, often sandy, clays, which are overlain in turn by a medium-grained sandstone, supposed to be the equivalent of the Dakota sandstone. Succeeding this period of fresh-water deposits there was submergence, and marine conditions were again established, as is indicated by the change of the sediments to dark-colored fissile shale. This marine sedimentation continued until there had been deposited several thousand feet of shale, which

now represent the Colorado and Pierre formations. During this period there were several interruptions in shale sedimentation, which resulted in the deposition of sandstone and sandy shale. The most noteworthy of these was that in which the Mowry beds were laid down. During the period of Pierre deposition, which was of long duration, very uniform conditions prevailed, and there was apparently no break in shale sedimentation. The succeeding epoch marks the retreat of the Cretaceous sea. During this time there were extensive bodies of brackish water, which deposited sands, followed by fresh waters, in which were laid down several thousand feet of clay, sand, and marsh materials of the Laramie and associated formations.

Early Tertiary deposits.—During early Tertiary times there was extensive uplift throughout the Rocky Mountain province. This fact is indicated in the adjoining mountain districts, where late Tertiary deposits lie upon an eroded surface which has the general form of the present topography. These relations show that the uplift was truncated and the larger topographic features formed in early Eocene times. During the erosion of these uplifts there began in the Bighorn basin the accumulation of the thick sediments which now constitute the Wasatch formation. These were laid down by streams which, during most of the time, were sluggish and had extensive areas of overflow into bayous and lakes. By this means the basin was covered and partly filled with materials derived chiefly from the early Mesozoic sediments, which then extended higher on the slopes of the inclosing ranges. This derivation is shown by the character of the clays now comprising the Wasatch formation.

After a long period, during which there accumulated 2,000 to 3,000 feet of Wasatch sediments and possibly a considerable thickness of later Tertiary deposits, a new cycle of erosion began, caused either by uplift or by the development of a lower outlet for the drainage of the basin. Then began the erosion of the Tertiary deposits, but there was probably much shifting of drainage before the present system was developed.

WATER RESOURCES.

GROUND WATERS.

All of the larger streams in the Bighorn basin carry an abundance of good water, and in consequence few wells are needed, the water for domestic purposes being supplied by the streams directly or through the larger irrigation canals. In the vicinity of Germania a number of shallow wells obtain water from the later terrace gravels, but its quality is poor. At Garland a relatively deep surface well sunk in the Laramie formation obtained water which is highly mineralized, and there are a number of springs throughout the district which have small flows of alkali water derived from the gravel terraces.

Along Gray Bull River there are a few shallow wells that obtain water from the valley deposits, but many of the ranchers use river water. In the Bighorn River Valley the water of shallow wells is generally mineralized, and for this reason much of the domestic water supply comes from the river. The same conditions exist in the valleys of No Wood Creek and its principal tributaries. Along Owl Creek a number of shallow wells furnish water that contains more or less "alkali."

UNDERGROUND WATERS.

A number of the formations exhibited in the Bighorn basin consist largely of porous rocks, mainly sandstone. These rocks undoubtedly contain water in their underground beds. They outcrop around the outer portion of the basin and extend far up the slopes of the ridges, where in many places they imbibe water from rain and from streams fed by melting snows on the summits of the mountains. In their underground beds they lie immediately beneath impervious shales. To this extent the conditions for underground water are favorable, but the dips are generally steep, and the water-bearing formations are carried rapidly to depths too great to be reached by practicable well borings. Along the eastern side of the basin, between the Sheep and Bighorn Mountain uplifts, there is a small area where the conditions are favorable for artesian water. The structure of the formation in this region is shown in the cross sections on Pl. IV, p. 8. In several places along the eastern side of the basin there are long monoclinal slopes of Tensleep sandstone traversed by numerous mountain streams. These slopes afford excellent catchment areas for artesian water, and at their base, in the low valleys, the conditions for artesian water are very favorable. The most promising localities are the lowlands bordering Bighorn River on the west, in the region north of Ionia, in all the larger red-beds valleys along the base of the mountains between Shell and Tensleep creeks, and in the upper parts of the valleys of Alkali, Spring, Otter, and Little Canyon creeks.

Along Owl Creek Valley, in the vicinity of Embar, and near the mouth of Mud Creek, artesian water might possibly be obtained from the Cloverly formations at moderate depth.

The water-bearing formations of the basin are the Cloverly, Tensleep, and Amsden. Of these the Tensleep and Cloverly formations are perhaps the most important. The latter consists largely of sandstone, like the water-bearing sandstone beneath the central Great Plains. Though no practical tests have been made of the water capacities of the Cloverly sandstones in this region it is probable that they contain considerable water. They lie at a depth of several thousand feet from the surface under a great part of the basin, but in the region east of the Sheep Mountain uplift, between Shell Creek and Shoshone River, they can be reached by well borings less than 1,200 feet deep. Flows could be obtained, however, only in the valleys of the streams, and as most of these streams carry an abundance of fine water artesian wells are not required. The Laramie and associated formations are water bearing, but owing to their steep dips, especially in the northern portion of the Bighorn basin, it has not been practicable to sink artesian wells into them. In Gray Bull Valley, in the vicinity of Meeteetse, however, several small flows have been obtained from the sandy members of these formations. The Tensleep and Amsden formations in the basin are very promising artesian-water horizons, but they are generally too deeply buried by overlying sediments to be reached by well borings.

Artesian water could probably be obtained in the valley of Sage Creek, between Frannie and Shoshone River, at depths not exceeding 2,000 feet. The first water-bearing bed which would be encountered in this region in sinking a deep well is a sandstone in the upper part of the Colorado formation. At Cowley this sandstone was penetrated at a depth of about 500 feet. The next water-bearing horizon below the

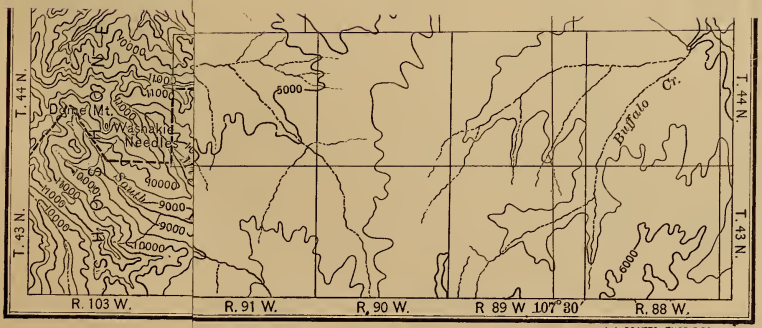
sandstone of the Colorado formation is the Cloverly formation, which is about 1,200 feet deeper, or approximately 1,700 feet from the surface at Cowley. Northwest of Frannie, outside the region to which this paper relates, artesian flows were obtained at a depth of 1,000 feet by the Montana and Wyoming Oil Company in borings made for oil. In the valley of Gypsum Creek there is a small area where artesian water could probably be obtained at less than 400 feet.

IRRIGATION.

General statement.—Irrigation has been practiced in the Bighorn basin for about twenty years, but its growth and development have been necessarily slow until recently. The region is far from good markets, and for the first few years irrigators were compelled to depend entirely upon the local demand for the disposal of their produce. This demand has sometimes been inadequate, and farmers were obliged to hold their grain from one season to another or give it in exchange for other commodities. These conditions have retarded development in some of the irrigated districts. Settlement was first made along the eastern side of the basin, and here, in the valleys of the larger mountain streams, some of the earliest irrigation ditches were constructed. The lowlands bordering the streams were first farmed, but as the population increased higher portions of the valleys were brought under cultivation, and at present a large percentage of the irrigable lands is utilized (Pl. XII). Extensive preparations are also being made, both by the Government and by private enterprise, to reclaim large tracts of land along Bighorn and Shoshone rivers and Dry Creek in the central portion of the basin (see p. 46).

Bighorn River.—Along the Bighorn River Valley in the northern part of the basin irrigation is not extensively practiced. The low bottom lands are generally very sandy, and the gravel terraces bordering the river are too high to be watered by short ditches. Small marginal areas are irrigated along the western side of Bighorn River, mainly below the mouth of Gray Bull River, in the vicinity of Crystal; along Alkali Creek, a small tributary of Bighorn River from the east, and in the vicinity of Kane. None of these areas are large. The water is usually conveyed by small ditches, each ranch having a separate canal. Crooked Creek, a tributary of Bighorn River from the west, supplies water for a narrow area of valley land along both sides of the stream from its mouth to the base of Pryor Mountain. Above Basin on Bighorn River several irrigated districts occur, and at present two large canals, the Hanover canal and Bighorn County canal, are being constructed on either side of the river, which will reclaim approximately 48,000 acres of land between Winchester and the mouth of Gray Bull River.

Shoshone River.—At present, irrigation along Shoshone River is practiced mainly in two districts; one lying on the southern side of the river between Cody and Corbett's bridge (Pl. XIII, *A*), the other, a larger area, extending eastward from Garland bridge to Bighorn River. On the northern side of Shoshone River the Cincinnati canal covers a large area. It is about 25 miles long, and furnishes water for the region around Byron and Cowley, the total area irrigated comprising approximately 23,000 acres. South of Shoshone River is the Lovell Irrigation Company's canal, which extends from a point south of Garland to Bighorn River. This is a



L. L. POATES, ENGR'G CO., N.Y.


IRRIGATION MAP
OF THE
BIGHORN BASIN
WYOMING
BY
C. A. FISHER
1905
Scale
10 miles
Contour interval 500 feet
LEGEND
Area in which the greater part of land is irrigated
Area to be irrigated by proposed canals
Storage reservoirs
WYOMING—MONTANA BOUNDARY LINE
BUFFALO BASIN
TATMAN MOUNTAIN
THE HONEYCOMBS
WINCHESTER HILLS
L. L. POATES, ENGR'G CO., N. Y.

high-line canal, and when completed will furnish water for all the higher irrigable land on the southern side of Shoshone River. A number of small ditches supply water to the lower portion of the valley between Lovell and Ionia. The valley lands are very fertile, especially in the vicinity of Lovell, and a variety of crops are cultivated. Alfalfa is the staple, but during the last three years much grain has been produced. Cultivation of sugar beets has been attempted and has generally been successful.

Clark Fork.—Along Clark Fork and its various tributaries much land is irrigated, as shown in Pl. XII. Throughout the upper portion of Clark Fork Valley the alluvium is composed largely of coarse gravel and bowlders, containing only a small proportion of sand and silt, and in consequence is not well adapted to cultivation. The valley of Pat O'Harra Creek, the principal tributary of Clark Fork, is very narrow, but is exceptionally fertile. Along Paint, Newmeyer, and Little Rocky creeks and the upper courses of Bennett and Line creeks there are a few small irrigated farms.

Gray Bull River.—Irrigation is extensively practiced along the entire course of Gray Bull River, but the amount of water in the stream is not adequate for the irrigation of all the valley lands without storage of its flood waters. A preliminary survey was made in 1899 for the purpose of locating a storage reservoir on the headwaters of the Gray Bull, and, as a result of this investigation, a dam and reservoir site was located on the river about 10 miles above Fourbear. The approximate boundaries of the irrigable lands are shown in Pl. XII. The soil is very fertile, and a large amount of hay and grain is raised in the vicinity of Meeteetse, where irrigation has been practiced for many years (see Pl. I, *B*).

Shell Creek.—The waters of Shell Creek and its tributaries have been used for irrigation for nearly twenty years. The stream has a large flow of water, and its fall is about 25 feet to the mile. It is bordered by a relatively wide valley, which has gentle slopes, affording ideal conditions for irrigation. The soil is generally deep and fertile and well adapted to the cultivation of a variety of crops. A number of small ditches have been taken out on both sides of the stream, and a large part of the land is farmed. Alfalfa is the principal crop, but grain also is raised. There are a number of bearing orchards along Horse Creek, the largest tributary of Shell Creek from the north. The seasons are of sufficient length in this region to insure the maturity of most crops.

Other flowing streams.—A portion of the land is irrigated along the valleys of Gooseberry, Grass, and Owl creeks. The latter has a wide, fertile valley, only a part of which is irrigated, owing to a shortage of water. Owl Creek has a vigorous flow for a short period during the flood season, but this flow rapidly decreases, and in midsummer the stream below Embar is nearly dry.

On No Wood Creek and its principal tributaries, Paintrock and Tensleep, the valley land is extensively irrigated. The soil along these streams, although predominately sandy, is very fertile, and a variety of crops are cultivated. Small storage reservoirs have been located on Dry Cottonwood and the East Fork of No Water creeks, and the land to be irrigated from these reservoirs is shown in Pl. XII.

Dry Creek.—Around Germania there is an irrigated district comprising about 12,000 acres, which receives its water supply from the Branch canal. This canal is diverted from Gray Bull River in the vicinity of Fenton. A large acreage of oats, wheat, and alfalfa is here under cultivation; also a variety of vegetables. As Dry Creek is an intermittent stream the community is dependent upon the ditch water for domestic uses as well as for irrigation.

The Bighorn Basin Development Company is now making preparations to reclaim all the irrigable lands along Dry Creek from Oregon basin to Bighorn River. The water is to be taken from South Fork of Shoshone River near the mouth of Belknap Creek and carried through a high-line canal for nearly 30 miles to Oregon basin, where it is to be stored. From here it will be distributed by two large canals—the Shoshone and the South Fork. The lands to be reclaimed by this company are shown in Pl. XII.

Irma Flats.—Southwest of Cody, Wyo., is a small farming district comprising about 2,000 acres, known as the Irma Flats. This district is supplied with water by the Cody canal, which has its headgate on South Fork of Shoshone River near the mouth of Marquette Creek.

Shoshone project.—The Government is now constructing a dam across Shoshone River at the upper end of Shoshone Canyon for the purpose of storing a portion of the flood waters of that river. The dam is to be 85 feet wide in the river bed and 165 feet wide at an elevation of 210 feet. A dam of this size will have a storage capacity of 159,500 acre-feet. The water from the storage reservoir is to be used for irrigating along the northern side of Shoshone River in a district extending from the mouth of Shoshone Canyon to beyond Frannie station, a distance of about 60 miles, and comprising an area of about 282,000 acres of level land. (See Pl. X, *A*.) The distribution of the land to be irrigated is shown in Pl. XII, and the proposed dam site (Pl. II, *B*) and storage-reservoir site in Pl. XIII, *B*.

MINERAL RESOURCES.

COAL.

GENERAL DESCRIPTION.

Coal is the principal mineral resource in the sedimentary formations of the Bighorn basin. It occurs mainly in the so-called Laramie formation, although on the western side of the district a coal, said to be of good quality, is found in the upper part of the Benton group, and on No Wood Creek, 12 miles southeast of Bonanza, a local deposit of coal is mined from the Cloverly formation. The coal is found at various horizons throughout the Laramie and associated formations, but most of the deposits of workable thickness are in a basal member of this formation or possibly in beds still lower. Coal is widespread in its distribution within the area occupied by the Laramie and associated formations. The greatest development, however, is found in places where the larger streams expose the coal measures. Here the most favorable conditions exist for locating mines and the increased settlement of the irrigated valleys along the streams afford local market for the coal. The various districts in the Bighorn basin, where the principal development of the

A. SHOSHONE RIVER VALLEY NEAR CORBETT, WYO.

B. SHOSHONE RESERVOIR SITE.

North and south forks of Shoshone River above Shoshone Canyon.

coal deposits has taken place, are described separately. The limits of these districts are arbitrarily taken and they are designated by the nearest town.

CODY DISTRICT.

Coal is mined at several localities in the vicinity of Cody. The Navine mine, 3½ miles northeast of Cody, on the opposite side of Shoshone River, is the oldest mine in the district. Coal has been taken out of this opening for several years to supply a small ranch trade along the valley. The deposit is between 2 and 3 feet thick. During the last three years the increase in population in the vicinity of Cody has caused a greater demand for fuel, and in consequence several new mines have been opened. These are the Burns & Rogers mine, the mine of the Cody Coal Company, and others. The Burns & Rogers mine is situated 5 miles south-southeast of Cody, on the west rim of a small syncline through which Sage Creek flows. The coal here is in the lower portion of the coal-bearing measures. The deposit consists of three benches separated by two slate partings. It has an eastward dip of 47° and is included in beds of massive gray sandstone. An incline 90 feet deep has been driven on the seam, with a large room on either side. The coal is hard and black, with a bright luster and uneven fracture. It does not break up badly on exposure to atmospheric agencies and as a domestic coal is said to be very satisfactory. The product of this mine will probably never be large, for the deposit is thin and the dip of the beds is so steep that the limit of economic working will soon be reached. This coal finds a market in Cody and in the Shoshone River Valley. The following section was measured at the Burns & Rogers mine:

Section at the Burns & Rogers mine, near Cody, Wyo.

	Ft.	in.
Coal		10
Impure coal		6
Coal	1	2
Gray slate		3
Coal	1	

During the past season the Cody Coal Company has opened a mine on the northern side of Shoshone River about 3 miles east of Cody station. The coal occurs about 1,500 feet above the top of the Pierre shale in beds dipping at an angle of 45° to the east. The deposit is about 4½ feet thick and is apparently of good quality, although no analysis of the product was available. The opening of this bed is in the face of the bluffs about 30 feet above the railroad, so that the coal can be loaded for shipment at small expense when the new side track now being built is completed. The mine is well timbered and preparations are being made for more extensive development. A section of the deposit is as follows:

Section of Cody Coal Company's mine, Cody, Wyo.

	Feet.
Dark sandy clay	6
Coal	4
Coaly shale	2
Dark sandy clay	8
Gray massive sandstone	20

Arrangements are now being made by another company to develop coal beds at the same horizon on the southern side of Shoshone River.

Some prospecting has been done on Sage Creek and its tributaries in the vicinity of Frost's ranch. Other prospects occur in the high bluffs of Wiley's ranch and on Dry Creek east of Oregon basin. None of these openings are worked at present. Some development work has been done on a bed of coaly shale on the eastern side of Sage Creek about 2 miles above its mouth. The coal occurring in the Colorado formation just west of Cody bridge was formerly mined to some extent.

MEETEETSE DISTRICT.

In the vicinity of Meeteetse there are a number of coal mines which have been operated more or less extensively for the last fifteen years. The region is one of considerable structural complexity, with a number of low anticlines and intervening synclines crossing it. This folding has greatly increased the surface area of the coal-bearing formations, bringing the productive beds near the surface over a considerable area.

The Conie mine, on the Meeteetse rim, 12 miles northwest of Meeteetse, was reopened in 1903 after lying idle for several years. The coal is in relatively thin beds, lying nearly horizontal. It is black with an unusually bright luster, brown streak, and subconchoidal fracture. The woody structure is maintained to a marked degree, and its resistance to weathering is slight. Its occurrence in a soft-clay formation renders it difficult to mine and the absence of a solid roof necessitates elaborate timbering, greatly increasing the cost of operation. The mine is located in an inaccessible place and will probably never be extensively developed. The character of this coal bed is illustrated in the following section:

Section at Conie mine, near Meeteetse, Wyo.

	Ft.	in.
Coal	1	2
Bony coal		7
Coal		11
Dark-gray slate		4
Coal	1	6
Dark-gray slate	1	8
Coal	1	6
Slate		4
Coal		8

The Orr mine is situated on a branch of Meeteetse Creek, about 3 miles northwest of Wise. It is well opened with a double well-timbered entry, extending 100 feet from the outcrop. The bed consists of two benches, each 3 feet thick, separated by a layer of light-bluish-gray slate which is characteristic of this horizon. The coal is black with a bright luster, brown streak, and uneven fracture. This mine is worked during the winter months with a seasonal output of 300 to 400 tons. Considerable prospecting has been done near the Orr mine and one opening has been made about a mile south which exposes a 6-foot bed of coal.

The Blake mine is located about 3 miles above Meeteetse, on the north bank of Gray Bull River. Here a seam 5 feet 9 inches thick has been extensively operated,

and is one of the oldest openings in the district. The dip of the beds is 9° NE. The main entry is about 150 feet in length, with several side entries. The workings are too low in the river bank for perfect drainage to be effected, and some little difficulty has resulted from this condition. Operations were first begun at this place in 1892, but there was only a small output until 1898, when the property was purchased by the present owners. The total production from 1898 to 1902 exceeded 2,000 tons. In 1902 the product amounted to 900 tons with a market value of $2 per ton at the mine. At present the mine is not worked. There is another opening on the same horizon a short distance up the river which was formerly owned by McDonald & Cottle, of Thermopolis. The dip in this region is low and the conditions are generally favorable for more extensive development of these properties.

Section at the Blake mine, near Meeteetse, Wyo.

	Ft.	in.
Bony coal		6
Clay and sandstone	6	
Coal	3	3
Bluish-gray slate		3
Coal	2	6
Impure coal		6

During the summer of 1904 an opening was made on a bed of coal in the upper part of the coal-bearing formations near the mouth of Meeteetse Creek, about 2 miles north of Meeteetse, Wyo. It is now known as the Woodruff mine. The seam is 4 feet thick with no partings. It is overlain by hard, gray sandstone and underlain by a dark-colored compact clay. An entry 150 feet deep has been driven in the seam, with several large rooms on either side. The coal is hard and black with a bright luster. It appears not to break up badly upon exposure, and as a domestic coal is said to be very satisfactory. No analysis has been made of this coal. During the past two years the Woodruff mine has had a total output of 2,200 tons, which sells at $2.25 per ton. The coal finds a ready market at Meeteetse, Wyo.

Another mine recently opened near Meeteetse is owned by Mr. Erskin. It is located in sec. 13, T. 48, R. 101, about 2½ miles above Meeteetse, in the lowland of the Gray Bull Valley. This mine is on the same seam as the Edward Blake mine, which has been worked for many years on the northern side of Gray Bull River. The coal beds have a dip of 6° to the east and are somewhat thicker than on the opposite side of the valley. The output for last season, during the period of development of the mine, was about 400 tons.

There is a bed of coal 3 to 4 feet in width, occurring in dark-gray sandy shales 400 feet below the base of the Wasatch, about 3 miles southeast of Meeteetse. This coal has been prospected at a few places along the stage road between Meeteetse and Moon's ranch, on Gooseberry Creek, but no mines have been opened. It is possible that a more extended search for coal at this horizon might result in the discovery of workable beds.

That portion of the Meeteetse district lying south of Gray Bull River is separated into two parts by erosion along an anticlinal fold. The main body of coal-bearing measures lies east of Wood River, between Gray Bull River and Gooseberry

Creek, and a detached portion occurs west of Wood River. There are several anticlinal folds in the main body which bring the lower coal-bearing measures of the Laramie to the surface in a number of places along Gooseberry Creek, but openings have been made in only two localities. In a small ravine entering Gooseberry Creek from the south, and on the eastern rim of a small anticline, there is a coal opening known as the Dickie mine No. 1. This mine exposes a bed of bright, clean-looking coal 4½ feet thick without parting. The coal is immediately overlain by a 2-foot layer of gray clay, fine grained and compact, containing carbonized plant fragments. The coal is in the lower part of the coal-bearing measures and dips at an angle of 17° ENE. The mine has never been worked extensively and the main entry extends but a few feet. The coal, however, is of good quality and the general conditions are favorable for development. There is another bed about 12 feet lower, the general character of which could not be ascertained owing to talus. The accompanying section shows the relative position of the two beds:

Section at the Dickie mine No. 1, on Gooseberry Creek, Wyoming.

	Feet.
Gray compact clay	2
Coal	4½
Gray clay	3
Buff sandstone	6
Brown sandstone	2
Impure coal	6

About 3 miles southeast of Dickie mine No. 1, and 1 mile north of Grass Creek, Mr. Dickie has opened a coal bed 8 feet 3 inches thick, which is locally known as Dickie mine No. 2. The coal occurs near the base of the coal-bearing measures, which here comprises the western rim of a large eroded anticline extending from the vicinity of Gooseberry Creek southeastward to Grass Creek and intersecting the latter at a point 3 miles above the mouth of Prospect Creek. The longitudinal axis of this anticline is 12 to 15 miles long and the transverse axis is considerably shorter. The central body of the basin is composed of Pierre shale, surrounded by coal-bearing sandstone. The only coal openings observed on this sandstone rim were the Dickie mine No. 2 and a small showing on the southern side of Grass Creek about a mile distant. Coal of this horizon is said to outcrop, however, at frequent intervals along the southern rim of the anticline for some distance. The coal seam in Dickie mine No. 2 consists of two benches, separated by the usual bluish-white shaly parting near the middle. A 2-inch layer of light-gray shale also occurs near the top of the upper bench, but neither of these partings is sufficiently thick to affect materially the productive capacity of the seam. The coals of the upper and lower benches exhibit no essential points of difference in quality. The product is rather hard and compact, with an unusually bright luster, and a chemical analysis shows it to be an average quality of lignite. The mine is not operated at present, but the quality of the material, combined with the size and character of the seam, render it a desirable property. A section of the bed is given below:

Section at Dickie mine, No. 2, near Grass Creek, Wyoming.

	Ft.	in.
Coal	4	6
Light bluish-gray slate		3
Coal		9
Light-gray slate		2
Coal	3	

The small detached area of coal-bearing measures lying west of Wood River is structurally a synclinal trough comprising about 25 square miles and extending from a point 3 miles north of Gray Bull River southeastward to Wood River. This area is about 10 miles long and 2 to 3 miles wide, and its axis trends N. 5° W. The formation is the lower part of the coal-bearing measures. The sandstones of this formation in the region are heavily developed, and massive sandstone layers 20 to 30 feet thick occur immediately above and below the coal horizon, the upper having a white and the lower a yellowish tint. The color and thickness of these two sandstone layers are very persistent throughout the Meeteetse district, and serve as an indicator of the position of the coal. The dips vary from 20° to 40° from rim to center, with a direction according to their position on the periphery of the syncline. They are very steep along the eastern and northern sides, but to the west and south they decrease materially. The area is encircled by a continuous coal outcrop. The lower coal bed of the basal sandy division probably underlies the entire district, and the upper seam, 75 feet higher, here locally attains a workable thickness. Development has been chiefly confined to Sunshine Gulch and its tributaries, about 3 miles north-northwest of Sunshine post-office, although openings have been made at other points within the area. None of these localities are operated at present, but the coal is said to be of good quality. The average thickness of the lower coal bed in Sunshine Gulch is 6 feet, while the upper seam is only 2 feet 8 inches.

A coal bed averaging 3 feet in thickness contains about 3,000,000 tons of coal per square mile, but of course there is considerable loss in working. There are now in this field about 18 square miles underlain by coal that would doubtless average 4 or more feet in thickness. On this estimate the field has a productive capacity of 72,000,000 tons. A trial pit near the north end of this area, in the sandstone bluffs on the south side of Gray Bull River, exhibits the following section:

Section at Vetter's coal opening, near Meeteetse, Wyo.

	Ft.	in.
Bony coal		3
Coal		10
Bony coal		2
Coal	1	6
Light bluish-gray slate		3
Coal	1	
Dull-gray slate	1	
Coal		4
Bluish-gray clay	2	6

South of the Meeteetse district, in the vicinity of Embar, there is a small opening known as the Smith mine, which was formerly operated to some extent, but at present is abandoned. Some of the earlier analyses of this coal show a high fuel

ratio, but an unusually large amount of moisture. There is another small mine, about 2½ miles northeast of Middleton post-office, known as the Eades mine. The bed is 4 feet thick without parting, and occurs in the massive gray sandstone not far above the top of the Pierre shales. The beds dip 9° to the north. From an incline about 60 feet in length that has been driven on the dip a small amount of coal is taken out during the winter season. The coal in appearance is black, with a bright luster and uneven fracture. It does not weather easily. The following section was measured:

Section at Eades mine, near Middleton, Wyo.

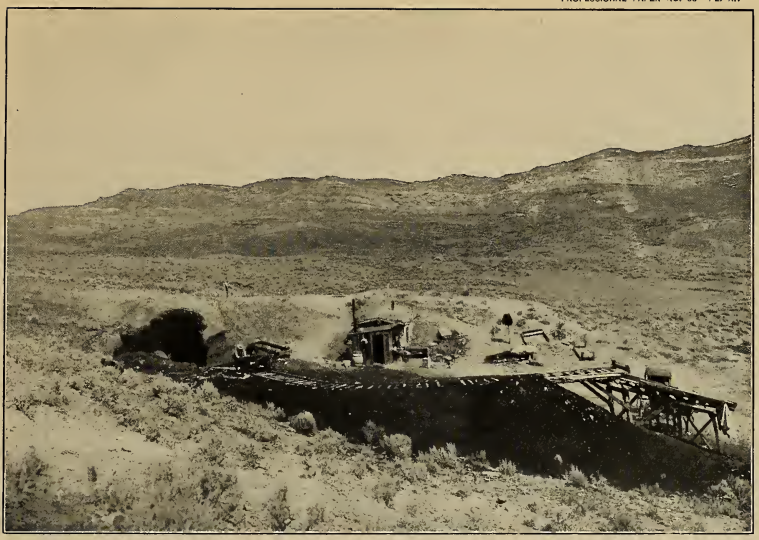
	Feet.
Dark-gray compact clay	2
Impure coaly shale	1
Coal	4

THERMOPOLIS DISTRICT.

This district is located on the western side of Bighorn River, about 12 miles north-northeast of Thermopolis, and a few miles below the mouth of Kirby Creek. The formation consists of alternating layers of massive gray sandstone, sandy shale, and clays with a locally developed clinker bed occurring immediately below the principal coal seam of the district. This is the only clinker bed thus far observed in the Bighorn basin. The dip of the beds is 17° NNE. The Jones mine was opened in this district in the summer of 1889, but the output was small for the three following years, scarcely exceeding 200 tons a year. Since 1900 the annual output has increased to over 1,000 tons, but as yet only a small part of the field has been worked, and the present production of this locality could be increased many times. Operations have now ceased at the Jones mine, and a new opening has been made by McDonald & Cottle (Pl. XIV, *A*). The principal bed is 9 feet thick, overlain by a bed of sandy clay of variable thickness. Above this is another coal bed 5 feet thick. In the McDonald & Cottle mine the sandy clay reaches a minimum thickness of 2 inches, which practically unites the two seams, giving a total thickness of 14 feet (Pl. XIV, *B*). This is the thickest coal seam thus far observed in the Bighorn basin. Five other closely adjacent beds occur, four below and one above the 14-foot bed; three of the lower beds are said to be workable. The uppermost, outcropping 25 feet below the McDonald & Cottle vein, is 3 feet thick and apparently of good quality. The total thickness of the various beds exposed within close vertical range is approximately 30 feet. The material is a bright, firm, free-burning variety of coal. It gives a brown streak, breaks in blocks, and does not crumble easily on exposure. An analysis shows a rather high per cent of fixed carbon and moisture and only a small amount of ash. At the McDonald & Cottle mine the following section was taken:

Section at the McDonald & Cottle mine, near Thermopolis, Wyo.

	Ft.	in.
Coal	5	
Dark-gray sandy clay		2
Coal	9	



A

B

McDONALD & COTTLE MINE NEAR THERMOPOLIS, WYO.

A. Entrance. *B*. Coal bed.

An area of 1 square mile underlain by a coal bed 14 feet thick would contain 14,000,000 tons of coal, an amount far exceeding the total product of the Red Lodge mines during the past fourteen years. Of course, there is always a loss in working, and in an area of broadly lenticular coal deposits allowance must be made for a certain amount of variation in thickness. In an area underlain by 30 feet of coal, 1 square mile would contain 30,000,000 tons, or supposing that on an average only one-half that thickness were found, there would be 15,000,000 tons of coal. A determination of the productive capacity of the entire Thermopolis district was not undertaken in the present reconnaissance. The total coal acreage of this region can be only rudely estimated, for no systematic prospecting has ever been conducted, but coal outcrops may be seen along the strike of the beds for several miles, and as the dip is uniform and moderately low the field is undoubtedly large.

NO WOOD DISTRICT.

An opening has been made in a coal bed which outcrops near the base of a prominent hill at the head of Bud Kimball Draw, 14 miles southwest of Tensleep, Wyo. Coal is not mined here regularly, but many of the settlers along the No Wood Creek Valley obtain their fuel supply from this place. The coal bed, which occurs in the lower part of the Laramie and associated formations, has an aggregate thickness of about 6½ feet, consisting of four benches separated by a parting of bony coal and brown leaf-bearing shale.

Section of coal-bearing beds near head of Bud Kimball Draw, Wyoming.

	Ft.	in.
Brown leaf-bearing shale		0
Very impure coal		10
Gray sandstone		4
Coal containing thin layers of bone	3	6
Brown leaf-bearing shale		10
Bony coal		3
Coal		9
Bony coal		4
Coal	1	6
Bony coal		6
Coal	1	
Total	9	10

About 3 miles southeast of Bell's ranch, on No Wood Creek, there is a small coal district. The principal interest attached to this locality is the fact that the deposits are contained in the basal sandstones of the Cloverly formation, less than 50 feet above the Morrison formation. The coal has been prospected at frequent intervals for 2 or 3 miles along the strike, which here trends east-southeast, but at present operations are confined to one opening, known as the Diehl & Bell mine. The deposit consists of two benches each 4 feet thick, separated by a 2-inch layer of dark-colored shale. In appearance the coal is dark, with dull, earthy luster, conchoidal fracture, and resembles closely a carbonaceous shale. The accompanying section will show the thickness and relative position of the coal seams.

Section at Diehl & Bell mine, near Tensleep, Wyo.

	Ft.	in.
Coal	4	
Dark-gray slate		2
Coal	4	

BASIN DISTRICT.

The next locality of coal outcrops to the northwest is locally known as the Basin district, because of its nearness to Basin, the county seat of Bighorn County. There are two small mines in this district; the larger one, located near the mouth of No Wood Creek, about 5 miles southeast of Basin, is owned by Rogers & Gapen. It has been worked continuously for about five years, although coal has been taken from this opening for more than a decade. The deposit has a measured thickness of 5 feet and contains many thin, slaty partings, which, although numerous, are in total thickness insufficient to render the deposit unfit for economic development. Since 1900 the product has averaged about 400 tons a year, with a market value of $2 per ton at the mine. The character of the seam is illustrated in the following section:

Section at the Rogers & Gapen mine, near Basin, Wyo.

	Ft.	in.
Coal	1	1
Impure coaly shale		1
Coal		8
Black shale		2
Coal		7
Dark-gray clay		6
Coal		5
Coaly shale		2
Coal		11
Dark-gray clay		2
Coal	1	3

There is another mine in this district, located about 1 mile southwest of Basin, owned by G. N. Mecklen. The bed is 2½ feet thick, with a 6-inch shaly parting near the base. The coal is contained in sandy beds, which here dip to the south at such a steep angle that the limit of economic mining will soon be reached. This mine produces about 600 tons a year, which is consumed by the residents of Basin and the Bighorn River Valley. The mine is poorly improved and the bed is too thin to warrant any considerable development, as is shown by the following section:

Section of Mecklen mine, near Basin, Wyo.

	Ft.	in.
Coal	2	
Dark-gray slate		6
Coal		6

Along the exposed area of the coal-bearing formation, between Gray Bull and Shoshone rivers, some prospecting has been done, resulting in the location of a few thin coal deposits, all of which are under the limit of a profitable working thickness.

GARLAND DISTRICT.

About 3 miles northwest of Garland there is a small coal-mining district. The coal occurs in sandstones comprising the lower portion of the coal-bearing measures. The productive beds outcrop in low sandstone ridges that dip gently southwestward and soon pass under higher beds toward the center of the basin. Two mines are worked at present, one by the Wyoming Coal and Fuel Company and the other by the Garland Coal Company. They are located within a few yards of each other and both are working on the same coal horizon, though a comparison of the deposits at the two openings shows considerable variation. At the former the seam is composed of an upper and a lower bench containing two distinct varieties of coal. In the upper bench, which is 2 feet 2 inches thick, the coal is black, with a bright luster. It occurs in layers and breaks into blocks. The lower bench, which is 1 foot 4 inches thick, consists chiefly of a brown, coaly shale with numerous thin layers of coal. The proportion of shale to coal varies, the former sometimes disappearing entirely. The two benches are not separated by a layer of slate, as is usually the case at this horizon, but the sudden change in the character of the material indicates the dividing line.

At the Garland Company's mine a slightly different section is observed. Here there is an increase in the thickness of the upper bench, but in quality there appeared to be no essential points of difference. In the lower bench the coal predominates over the coaly shale. The change is due to the rapid thickening and uniting of the thin coal layers. The product of both benches resists weathering fairly well for a lignite. Midway between the two mines the Wyoming Coal and Fuel Company has opened at this horizon a trial pit, which exhibits 4 feet 3 inches of coal without parting. The coal of the lower bench is entirely free from shale, and in its physical properties appears superior to that of the upper bench. The beds in this region have uniformly low dips and the coal could be easily mined. The mines are less than 1 mile from the Mantua switch on the Toluca-Cody branch of the Burlington and Missouri River Railroad, so that a side track might be constructed at small cost, which would enable the companies to ship their coal. The following measurements were made at the three different openings along the strike:

Section at the Wyoming Coal and Fuel Company's mine, Garland, Wyo.

	Ft.	in.
Coal	2	2
Brown carbonaceous shale with streak of coal	1	4

Section at the Garland Coal Company's mine, Garland, Wyo.

	Ft.	in.
Dark-gray clay	2	
Coal	3	6
Coal with streaks of carbonaceous shale	2	6

Section at coal prospect, made by Wyoming Coal and Fuel Company, Garland, Wyo.

	Ft.	in.
Dark-gray compact clay	4	
Coal	4	3

SILVER TIP DISTRICT.

This is a small district located on Cottonwood Creek on the north side of the divide between Clark Fork and Shoshone River. The deposit has been prospected at several places in the immediate vicinity, but the principal opening, the Silver Tip mine, is in sec. 29, T. 58, R. 100. Here considerable coal has been taken out for the last three years, chiefly to supply the ranch trade of Clark Fork Valley. The total thickness of the bed is 5 feet, including two partings of impure coal and a thin layer of soft light-colored clay. The main entry is driven in about 125 feet from the outcrop, and throughout this distance the character of the coal bed fixed appears to be uniform, and analysis of this coal shows a moderate amount of carbon and volatile matter with relatively low percentages of water and ash. A section of the coal bed at the Silver Tip mine is here given:

Section at Silver Tip mine on Cottonwood Creek, Wyoming.

	Feet.
Gray compact sandy clay	4
Brown leaf-bearing shale	3
Coal	5
Gray sandstone	6
Impure coal with streaks of leaf-bearing shale	2
Dark-colored sandstone	5

BENTONITE.

The variety of clay known as bentonite was first described in 1898, by the late Prof. W. C. Knight, of the Wyoming State School of Mines, and since that time several articles have appeared in scientific journals, a list of which are given below.[a] The mineral is a hydrous silicate of alumina, possessing peculiar physical properties. It occurs at various horizons in the Colorado formation and in the overlying Pierre shale. Fresh bentonite has a pale yellowish-green color, but on exposure it changes to a light-cream tint. It is a fine-textured, soft, massive variety of clay, which is unctuous to the touch and which, upon the addition of water, forms an emulsion. It is characterized by its unusual power of absorption, having the capacity of absorbing three times its weight of water. In a comparative test it is reported to have taken twice as much nitroglycerine as infusorial earth. When first taken from the quarry, it breaks with conchoidal fracture, but upon exposure loses this property and crumbles to a light yellowish powder resembling corn meal. The specific gravity of this clay, when fresh, is 2.18. Its resemblance to ehrenbergite of Germany has been pointed out by Mr. Knight and its relationship to montmorillonite by Mr. Read. The clay from different localities varies somewhat in composition, but in general it is quite uniform in a single deposit.

This clay has been used with success in various ways, chiefly in the manufacture of paper. It has also been used as a soap. It is regarded valuable as a packing for a special kind of horseshoe and as a diluent for certain powerful drugs in powdered

[a] Knight, W. C., Eng. and Min. Jour., vol. 63, 1897, pp. 600-601; Knight, W. C., Eng. and Min. Jour., vol. 66, 1898, p. 491; Merrill, George P., Ann. Rept. U. S. Nat. Mus., 1899, pp. 340, 348; Slosson, E. E., Tenth Ann. Rept. Wyo. Coll. Agric. and Mech., 1900, Extract. p, 14; Read, Thomas T., Eng. and Min. Jour., vol. 76, 1903, pp. 48, 49; Darton, N. H., Description of Newcastle district: Geologic Atlas U. S., folio No. 107, U. S. Geol. Survey, 1904, pp, 5, 9; Merrill George P., The Non-Metallic Minerals, 1904, pp. 233, 243; Fisher, C. A., Bull. U. S. Geol. Surv. No. 260, 1905, pp. 559-563.

form. Dr. E. E. Slosson, of the University of Wyoming, has recommended its use as a retarder for certain kinds of plaster.

Bentonite deposits were observed at many localities in the Bighorn basin, where they usually occur in the Colorado shales about 100 feet below the Mowry beds, although in one locality, near the Silver Tip coal mine, they are reported in beds above the Colorado formation. One of the most extensive deposits of bentonite observed in this district is on Dry Creek, about 8 miles east of Frannie, Wyo. Here the bentonite is in the black shales of the lower part of the Colorado formation, a short distance below the Mowry beds, which are well developed at this place. The deposits have a total thickness of 11 feet, distributed throughout a vertical range of 100 feet. The thickest layer is about 7½ feet. Below the bentonite, beds of dark shale abound, and above are lighter shales containing bands of iron concretions. The material at this locality is a gray, fine-grained, massive clay, with green and yellow tints and is apparently of good quality throughout. The thin seams of gypsum, sometimes associated with the clay, are present though not conspicuous. The following section will show the approximate position of the different deposits at this place:

Section of a portion of the Colorado formation on Dry Creek, Wyoming.

	Feet.
Bentonite	2
Dark fissile shale	12
Bentonite	7½
Shale	30
Bentonite	1
Shale containing thin layers of bentonite	50

Near the head of Dry Gulch, about 5 miles north of Cowley, Wyo., a 1½-foot layer of bentonite is found near the top of the Colorado formation. The following section shows the materials above and below the clay:

Section taken from head of Dry Gulch, Wyoming.

	Feet.
Black shale capped by brown sandstone	6
Bentonite	1½
Black fissile shale	20

During the last field season deposits of a clay possessing properties similar to bentonite were discovered in the lower part of the coal-bearing measures; also in the overlying Wasatch formation. Those in the former are associated with thin deposits of coal and coaly shale in sandy beds outcropping at the head of Bud Kimball Draw, 12 miles southeast of Tensleep, Wyo. A section of the deposit is here given:

Section of bentonite at head of Bud Kimball Draw, Wyoming.

	Feet.
Brown leaf-bearing sandy shale with streaks of coal	2
Dark-gray clay	4
Bentonite	6
Light-gray clay	6
Gray sandstone with carbonized wood particles	1
Impure coal	1
Gray sand.	

In the badlands of the Wasatch formation, on the southern side of Cottonwood Creek, about 10 miles southeast of Meeteetse, an impure bentonite occurs.

GYPSUM.

The gypsum deposits of the Bighorn basin are mainly in the Chugwater formation. They occur also in the lower part of the Sundance formation, and at one locality a deposit 8 feet thick was observed in the upper part of the Morrison formation. In the Chugwater red beds there is usually a gypsum layer 30 to 40 feet thick near the top of the formation and generally one of equal thickness at or near its base. Along the southern side of the basin the gypsum at the base of the red beds is absent. Thinner beds of gypsum are found at various horizons in the Chugwater formation, but these appear to be of local deposition. In most places where the gypsum has been carefully examined it is apparently of good quality, though no analyses have been made to determine its exact chemical nature. It is a white, compact, massive variety and generally occurs in beds that are free from partings. The following section, taken on Trail Creek northwest of Cody, will show the position of the gypsum in the upper part of the Chugwater red beds:

Section of a portion of the Sundance and underlying Chugwater formation on Trail Creek, Wyoming.

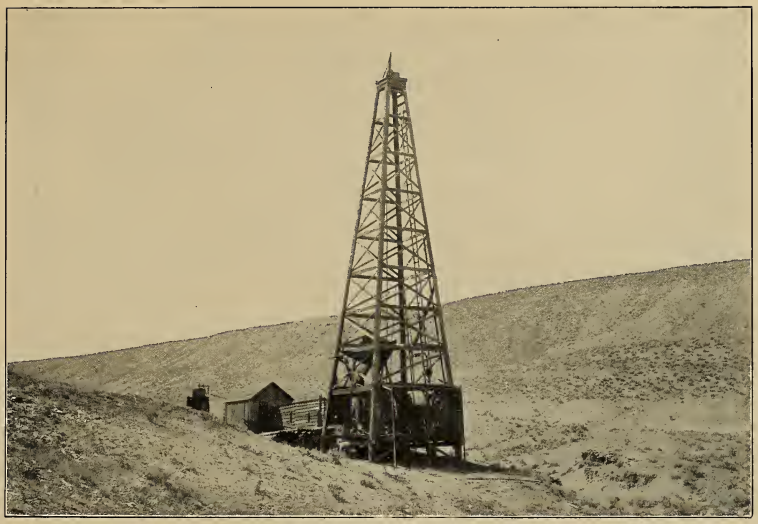
	Feet.
Green shale containing thin limestone layers (Sundance)	3½
Red sandy shale containing thin layers of gypsum (Chugwater)	12
White massive gypsum	30
Red sandstones (red beds).	

About 10 miles south of Cody a deposit of gypsum was observed in the upper part of the Morrison formation. The following section shows its relative position:

Section of a portion of the Morrison and overlying Cloverly formation south of Cody, Wyo.

	Feet.
Brown, coarse-grained, cross-bedded sandstone (Cloverly)	60
Reddish sandy shale with thin gypsum layers	25
White massive gypsum	8
Reddish sandy shale with thin gypsum layers	15

Though there are extensive deposits of gypsum throughout this area no attempt has been made to utilize the product except in a very small way. There is a stucco mill about 10 miles northeast of Windsor post-office, Wyo., in the southern part of Montana, where plaster is manufactured from a gypsum deposit near the base of the Chugwater red beds. The beds mined at this place are about 15 feet thick, and the product is of good quality. The material is ground and placed in ovens, where it is calcined at a red heat in order to drive off the chemically combined water. A retarder is then added to prevent it from hardening too quickly when water is applied. After this it is mixed with hair and placed in barrels ready for shipment. The entire process of converting the gypsum into stucco is relatively simple and inexpensive. The finished product of this mill is sold at Bridger at $12 a ton, but the output is not large.



A. OIL WELL AND DERRICK NEAR BONANZA, WYO.

B. HOT-SPRINGS DEPOSITS AT THERMOPOLIS, WYO.

OIL AND GAS.

Bonanza oil field.—Several attempts have been made to obtain oil from the Cretaceous shales throughout the Bighorn basin, but generally without success. About three-fourths of a mile southwest of Bonanza, near the axis and at the northern end of a small anticline in the Colorado formation, several oil seeps furnish a small amount of oil. The oil is from a thin-bedded sandstone underlying the Mowry beds of the Colorado formation. This surface indication has caused many persons to believe that oil in paying quantities might be obtained by drilling, and consequently several deep borings have been made in this region (Pl. XV, *A*). None of these have been successful, and at present all exploration has ceased. Oil from the Bonanza district has been studied by E. E. Slosson, of the University of Wyoming, and the distillation of the product is given below:

Distillation of Bonanza petroleum.[a]

No.	Boiling point.		Specific gravity.	Degree Baumé.	Flashing point.		Burning point.	
	°C.	°F.			°C.	°F.	°C.	°F.
1	60–157	140–314	.762	53.5	Below 15	Below 59	Below 15	Below 59
2	157–200	314–392	.792	46.5	18	64	36	97
3	200–237	392–459	.822	40.3	38	100	78	172
4	237–273	459–523	.843	36.1	82	180	108	226
5	273–297	523–567	.853	34.1	108	226	132	270
6	297–329	567–624	.867	31.4	121	250	161	327
7	329–371	624–715	.876	29.8	46	115	162	323
8	371–391	715–736	.861	36.6	Below 15	Below 59	52	125
9	391–340	736–646	.849	34.8	Below 15	Below 59	48	118
Crude			.850	34.6	19	66	33	91

[a] 280 cm.³ distilled in 10 per cent fractions.

A deep boring for oil was made at the mouth of Cottonwood Creek, on Shoshone River, near Cody, Wyo., but no oil was obtained. The well is located on the western slope of a small anticline in Colorado shale.

Byron gas field.—Plans are now being made to sink a deep well on the western side of a broad anticline, along the axis of which a small area of Pierre shale is exposed. Shoshone River crosses the southern end of the anticline and has cut for some distance into the shale. In the low valley of this stream near the center of the anticline there are places where gas escapes in considerable quantity from the alluvial sands. It probably is derived from the underlying shales of the Pierre formation. The gas burns readily, but its quality was not ascertained. The boring which is now proposed will doubtless demonstrate whether or not gas is present in sufficient amount to warrant development.

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

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BUILDING STONE.

Sandstone.—Several varieties of building stone are found in the various formations exposed in the Bighorn basin, but at present only a small amount is used. These varieties comprise sandstone, limestone, marble, and granite. A sandstone used for building occurs in the upper part of the Benton formation, and in some districts the Cloverly formation furnishes a sandstone of moderate firmness and pleasing color. The Chugwater formation also contains layers of sandstone which, on account of their rich red color, have been used as an ornamental stone. The sandstones of the Laramie and associated formations are generally too soft to be used in construction work.

Limestone.—Limestone, although abundant, is not generally used as a building material. A very pure variety of limestone, resembling marble, occurs at the top of the Madison formation. In the Bighorn Mountains this stone has been quarried for trial. It is of a light-cream color, fine grained, uniform in texture, and apparently of good quality.

Granite.—In Shoshone Canyon, west of Cody, granite is exposed which might prove to be of good quality for building stone. It is a dark gray, moderately coarse-grained variety and appears to be firm and durable. The material is to be used in the large Government dam across Shoshone River, now in course of construction.

GRAVEL.

The later Quaternary gravels along the south side of the Shoshone River Valley have been used by the Burlington and Missouri River Railroad Company as roadbed material. Gravel especially well suited for this purpose is found about 2 miles west of Garland. Here a switch has been built and a large amount of gravel is taken out. The gravels of this region are dark colored, owing to the presence of a large amount of volcanic material.

FIRE CLAY.

The Cloverly formation throughout this general region has the usual interstratified beds of clay and shale which in other districts are of refractory character, suitable for fire clays of good quality. None of these clays throughout the basin have been tested, but it is possible that they may prove to be of good quality.

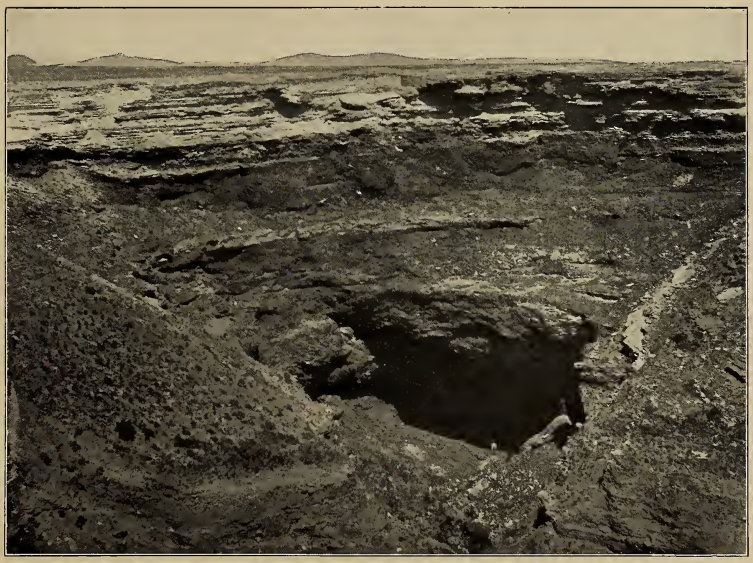
GOLD.

Bald Mountain district.—During the past decade various attempts have been made to develop gold mines in the vicinity of Bald Mountain, but the results have not been encouraging. The gold occurs in the basal gravels of the Deadwood formation, especially where these gravels have been mixed with disintegrated portions of the underlying granite and redeposited as a valley filling. The gold is fine grained and free, but values are low and its distribution throughout the gravels is apparently irregular. The highest assays reported are $2 a ton, but the amount is usually much less.

Bighorn basin region.—Gold is mined from placers along Clarks Fork, in the vicinity of Clark, and on Shoshone River below the mouth of Alkali Creek. The output has never been large at either of these localities.

A. SHOSHONE RIVER AT CODY HOT SPRINGS.

Showing Quaternary gravels and extinct geyser cone.



B. SINK HOLE IN GEYSER DEPOSITS.

MINERAL WATERS.

CODY HOT SPRINGS.

Description.—About 3 miles west of Cody, in the bed of Shoshone River, there are a number of warm mineral springs. Formerly springs of this character occurred on both sides of the river, but at present they are confined mainly to the north side, where, along the water's edge, within a distance of about 200 feet, five or six springs are found. The water issues from crevices in Embar limestone immediately underlying the Chugwater red beds, which here dip eastward at an angle of about 15°. These beds are overlain by a deposit of Quaternary gravel 25 to 30 feet thick, capped by about 20 feet of travertine. Near the middle of the stream is a large spring which flows vigorously and is evidently under considerable pressure. During times of low water this spring is very noticeable, but in the flood season it is entirely covered by the river water. No analysis has been made of the spring water, but it evidently contains a large amount of hydrogen sulphide and probably some sulphuric acid. It is also otherwise considerably mineralized. The water is clear, warm, and emits a strong sulphurous odor. In the warmest spring it has a temperature of 98°. The water is diverted into pipes which lead to a sanitarium, where it is used both for bathing and for medicinal purposes. Closely associated with the springs are vents or crevices in the rock, from which large volumes of hydrogen-sulphide gas escape, and the limestone immediately surrounding these vents is considerably altered.

The geologic structure of this region is relatively simple, as is shown in cross section No. 3 of Pl. IV. The springs occur at the lower end of Shoshone Canyon, at the base of Rattlesnake Mountain, which is a moderately broad anticlinal ridge branching from the front range of the Absaroka Mountains. The anticline has long, gradual slopes on the east and steep dips on the west, and it rises to an altitude of about 8,500 feet. It is noteworthy that the greatest thermal activity has taken place on the side of lowest dips. Shoshone Canyon exposes the structure of the uplift down to and into the crystalline rocks.

Hot-spring deposits.—Hot-spring deposits occur at different levels in Shoshone Canyon and at its upper and lower end, far above the present level of the river. On the north side of the river, just below the mouth of Shoshone Canyon, there is a broad travertine terrace covering several acres, and smaller areas are found along the east side of Cedar Mountain from Shoshone River southward for about 2 miles. The distribution of these deposits is shown on the geologic map, Pl. III. A number of extinct geyser or hot-spring cones occur. The most prominent of these on the south side of Shoshone River is shown on Pl. XVI, *A*. On the north bank of the river, a short distance north of the sanitarium, there is an empty crater about 70 feet in diameter and 40 feet deep (Pl. XVI, *B*), indicating the position of a hot pool, and a short distance northeast of this there is a smaller crater of similar nature.

Source of water.—It is difficult to ascertain definitely the source of water of the Cody hot springs, but the flow is probably not derived from the formation in which the springs occur. Two water-bearing horizons underlie the Embar limestone—the Tensleep and Deadwood formations—and the water is probably derived from one of these sources. Under these conditions its only means of escape to the surface

is through fractures in the strata along the side of the arch. If the water is derived from the Tensleep formation a very high heat gradient of the earth's crust in this region must be assumed in order to account for the temperature of the spring water, for this formation is not deeply covered by overlying beds between the area where the water passes underground and the point of its reappearance at the springs. If the water comes from a deeper-seated source, such as the Deadwood formation, its temperature can be satisfactorily accounted for. The sandstone at the base of the Deadwood, which is the only water-bearing horizon of the formation, is about 2,200 feet below the surface at the springs. Assuming that the mean annual temperature at Cody is 50° and that there is an increase in temperature of 1° for every 50 feet underground below the first 50 feet, the temperature of the earth's crust at a depth of 2,200 feet would be about equal to the temperature of the spring water. It seems probable, therefore, that the water of the Cody hot springs is derived from the base of the Deadwood formation and that it rises to the surface under hydrostatic pressure, through fractures in the strata along the base of the Rattlesnake Mountain anticline.

THERMOPOLIS HOT SPRINGS.

At Thermopolis, on Bighorn River in the southeastern part of the Bighorn basin, there is a hot mineral spring the flow of which has been variously estimated at from 3,000 to 4,000 gallons a minute. Calcium carbonate is the principal ingredient of the water, while magnesium sodium and calcium sulphate are present in smaller amounts. (Pl. XV, *B*, p. 58.) An analysis of this water made by Prof. E. E. Slosson, of the University of Wyoming, is here given:

Composition of the waters of Thermopolis Hot Springs, Wyoming.

SiO_2	4.986	$CaSO_4$	13.156
Fe_2O_3 and Al_2O_3	.227	$CaCO_3$	40.454
KCl	10.249	NaCl	26.195
Na_2SO_4	15.110		
Mg_2SO_4	19.443		129.820

There are two sanitariums and a large plunge located near the spring, and the place is rapidly becoming a popular health resort for people of northwestern Wyoming. The Thermopolis hot springs have been described by Mr. N. H. Darton.[a]

WARM SPRINGS IN BLACK CANYON.

Warm springs are reported from Sheep Canyon in the northeastern part of the basin, and farther up Bighorn River at the upper end of Black Canyon there is a small spring of mineral water which is noticeably warmer than the river water.

SULPHUR.

Sulphur occurs in local deposits on the southern side of Shoshone River, at the lower end of Shoshone Canyon, and along the western side of Sulphur Creek for about 2 miles above its mouth. It was deposited by heated waters and gas from the numerous hot springs that once existed in this region. A large amount of prospect-

[a] Geology of the Owl Creek Mountains, etc.: U. S. Senate Doc. No. 119, 59th Congress, 1st session.

ing has been done, and development of this resource is at present being considered. The material appears to be of excellent quality, but there is some doubt whether it occurs in sufficiently large quantities to warrant extensive development. Sulphur also occurs in hot-spring deposits at Thermopolis, Wyo.

CLIMATE.

There is a wide range of climate in the Bighorn basin region, corresponding mainly to differences of altitude. On the high mountains surrounding the basin heavy snows usually begin early in September and continue until April, while in the center of the basin snow rarely lies on the ground for any great length of time and only a few days of cold weather occur during the winter months. Very few meteorologic data concerning the climatic features of the mountainous regions are available, but in several places in the basin systematic observations have been made by the Weather Bureau since 1898. The following table gives a record of the monthly and annual mean temperature at Basin, Wyo., for a period of five years, 1898 to 1903, inclusive, with the exception of 1901:

Records of the monthly and annual mean temperature, etc., in round numbers, at Basin, Wyo.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.			Killing frost.	
													Mean.	Extremes.		Last in spring.	First in autumn.
														Max.	*Min.*		
1898	.....	.....	.....	.....	.....	.....	73	.....	.....	41	28	12	.....	.....	.....	.....	.....
1899	18	2	20	46	55	68	74	70	59	43	34	12	42	107	−51	May 5	Sept. 7
1900	14	12	30	45	60	72	78	74	60	48	30	27	46	114	−36	Apr. 18	Sept. 15
1902	12	23	36	46	61	67	74	73	59	49	32	20	46	107	−39	May 4	Sept. 18
1903	22	16	34	46	55	70	74	73	61	48	30	22	46	107	−17	June 9	.....
Average.	16	13	30	46	58	69	74	72	60	46	31	19	45	.....	.....	.....	.....

RAINFALL.

There is a moderate amount of rainfall in summer throughout this general region, especially in the mountainous districts, where it has been variously estimated from 30 to 40 inches. On the lower lands in the interior of the basin arid conditions prevail. Here the snowfall is light and the amount of rain small, the average annual precipitation varying from 3 to 10 inches. During the summer there are a few heavy showers, but they are usually of short duration. A record of the monthly and annual precipitation at Basin, Wyo., for a period of six years, 1898 to 1903, inclusive, is given in the following table:

Records of the monthly and annual precipitation at Basin, Wyo.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1898	.....	.....	.....	.....	2.28	0.80	0.10	0.14	0.06	1.13	0.20	0.10	.....
1899	1.84	3.56	1.94	0.13	0.57	0.53	0.22	0.27	0.23	0.38	0.00	0.27	9.94
1900	0.08	T.	T.	1.06	0.58	0.29	0.06	0.15	0.31	0.36	0.02	T.	2.91
1901	0.00	0.16	T.	0.36	1.59	1.46	0.05	0.83	0.25	0.12	0.17	0.85	5.84
1902	0.16	0.14	0.27	0.85	0.61	0.24	0.21	0.04	0.08	T.	0.03	T.	2.63
1903	T.	0.21	T.	0.86	0.81	0.62	0.96	T.	0.26	T.	T.	0.06	3.78

T.=Trace.

CULTURE.

Settlement here, as elsewhere, is determined by geologic and climatic conditions. Along the larger streams, where water is available, settlements are numerous, while the higher badlands and grazing districts are practically uninhabited. The high mountains on both sides of the Bighorn basin are only thinly populated. The Bighorn Mountains, owing to the heavy snows, the long winters, and the prevalence of frosts during the nights of summer are not suited to farming and they are therefore without permanent inhabitants. During the summer, however, herders, prospectors, and forest rangers live in the mountains, but the season is very short. The same is true of the highlands on the eastern front of the Absaroka, Beartooth, and a portion of the Shoshone mountains. Here, for a short season during the summer, the summit of the range is occupied by ranchmen from the adjoining lowlands.

There are a number of medium-sized towns throughout the Bighorn basin. The town of Basin, located on the west side of Bighorn River in the east-central part of the basin, is a growing place of 600 to 800 inhabitants and the county seat of Bighorn County. It is located on the new branch of the Burlington Railroad now being built from Frannie to Worland, and is the central trading point for farmers living along a portion of the irrigated valleys of Bighorn and Gray Bull rivers and on Shell and No Wood creeks. The largest town in the basin is Cody, having a population of about 1,200. It is situated in the northwestern part of the district, near the southern termination of the Rattlesnake Mountains. It occupies a central location in a relatively large irrigated district, lying along Shoshone River and its more important tributaries. The warm mineral springs near Cody are used considerably for medicinal purposes and bathing and in consequence attract a few health and pleasure seekers to this place during the summer months. Cody is the base of supplies for the Shoshone irrigation project, which has its dam and storage reservoir about 5 miles above the town. Thermopolis is the third town in point of size in the Bighorn basin. It is situated on Bighorn River, in the southern part of the district, where it draws a large ranch trade from settlers along the irrigated lands of the neighboring streams. The most attractive feature of the place is the large hot springs which are extensively used for bathing and medicinal purposes and are rapidly becoming a favorite resort for the people of northwestern Wyoming. Meeteetse is a town of about 400 inhabitants, located on Gray Bull River in the western part of the basin, in the midst of both a grazing and irrigation district. It is the base of supplies for a large mining camp at Kirwin and is a central trading point for the southwestern part of the district.

Garland is a small town on the Burlington Railroad, in the northern part of the district, from which a large amount of freight is hauled to the interior of the basin. A short distance east of Garland are Byron, Cowley, and Lovell, small agricultural towns having a population of from 400 to 500. Worland, the terminus of the new Burlington road, is a growing town of 100 to 200 inhabitants, and along the eastern side of the basin there are several small trading points, including Shell, Bonanza, Hyattville, Tensleep, and Rome.

The valley of Shoshone River between Cody and Corbett is thickly settled by farmers. Between Corbett and Garland there are no ranches at present, but during the last year a number of claim shanties have been constructed on the land included under the proposed Government canal. Below Garland, in the vicinity of Byron, Cowley, Lovell, and Ionia, lies the most thickly populated district of the region. There are only a few scattered ranches along Bighorn River below Basin, but farther up a number of thickly populated districts occur and the entire valley is being rapidly settled. Along Shell, Paintrock, and Tensleep creeks ranches are numerous, and there are a few on Crooked, Beaver, Trapper, Bear, and Alkali creeks. Ranches occur at intervals along No Wood Creek, and on Dry Creek, about 15 miles above its mouth, there is a small German settlement around Germania. Gray Bull Valley is thickly settled throughout its entire course in the basin and on its largest tributary, Wood River, there are a number of well-improved ranches. The valley of Clark Fork, in the northwestern part of the area, is extensively farmed, and a few small places have been located on Newmeyer, Paint, and Pat O'Harra creeks. Along Owl Creek ranches occur at frequent intervals, but along Meeyero, Grass, and Gooseberry creeks they are generally 8 to 10 miles apart.

INDEX.

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[Professional Paper No. 53.]

The serial publications of the United States Geological Survey consist of (1) Annual Reports, (2) Monographs, (3) Professional Papers, (4) Bulletins, (5) Mineral Resources, (6) Water-Supply and Irrigation Papers, (7) Topographic Atlas of the United States—folios and separate sheets thereof, (8) Geologic Atlas of the United States—folios thereof. The classes numbered 2, 7, and 8 are sold at cost of publication; the others are distributed free. A circular giving complete lists may be had on application.

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Correspondence should be addressed to

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

JULY, 1906.

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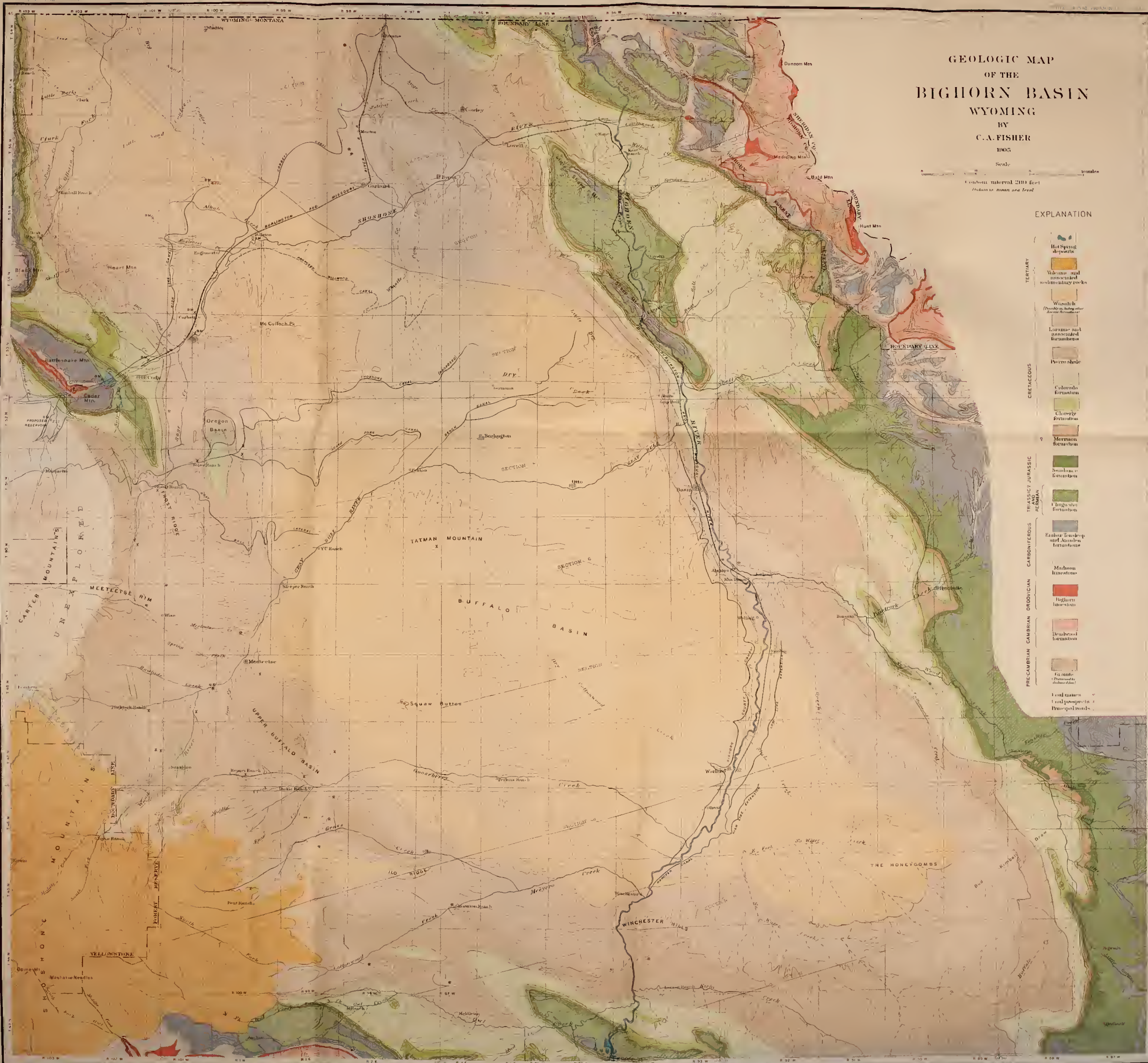
GEOLOGIC MAP
OF THE
BIGHORN BASIN
WYOMING
BY
C. A. FISHER
1905
Scale
Contour interval 200 feet
Datum is mean sea level
EXPLANATION
TERTIARY
Hot Spring deposits
Volcanic and associated sedimentary rocks
Wasatch
Laramie and associated formations
CRETACEOUS
Pierre shale
Colorado formation
Cloverly formation
Morrison formation
JURASSIC
Sundance formation
TRIASSIC? AND PERMIAN
Chugwater formation
CARBONIFEROUS
Embar Tensleep and Amsden formations
Madison limestone
ORDOVICIAN
Bighorn limestone
CAMBRIAN
Deadwood formation
PRE-CAMBRIAN
Granite
Coal mines
Coal prospects
Principal roads
WYOMING-MONTANA
BOUNDARY LINE
Dunoon Mtn
Medicine Mtn
Bald Mtn
Hunt Mtn
Heart Mtn
Black Mtn
Rattlesnake Mtn
Cedar Mtn
PROPOSED RESERVOIR
Oregon Basin
Mc Culloch Pk
SHOSHONE
Burlington
Basin
TATMAN MOUNTAIN
BUFFALO BASIN
Squaw Buttes
UPPER BUFFALO BASIN
CARTER MOUNTAINS
UNEXPLORED
MEETEETSE RIM
SHOSHONE MOUNTAINS
FOREST RESERVE
YELLOWSTONE
THE HONEYCOMBS
WINCHESTER HILLS
Dry Creek
Gray Bull River
Greybull
Cowley
Lovell
Garland
Cody
Meeteetse
Otto
Worland