THE GREAT FALLS COAL FIELD, MONTANA.[a]

By CASSIUS A. FISHER.

INTRODUCTION.

The present paper is a brief preliminary statement of the results of a detailed survey made of the Great Falls coal field, Montana, during the season of 1906 by W. R. Calvert, H. M. Eakin, and the writer. The principal resource of this region is coal, and, as the investigation was made primarily to determine the classification of the public lands, the work was conducted with a view to defining as far as practicable the limits of the coal areas with respect to legal subdivisions of such lands.

The Great Falls coal field was first examined by geologists of the Transcontinental Survey in 1879. In the course of this investigation the coal-bearing horizon was studied and traced from Judith River to Belt Creek by the late George H. Eldridge.[b] Later a brief examination was made of this coal field by J. S. Newberry[c] in the interests of the Great Northern Railway. During the spring of 1891 W. H. Weed, while making an examination of the coal field of Montana for the United States Geological Survey, visited this region and later described the deposits in considerable detail.[d]

LOCATION.

The Great Falls coal field is situated along the base of the Rocky Mountain front range in north-central Montana. As first described by Weed, it extends as a zone of comparatively narrow width along the base of the Rocky Mountains from a point near Musselshell River northwestward to the international boundary line between Canada and the United States. While coal-bearing rocks of Lower and Upper Cretaceous age occur throughout this area, more detailed investigation of the field during the last season has shown that coal beds of commercial importance lie mainly to the east of Missouri River. West and north of that stream to Teton River the coal beds are, so far

[a] A full account of this coal field is being prepared and will appear as a separate publication of the Geological Survey.

[b] Eldridge, George H. Montana coal fields: Tenth Census of the U. S., vol. 15, 1880, pp. 740-757.

[c] Newberry, J. S., The Great Falls coal field: School of Mines Quarterly, vol. 8, 1887, No. 4.

[d] Weed, W. H., Two Montana coal fields: Bull. Geol. Soc. America, vol. 3, 1892, p. 304.

as observed, of less than workable thickness. Although no detailed examination was made of the area bordering the Lewis Mountains north of Teton River, the best information that could be obtained indicates that this area does not contain coals of commercial importance.

Within that portion of the Great Falls coal field which lies between Missouri and Judith rivers, where the present investigation was made, there are three districts underlain by workable coal. For convenience, these are here designated the Sage Creek, Otter Creek, and Sand Coulee districts. In the following discussion the term Great Falls coal field is used in the more limited sense, as applying to the field east of Missouri River. (See Pl. X.)

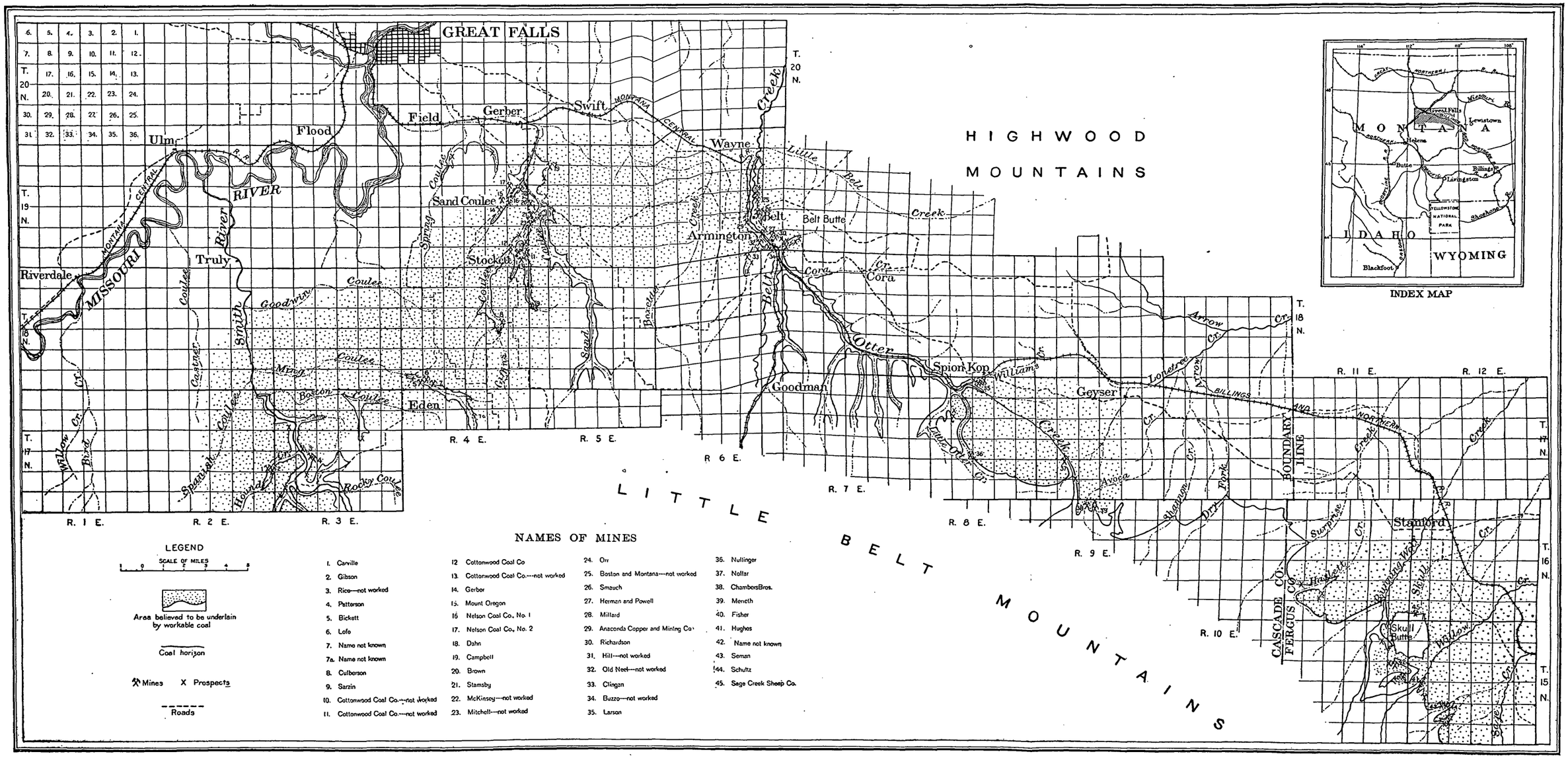
TOPOGRAPHY.

The Great Falls coal field lies in a region whose topography is transitional between that of the plains and that of the mountains, including areas characteristic of both provinces. Its salient features are broad, gentle slopes and plateaus bordering the adjacent mountain ranges. These plateaus are traversed by numerous mountain streams which flow through deep and relatively narrow valleys, especially in that portion of the district lying west of the Otter Creek divide. East of this divide the valleys are relatively narrow throughout a zone bordering the Little Belt Mountains, but farther out on the plains, where they have developed in softer Cretacous rocks, they are usually wide and open. Along the southern margin of the district, from Smith River to the head of Otter Creek, the surface of the plains rises gradually by sloping plateaus, culminating in a zone of high, hilly country bordering the Little Belt Mountains, which lie to the south. West of Missouri River the surface rises by successive plateaus toward the base of the Lewis Range.

There is a moderate range of altitude within the area described. The highest points are along the base of the Little Belt Mountains, where the more prominent summits reach altitudes of 4,500 to 5,000 feet. The lowest point in the district is along Missouri River below the Big Falls, at an elevation of about 3,000 feet above sea level. The average altitude of the region is between 3,500 and 4,000 feet. The extreme variation of altitude for any given locality is about 1,300 feet in a horizontal distance of 1½ miles. This difference of elevation is found between Belt Creek and the summit of Belt Butte at the town of Belt. The relative differences in altitude of valley bottoms and plateau summits range from 300 to 600 feet.

GEOLOGIC OCCURRENCE OF COAL.

Throughout the Great Falls coal field coal occurs in the lower part of the Kootenai (Lower Cretaceous) formation, mainly at one horizon,



INDEX MAP

LEGEND

SCALE OF MILES 1 0 1 2 3 4 5

Area believed to be underlain by workable coal

Coal horizon

⚒ Mines X Prospects

Roads

NAMES OF MINES

1. Carville
2. Gibson
3. Rice—not worked
4. Patterson
5. Bickett
6. Lofo
7. Name not known
7a. Name not known
8. Culberson
9. Sarzin
10. Cottonwood Coal Co.—not worked
11. Cottonwood Coal Co.—not worked
12. Cottonwood Coal Co
13. Cottonwood Coal Co.—not worked
14. Gerber
15. Mount Oregon
16. Nelson Coal Co., No. 1
17. Nelson Coal Co., No. 2
18. Dahn
19. Campbell
20. Brown
21. Stamsby
22. McKinsey—not worked
23. Mitchell—not worked
24. Orr
25. Boston and Montana—not worked
26. Smauch
27. Herman and Powell
28. Millard
29. Anaconda Copper and Mining Co.
30. Richardson
31. Hill—not worked
32. Old Neet—not worked
33. Clingan
34. Buzzo—not worked
35. Larson
36. Nullinger
37. Nollar
38. Chambers Bros.
39. Meneth
40. Fisher
41. Hughes
42. Name not known
43. Seman
44. Schultz
45. Sage Creek Sheep Co.

MAP OF THE GREAT FALLS COAL FIELD.

By Cassius A. Fisher and W. R. Calvert.

which is 60 feet above the base of the formation. Coal of workable thickness is not continuous, however, at this horizon, but varies locally. The Kootenai formation has a thickness of about 475 feet and consists mainly of sandstones and sandy shales occurring in alternate succession. In the lower part sandstones predominate and are massive in character, but higher in the formation the proportion of sandstone decreases, and the beds consist largely of red shales and clays with here and there a thin layer of sandstone. The formation rests with apparent conformity upon the variegated sandy shale and sandstone of the Morrison and is overlain by the somber-colored shale and sandstone of the Colorado formation. A generalized section of the sedimentary rocks of the Great Falls coal field is given below:

Generalized section of sedimentary rocks in Great Falls coal field.

	Feet.
Colorado formation (Upper Cretaceous):	
Shale, dark gray, sandy, with thin layers of sandstone	80
Sandstone, dark gray	10
Volcanic ash	30
Shale, dark colored, sandy, with thin layers of sandstone	80
Shale, sandy, or impure sandstone	20
Shale, dark, sandy	75
Sandstone, gray, forming belt around Belt Butte	50
Shale, dark, sandy	80
Shale, dark, sandy in lower part	125
Shale, dark, sandy, containing massive sandstone members, locally calcareous at top	180
Kootenai formation (Lower Cretaceous):	
Shale, red, sandy, and clay, with few thin sandstone layers	195
Shale, red, sandy, capped by sandstone	20
Limestone	5
Shale, red, sandy, capped by sandstone	20
Shale, red, sandy at top	30
Shale, red, sandy, with here and there a thin sandstone layer	50
Shale, red, containing lenses of impure limestone and capped by gray limestone	30
Sandstone, gray, massive	40
Coal and coaly shale	10
Sandstone and sandy shale	60
Morrison formation (Jurassic?):	
Sandstone, gray	25
Shale, sandy, variegated, containing thin layers of sandstone and limestone	75
Ellis formation (Jurassic):	
Sandstone, massive, gray, weathering light brown, conglomeratic at base	100

The foregoing section is compiled from a number of detailed measurements made in various parts of the field, and as individual beds vary materially in different localities it can not be regarded as typical of any one locality. It is introduced here mainly to show the succession of the beds and the position of the coal in the stratigraphic column.

The geologic structure of the coal field is comparatively simple. The rocks dip, at relatively small angles, to the northeast, away from the adjoining mountains. In a narrow zone bordering the Little Belt Range the rocks dip from 10° to 15°, but in their extension toward the plains they flatten rapidly, and in the area underlain by coal the dips rarely exceed 4°. An exception to this occurs in the vicinity of Skull Butte, where a local doming of the sediments, probably due to a laccolithic intrusion of igneous rock, increases the dip to 25°. A close examination of the canyons throughout the coal area, where the dips are low and in general to the north, shows that these nearly horizontal beds are in reality gently folded into a series of low anticlines and shallow synclines, most of which are not perceptible to the casual observer. Minor faults are also more or less common throughout the coal area, especially in the vicinity of Belt, where they have caused some difficulty in mining the coal.

The irregularity in the occurrence of workable coal at the horizon above referred to is a characteristic feature of the beds of this field that was observed early in the investigation, and an effort was made to trace out, as far as possible from a study of the outcrop, the limits of the areas underlain by workable coal. These coal areas or basins, as they have been previously designated, are three in number and include a total area of approximately 316 square miles. The largest, comprising about 230 square miles, lies south of Great Falls, extending from a point a short distance east of Belt Creek westward beyond Smith River. (See Pl. X.) It is possible, however, that the coals of this basin continue southward throughout the territory lying between the Big and Little Belt mountains, but no examination was made of this region. The district examined is drained by Sand Coulee and its tributaries and is known as the Sand Coulee basin. To the east the next district underlain by coal of commercial importance lies between Little Otter and Geyser creeks and is designated Otter Creek basin. This is the smallest coal basin in the district, including only about 38 square miles. Still farther east, in the vicinity of Skull Butte, there is a third coal basin which, owing to its nearness to Sage Creek, the main drainage channel of the district, is called the Sage Creek basin. It includes about 48 square miles.

DETAILED DESCRIPTION OF COAL DEPOSITS.

SAND COULEE BASIN.

GENERAL CONDITIONS.

The Sand Coulee basin is underlain by one coal-bearing bed of commercial importance. In this bed, consisting of coal interbedded with

layers of bone, shale, and clay, the coal content ranges in thickness from 6 to 14 feet in different parts of the field. At Belt, near the northeast end of the basin, where the bed has been opened at many places, the average thickness of twenty-six measured sections is 4 feet 7 inches. At Sand Coulee fourteen measured sections give an average thickness of 8 feet 7 inches, and along Smith River, where fewer openings have been made, an average of five sections shows a total thickness of 7 feet 6 inches of coal. In the vicinity of Belt the coal is divided into three distinct benches. The lower and upper benches are about equal in thickness; the middle bench is considerably thinner. A section of the coal bed in the Anaconda Copper Mining Company's mine, which may be regarded as representative of the Belt Creek mines, is given below:

Section of coal bed in Anaconda Copper Mining Company's mine, Belt.

	Ft.	in.
Coal	1	9
Bone		8
Coal		5
Bone		4
Coal	2	8
	5	10

At Sand Coulee the arrangement of the coal beds is somewhat different. Here the coal mined occurs in two principal benches, the upper much thicker than the lower, but between these two there is no middle bench, such as occurs in the Belt Creek mines. Above the upper bench, however, there are two higher layers of coal which have a maximum measured thickness of 5 feet 8 inches. These two higher coals are not mined in the Smith River region, where the number and arrangement of the coal benches are similar to those of the Sand Coulee district. The following are representative sections of the coal bed in the Sand Coulee and Smith River districts:

Section of coal bed in Cottonwood Coal Company's mine, Stockett.

Sandstone.	Ft.	in.
Coal		10
Bone		4
Coal	1	10
Bone		7
Coal	6	1
Bone		6
Coal	2	6
	12	8

Section of coal bed in Lofe's mine, near Eden.

	Ft.	in.
Coal	3	
Bone		10
Coal	1	6
Bone		8
Coal	3	
Bone	1	6
Coal	1	2
Shale.		
	11	8

From a comparison of the average thickness, number, and order of the various coal benches in the Belt, Sand Coulee, and Smith River mining districts, it is apparent that the coals of this basin are of lenticular character and that the total thickness of coal contained in the coal-bearing zone is greatest at the Sand Coulee mines.

DEVELOPMENT.

GENERAL STATEMENT.

Development of the coal resources of the Great Falls coal field was first begun in the Sand Coulee basin at Belt, where, in 1876, a small mine was opened and coal shipped overland to Fort Benton, a town situated near the head of navigation on Missouri River. For the first few years the coal output of this district was small, but with the opening of mines at Sand Coulee and on Smith River, which took place a few years later, the amount was increased. In 1885 the combined production of the Belt and Sand Coulee mines was 1,900 tons, of which 1,200 tons were from the Belt mines. During the following year the output of these two localities amounted to only 1,400 tons, the greater part being supplied by the Sand Coulee mines. The reports from Cascade County for 1887 give a relatively small yield, but during the following year, with the completion of the railroad to Sand Coulee, the total coal production of the region was materially increased. From 1888 to 1892 the annual coal output of the Sand Coulee basin increased steadily, but with the improvements made in the facilities for handling coal at the Sand Coulee mines during 1893, the total production of the region was increased over 100 per cent. Since 1880, when the first systematic record of the coal production of Montana was kept, Cascade County has been one of the largest producing counties in the State. Its output, together with that of the State, is shown in the following table:

Coal production of Montana and Cascade County from 1880 to 1906, inclusive.[a]

[Short tons.]

Year.	Montana.	Cascade County.	Year.	Montana.	Cascade County.
1880	224		1895	1,504,193	713,877
1881	5,000		1896	1,543,445	1,101,298
1882	10,000		1897	1,647,882	1,138,590
1883	19,795		1898	1,479,803	988,821
1884	80,376		1899	1,496,451	965,378
1885	86,440	1,900	1900	1,661,775	1,123,395
1886	49,846	1,400	1901	1,396,081	789,407
1887	10,202		1902	1,560,823	761,572
1888	41,467	4,600	1903	1,488,810	733,064
1889	363,301	166,480	1904	1,358,919	599,158
1890	517,477	200,435	1905	1,643,832	826,026
1891	541,861	198,107	1906	1,838,635	991,417
1892	564,648	242,120			
1893	892,309	516,460		22,730,990	12,702,465
1894	927,395	638,960			

[a] Mineral Resources U. S., 1880–1906, U. S. Geol. Survey.

Although at present coal prospects and small mines are located at many different places throughout the Sand Coulee basin, development is confined chiefly to the three localities where stream valleys crossing the district cut and expose the coal-bearing rocks. These districts of principal development are along Belt Creek, Sand Coulee, and Smith River.

BELT CREEK MINES.

Along Belt Creek and its tributaries near the town of Belt the coal bed has been extensively prospected and a number of mines are now being operated. The mine of the Anaconda Copper Mining Company is the largest in the district. In addition to this mine there are four smaller ones, which are worked continuously, and seven abandoned mines, some of which have produced considerable coal in the past. Prospecting has been extensive, especially along Nell Creek, on either side of Belt Creek, and in Armington Coulee. A number of diamond-drill prospect holes have been bored by the larger companies on the plateau west of Belt Creek in order to determine the character of the coal bed underlying their respective holdings.

SAND COULEE MINES.

Four coal companies are now operating along Sand Coulee and its tributary canyons in the vicinity of Stockett. These are the Cottonwood Coal Company at Stockett, the Nelson and Gerber coal companies at the town of Sand Coulee, and the Mount Oregon Coal Company. In addition there are a number of prominent individual producers. Those deserving of special mention are Dahn, Brown, and Stamsby mines. This locality was the second to receive attention in the development of the coal resources of the Great Falls coal field, but at present it is the largest producing district of the entire field and one of the largest in the State.

Branch railroad lines connect Stockett and Sand Coulee with the Neihart branch of the Great Northern Railway at Gerber station, and a large amount of coal is shipped from these towns to Great Falls and

also to more distant points along the Great Northern main line, both to the east and west.

SMITH RIVER MINES.

In the bluffs bordering Smith River and its tributaries, Hound Creek and Ming Coulee, the coal-bearing zone is exposed at many places. The coal has been mined intermittently throughout this district for over twenty-five years, and within the last decade extensive prospecting has been done in order to ascertain the extent of the coal bed in this portion of the Sand Coulee basin. Several small mines are now operated, and there are a few abandoned mines from which coal is occasionally taken. Those worked are the Gibson, Carville, Patterson, Bickett, and Lofe mines. These have a combined annual output of only a few hundred tons. The location of prospects and mines in this part of the Sand Coulee basin is shown on Pl. X (p. 162).

OTTER CREEK BASIN.

GENERAL CONDITIONS.

The Otter Creek coal basin, which is located southwest of Geyser, extending along Otter Creek for a distance of about 10 miles, lies mainly in T. 17 N., Rs. 8 and 9 E., but includes a small portion of T. 16 N., R. 9 E. It occupies a total area of about 38 square miles. The southern limits of the basin are definitely marked by the southern outcrop of the coal-bearing rocks, but to the east, north, and west the extent of the coal can only be inferred from a study of a comparatively small number of exposures. The limits of the basin thus determined are indicated in Pl. X. The Otter Creek basin is underlain by one bed of coal which ranges in thickness, as indicated by exposures, from 3 to 6 feet. The maximum thickness, however, in the center of the basin probably exceeds 6 feet. The coal generally occurs in two benches, although at one mine three distinct benches were observed. The maximum thickness of workable coal is 4 feet, as shown by the section at Nollar's mine, where it occurs in one bed with no partings. At other openings where two benches are present the lower is usually the thicker and contains the better quality of coal. The parting between the two benches is commonly bone. In the locality where three benches occur their total thickness is 2 feet 3 inches. It is difficult to give an average coal section of the Otter Creek basin, for only one mine has been opened which may be regarded as representative of the coal in the central part of the basin. This mine, owned by Mr. Nollar, shows a total thickness of 4 feet, as above stated. It is probable that over a considerable area the coal retains this thickness, but throughout the marginal portions it doubtless becomes much thinner.

DEVELOPMENT.

The coals of the Otter Creek basin have not been mined to any extent. Some coal has been taken out of different openings for a

number of years, but the basin as a whole is practically undeveloped. The Billings and Northern Railroad, now being constructed, will pass near the northern edge of the field, thus affording transportation facilities for coal mined in the future. At the present time only three small mines are worked in the district—the Nollar, Nullinger, and Chambers mines. Of these, only the Nollar mine is of sufficient size to be regarded as a factor in the production of coal in this district.

SAGE CREEK BASIN.

GENERAL CONDITIONS.

The Sage Creek basin, situated in the eastern part of the Great Falls coal field, a few miles south of Stanford, in the vicinity of Skull Butte, lies mainly in Tps. 15 and 16 N., Rs. 11 and 12 E., but embraces portions of Tps. 15 and 16 N., R. 13 E. The area described encircles Skull Butte, a dome-shaped uplift which exposes rocks older than the coal-bearing measures. This basin ranks second in the field in point of size, being slightly larger than the Otter Creek basin and considerably smaller than the Sand Coulee basin. It includes about 48 square miles.

So far as known, there is only one coal bed in this basin. Its thickness, including partings, ranges from 6 to 18 feet. Within this thickness of beds deposited under coal-forming conditions the aggregate amount of coal ranges from 2½ to 7 feet, usually occurring in the form of three distinct benches, which are generally recognized by miners in the district. The lowest bench has a thickness of about 2 feet and is regarded as the best coal mined. Above this is commonly a parting 2 to 6 inches thick, overlain by the middle bench of coal, which is from 12 to 16 inches thick. Overlying the middle bench is generally 1 to 6 inches of bone, which is followed in turn by the upper bench of coal, ranging from 1 to 3 feet in thickness. The coal is usually covered by 1 to 2 feet of dark-colored shale, which forms the roof of the mine. Above the shale there are in many places impure coaly layers interbedded with brown and black sandy leaf-bearing shales having a thickness of several feet. The next member in ascending order is a gray, massive sandstone ranging in thickness from 20 to 60 feet. In the outer portion of the basin the base of this sandstone forms in places the roof of the mine. A section representative of the coal bed in this locality is given below:

Representative section of coal bed in Sage Creek basin.

	Ft.	in.
Coal	2	
Bone		4
Coal	1	2
Coal, bony	1	
Coal	2	
	6	6

DEVELOPMENT.

The coals of the Sage Creek basin have not been extensively developed. Coal has been mined in this vicinity for many years, but owing to the lack of transportation facilities the output has never exceeded an amount necessary to supply a small local demand. At the present time the Billings and Northern Railroad Company is building a road through this district, which will afford an outlet for the coal. Already a number of diamond-drill prospect holes have been bored along Sage Creek and its tributaries in order to ascertain the northern and eastern limits of the coal bed, and while the present investigation was being conducted plans were being made to continue diamond-drill prospecting in the vicinity. At the present time only three small mines, owned by Messrs. Schultz, Seman, and Hughes, are being worked. The Schultz and Seman mines are located near together on the west side of Spring Draw, in sec. 20, T. 15 N., R. 12 E. The annual output of the former is about 1,000 tons; that of the latter is somewhat smaller. Neither of these mines is well equipped. The Hughes mine has only recently been opened. Besides the above-mentioned mines there are four abandoned mines, known as the Fisher, Sage Creek Sheep Company, Corwin, and McGregor. The locations of the mines and prospects are shown on Pl. X (p. 162).

QUALITY OF COAL.

During the investigation of the coal resources of this field a number of samples were taken of the coal in different localities for the purpose of chemical analysis. These samples were collected in a uniform manner and in compliance with specifications issued by the fuel-testing plant of the United States Geological Survey. A channel was cut perpendicularly across the face of the coal bed from roof to floor of such a size as to yield at least 5 pounds of coal per foot of thickness of coal bed. All material encountered in this cut was included in the sample, except partings more than three-eighths of an inch thick and lenses or concretions of sulphur or other impurities greater than 2 inches in diameter. The coal thus obtained was pulverized sufficiently to pass through a sieve of $\frac{1}{2}$-inch mesh, and after thorough mixing was divided into quarters, opposite quarters being rejected. This process was continued until the amount was reduced to about a quart sample. The material was then placed in a galvanized can, sealed by adhesive tape, and shipped to the chemical laboratory at St. Louis for analysis. The following table gives the result of these analyses:

Analyses of coal samples from Great Falls coal field, Montana.

[F. M. Stanton, analyst.]

	Sage Creek basin.		Otter Creek basin.		Sand Coulee basin. Belt district.			
Laboratory No.	3756.	3753.	3758.	3759.	3757.	3515.	3512.	3514.
Analysis of sample as received:								
Prox. Moisture	11.26	9.27	10.18	8.76	13.07	3.51	7.05	6.37
Prox. Volatile matter	25.85	29.57	24.82	25.72	21.79	26.39	25.47	27.55
Prox. Fixed carbon	46.49	45.90	45.25	50.36	43.26	50.60	49.34	45.20
Prox. Ash	16.40	15.26	19.75	15.16	21.88	19.50	18.14	20.88
Ult. Sulphur	4.56	3.96	3.01	3.91	1.30	3.74	1.67	2.04
Ult. Hydrogen	4.51	4.78	.....	4.40	4.23	4.13	4.36	3.92
Ult. Carbon	53.47	58.13	.....	58.93	49.35	61.51	58.10	56.14
Ult. Nitrogen	.69	.79	.....	.79	.69	.68	.64	.73
Ult. Oxygen	20.37	17.08	.....	16.81	21.95	10.44	17.09	16.29
Calorific value determined:								
Calories	5,122	5,675	.....	5,626	4,639	6,045	5,623	5,481
British thermal units	9,220	10,215	.....	10,127	8,350	10,881	10,121	9,866
Loss of moisture on air drying	5.50	4.60	4.60	4.80	6.00	1.60	2.60	2.70
Analysis of air-dried sample:								
Prox. Moisture	6.09	5.00	5.85	4.16	7.52	1.93	4.57	3.77
Prox. Volatile matter	27.35	31.00	26.01	27.02	23.18	26.81	26.15	28.30
Prox. Fixed carbon	49.18	48.00	47.43	52.90	46.02	51.44	50.65	46.46
Prox. Ash	17.38	16.00	20.71	15.92	23.28	19.82	18.63	21.47
Ult. Sulphur	4.82	4.15	3.15	4.11	1.38	3.80	1.71	2.08
Ult. Hydrogen	4.12	4.48	.....	4.03	3.79	4.02	4.17	3.73
Ult. Carbon	56.57	60.93	.....	61.90	53.14	62.51	59.65	57.70
Ult. Nitrogen	.73	.83	.....	.83	.73	.69	.65	.74
Ult. Oxygen	16.38	13.61	.....	13.21	17.68	9.16	15.19	14.28
Calorific value determined:								
Calories	5,420	5,949	.....	5,910	4,951	6,094	5,824	5,633
British thermal units	9,756	10,707	.....	10,637	8,888	11,058	10,391	10,139

	Sand Coulee basin. Belt district.			Stockett-Sand Coulee district.	Smith River district.			
Laboratory No.	3755.	3513.	3754.	4115.	4119.	4118.	4117.	4114.
Analysis of sample as received:								
Prox. Moisture	9.58	4.62	10.88	6.01	7.49	4.82	6.17	4.54
Prox. Volatile matter	23.24	30.51	20.27	28.43	27.29	27.17	27.03	27.44
Prox. Fixed carbon	52.24	46.14	41.97	51.42	51.44	46.13	52.03	47.95
Prox. Ash	14.94	18.73	26.88	14.14	13.78	21.88	14.77	20.07
Ult. Sulphur	2.00	3.59	1.79	2.38	2.32	2.84	4.36	4.09
Ult. Hydrogen	4.28	.....	3.72	4.46	4.68	4.36	4.43	4.23
Ult. Carbon	58.74	.....	47.37	63.61	62.21	56.98	61.62	58.66
Ult. Nitrogen	.67	.....	.52	.91	.88	.72	.93	.87
Ult. Oxygen	19.37	.....	19.72	14.50	16.13	13.22	13.89	12.08
Calorific value determined:								
Calories	5,518	.....	4,301	6,196	6,115	5,578	6,077	5,818
British thermal units	9,932	.....	7,742	11,153	11,007	10,040	10,939	10,472
Loss of moisture on air drying	5.00	2.10	5.40	2.40	2.60	1.90	2.20	1.70
Analysis of air-dried sample:								
Prox. Moisture	4.82	2.57	5.76	3.70	5.02	2.98	4.06	2.89
Prox. Volatile matter	24.46	31.17	21.42	29.13	28.02	27.69	2.763	27.91
Prox. Fixed carbon	55.00	47.13	44.42	52.68	52.81	47.03	53.20	48.79
Prox. Ash	15.72	19.13	28.40	14.49	14.15	22.30	15.11	20.41
Ult. Sulphur	2.10	3.70	1.89	2.43	2.38	2.90	4.46	4.13
Ult. Hydrogen	3.91	.....	3.30	4.33	4.51	4.24	4.25	4.18
Ult. Carbon	61.85	.....	50.08	65.17	63.88	58.08	63.02	59.66
Ult. Nitrogen	.70	.....	.55	.92	.89	.73	.95	.88
Ult. Oxygen	15.72	.....	15.78	12.66	14.19	11.75	12.21	10.74
Calorific value determined:								
Calories	5,808	.....	4,546	6,348	6,278	5,678	6,213	5,918
British thermal units	10,454	.....	8,184	11,427	11,300	10,244	11,185	10,654

These analyses show that the coals of the Great Falls region are to be regarded as medium grade bituminous. They contain on an average about 49 per cent of fixed carbon, 26 per cent of volatile matter,

18 per cent of ash, and 3 per cent of sulphur. The sulphur occurs largely in the form of iron-pyrite nodules which, together with other impurities, are present in such abundance as to render it necessary to wash the coal before placing it on the market. The sulphur nodules, after being separated from bone, shale, and other impurities, are sold as a by-product to the large smelters at Anaconda, Mont., where they are utilized in the process of pyritic smelting.

FUTURE DEVELOPMENT OF THE GREAT FALLS COAL FIELD.

The Great Falls coal field, owing to its geographic position and relation to other coal fields, is destined to remain one of the most important coal-mining districts of Montana. The territory which this field may be expected to supply with coal in the future lies mainly to the north and northwest. To the southeast there are a number of coal localities along Musselshell River which, with the development of proper railroad facilities, would probably become large coal-producing districts. Throughout the area bordering the Great Falls coal field on the north different conditions prevail. Here, although coal-bearing rocks occupy extensive areas both to the northeast in the vicinity of Havre and to the northwest along the base of the Rocky Mountain front range, yet from the best information obtainable the territory underlain by coal of workable thickness is not large and the quality is poor, so that much of this part of Montana must necessarily be supplied with coal from the Great Falls field. The Lethbridge field, located north of the international boundary line, is a large coal-producing district, but, as a result of the increased settlement of this part of the British possessions and the duty of 60 cents per ton, much of the output of this field will probably be consumed in Canadian territory, leaving a relatively small amount to be shipped into Montana.

Less than 10 miles from the northern edge of the Sand Coulee basin is located the town of Great Falls, a thriving business center, which has a population of about 18,000. None of its railroad lines are transcontinental, but it is situated on a very important branch connecting the main lines of the Great Northern and Northern Pacific. Railroads extend in four different directions from Great Falls—one southwestward to Helena and Butte; another northeastward to Havre, a small town on the main line of the Great Northern; the Montana and Great Northern northwestward to Shelby Junction; and the Neihart branch of the same road connecting Great Falls with Neihart. The last named is connected by a short branch road leaving it at Gerber station with Stockett and Sand Coulee, two of the larger coal-mining camps of the Sand Coulee basin. In addition to these roads the

Burlington extension from Billings to Great Falls is now under construction. This line will cross the northern edge of the Sage Creek and Otter Creek basins, thus affording shipping facilities for these two undeveloped coal areas. Preliminary surveys have also been made into Great Falls from the south, following Smith River downstream and passing through one of the most promising undeveloped portions of the field.

Another factor to be considered in the general development of this region is the unharnessed water power contained in the falls of Missouri River, located a few miles below the town of Great Falls. At present the Black Eagle Falls, one of the smallest of this series of cataracts and the only one which has been utilized, furnishes power for the large smelters owned by the Boston and Montana Company's flour mills, the city electric-lighting plant, and other minor industries. With the proper utilization of the Rainbow, Crooked, and Big falls, located farther down the river, sufficient power could be generated to supply many more large industrial enterprises. The presence of so large an amount of undeveloped water power within a relatively short distance of the large mining centers Butte and Anaconda makes Great Falls a favorable site for smelting plants.

The Great Falls region was formerly a grazing district and sparsely populated. Small tracts of land were irrigated here and there along the valleys, but with the growth in population and the increased demand for agricultural produce irrigation began to be more generally practiced along the larger streams, resulting eventually in the construction of several large canals by private individuals or small companies organized among the ranchmen. Extensive operations are now being carried on, both by the Government and by private enterprise, to reclaim larger tracts of land along Sun and Teton rivers and the highland lying between these two streams.

Although the Great Falls district is at present not very thickly settled, it is believed that the increasing railroad facilities, the completion of the Government irrigation projects, which will reclaim thousands of acres of fertile farming land, and the almost unparalleled advantages for the development of water power will cause the population to increase rapidly within the next decade. This increase will be attended by an increased demand for coal, both for domestic and steam purposes.

COALS OF CARBON COUNTY, MONT.

By N. H. Darton.

INTRODUCTION.

The area treated in this report comprises about two-thirds of Carbon County, Mont. It lies mainly in the central portion of the county, in and adjoining the valleys of Clark Fork and Rock Creek. The report sets forth the results of examinations made in the autumn of 1906 with a view of determining the extent of the workable coal beds and the structure and stratigraphic relations of the coal-bearing rocks. Previous reports on the coal of the region have consisted of some preliminary notes on the Red Lodge-Bridger mines by Wolff,[a] Weed,[b] Eldridge,[c] and Rowe,[d] and a brief notice of the Bear Creek field published by C. A. Fisher[e] in 1906.

GEOGRAPHY.

The portion of Carbon County treated in this report consists mainly of a hilly country lying between the western slope of Pryor Mountain and the northern side of the Beartooth Mountains. It is traversed from south to north by Clark Fork, a large stream which flows into Yellowstone River. The stream next in size is Rock Creek, which rises in the Beartooth Mountains and empties into Clark Fork northeast of Joliet. Clark Fork flows in a wide valley, into which enter numerous side valleys draining the ridges and plateaus on either side. In this valley are situated three villages of moderate size—Bridger, Fromberg, and Belfry—which are connected by railroad with the Northern Pacific system at Laurel. Rock Creek emerges from a mountain gorge 3 miles above Red Lodge and flows northward in a shallow valley, in which there is another branch of the Northern Pacific. This branch terminates at Red Lodge, a town of about 2,200 inhabitants, sustained largely by the extensive coal-mining operations. Joliet, a small but rapidly growing village, is also situated on Rock Creek.

[a] Wolff, J. E., Rock Creek coal field: Tenth Census, Rept. on Mining, 1875.
[b] Weed, W. H., Coal fields of Montana: Eng. and Min. Jour., vol. 53, 1892, p. 520.
[c] Eldridge, G. H., Bull. U. S. Geol. Survey No. 119, 1894, p. 53.
[d] Rowe, J. P., Montana coal and lignite deposits, Missoula, Mont., 1906.
[e] Bull. U. S. Geol. Survey No. 285, 1906, pp. 269–270.

On the map (Pl. XI) are shown the principal geographic features of the region, including the topography, which is represented by contours with intervals of 200 feet. The map is drawn largely from land-office plats, with various additions and modifications, many of which were obtained from the county map prepared by F. W. Hines. The topography is based mostly on barometric readings connected with points of known elevation at the various railroad stations and with the level line run by the United States Geological Survey from Red Lodge southward. This map will be found much more exact for the areas of coal, where many section corners were located, than for the adjoining region, where no attempt was made to do more than outline the topography.

The most notable topographic features are the deep, wide valley of Clark Fork; the elevated valley of Rock Creek, with its bordering terraces; the western slopes of the Pryor Mountain uplift east of Bridger, and the prominent ridge of limestone and granites on the flank of the Beartooth Mountains south of Red Lodge.

GEOLOGY.

SEDIMENTARY ROCKS.

GENERAL RELATIONS.

The sedimentary rocks outcropping in Carbon County comprise an extensive series of deposits from the pre-Cambrian granites and schists to the Fort Union formation. There is, in general, a regular succession from the "Red Beds" on the flank of Pryor Mountain uplift east of Bridger to the sandstones and shales overlying the uppermost coal measures south of Red Lodge, all having a nearly continuous dip to the southwest. On the northeast side of the high ridge south of Red Lodge these strata are cut off by a profound fault, along which Carboniferous limestone and underlying formations are uplifted with nearly vertical dips. The general stratigraphic succession in the coal-bearing and associated rocks of the area is as follows:

Coal-bearing and associated formations in Carbon County, Mont.

Period.	Formation.	Thickness.	Characteristics.
		Feet.	
Tertiary.....	Upper barren rocks.....	3,000	Soft massive sandstones and sandy shales.
Do.....	Bear Creek–Red Lodge coal-bearing rocks.	100–700	Sandstones and shales with several coal beds.
(?)	Lower barren rocks.....	6,000–7,000	Sandy shales and soft sandstones with a few thin coal beds.
(?)	Bridger coal bed.....	3–6	Coal with bone and shale parting.
Cretaceous.....	Montana shale.....	2,200+	Mostly dark-gray shale capped by massive buff sandstone.
Do.....	Colorado shale.....	1,200	Gray shale with thin hard sandstone near top.
Do.....	Cloverly sandstone.....	150	Sandstone and conglomerate with purple and gray clay member near top.

CRETACEOUS SYSTEM.

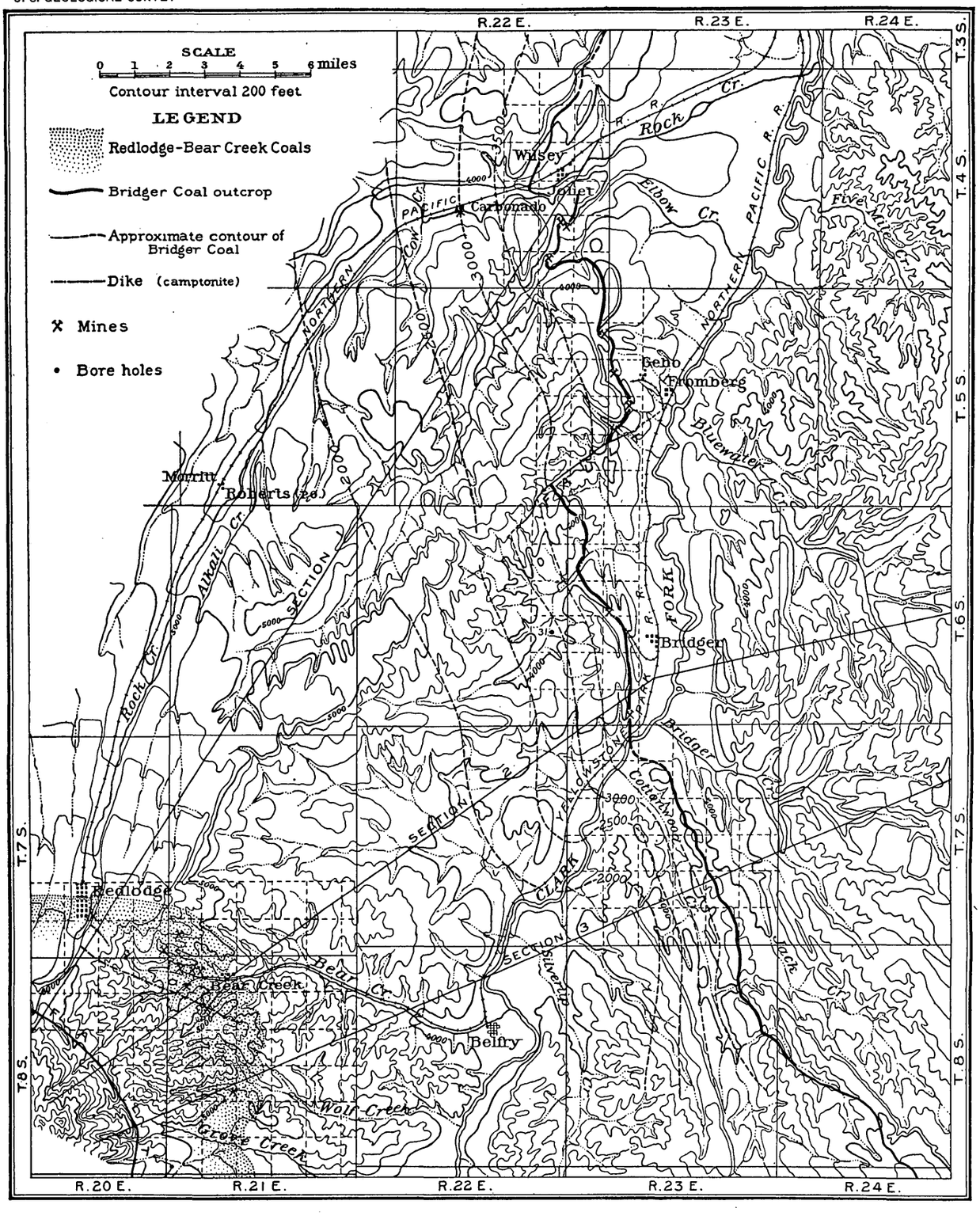
The Cretaceous system is represented in Carbon County by more than 10,000 feet of sedimentary rocks, of which only a small portion near the base are believed to be Lower Cretaceous. The upper limit of the system could not be ascertained and probably a large part of the upper beds in the basin, as well as the Red Lodge–Bear Creek coal-bearing rocks, are of Fort Union (early Eocene) age.

CLOVERLY FORMATION.

The Cloverly formation, consisting mainly of coarse, hard sandstones, outcrops on the slope of the Pryor Mountain uplift in Range 24. Its thickness ranges from 100 to 150 feet and owing to its hardness it gives rise to ridges of considerable prominence through which the streams have cut canyons with precipitous walls. The formation consists of three members. Its lower half is a coarse, massive, hard sandstone, in part conglomerate, especially toward the base. Next above are 50 feet or more of soft shale or clay, of gray and purplish tints, with thin sandstone beds included. At the top are a few feet of gray to buff slabby sandstones, usually weathering to a brownish color. The two lower members are believed to represent the Lakota and Fuson formations of the Black Hills, which are of Lower Cretaceous age, and the upper member to represent the Dakota sandstone or the Kootenai of Canada.

COLORADO FORMATION.

The Cloverly formation is overlain by 1,200 feet or more of gray shale, which outcrops in a wide belt of ridges east of Clark Fork and Jack Creek. These rocks dip gently westward. At the base are about 400 feet of soft shale of dark color; this is succeeded by 150 feet of harder shale, with thin beds of dark-colored, fine-grained sandstone that in the Bighorn uplift is known as the Mowry beds. This member gives rise to ridges of considerable prominence, many of them bearing a few scattered pine trees. It weathers to a light-gray color, and contains large numbers of fish scales, all of which are characteristic features. The Mowry beds are overlain by several hundred feet of light-gray shale with a few thin sandstone layers. This shale is capped by a very characteristic sandstone member, 20 to 50 feet thick, which forms a small but prominent ridge extending along the east side of the valley of Clark Fork to Bridger Creek and thence southeastward along the east side of the valley of Jack Creek. It is a gray, hard sandstone of moderately fine grain, ranging from massive to slabby in bedding. It undoubtedly represents a horizon which is persistent throughout Wyoming and eastern Colorado at or near the top of the Carlile formation, the uppermost member of the



MAP AND SECTIONS OF COAL BASIN IN CARBON COUNTY, MONT.

G, Granite and schist; D, Deadwood formation; C, Carboniferous limestone; T, Tensleep sandstones; M, Morrison and Sundance formations; Cl, Cloverly sandstone; N, Upper sandstone of the Colorado; S, Sandstone in the Montana, under Bridger coal; B, Bear Creek-Redlodge coal measures.

Benton group. Here and there in the shale a short distance below it occur concretions which contain remains of *Prionocyclus woolgari*, a fossil which also is characteristic of this upper Benton horizon. The sandstone is overlain by shale which appears to merge upward into the shale of the overlying Montana formation (Pierre). As there is no evidence of a break in the stratigraphic succession, probably there exists here a representative of the Niobrara formation, but owing to the lack of fossils and also of the distinctive limy deposits which characterize this formation in other regions, it is not distinguishable in Carbon County. Accordingly, no definite boundary can be drawn between the Colorado and Montana formations.

MONTANA FORMATION.

The wide valley of Clark Fork below the mouth of Bridger Creek is occupied by soft gray shale of the Montana formation, and the outcrop zone of this shale also extends southeastward up the valley of Jack Creek. The shale is 2,000 or more feet thick and is overlain by 200 feet of sandy shale and thin-bedded sandstone, merging upward into a massive sandstone 50 to 60 feet thick, which is tentatively regarded as the top of the formation. This sandstone constitutes a line of ridges and bluffs of moderate prominence in the slopes west of Bridger and Fromberg, north and south of Joliet, and along the south side of Jack Creek valley. It is buff to gray in color, massively bedded, and of moderate hardness. A few fossils were found in the shale, but no organic remains were observed in the sandstone.

On Cottonwood Creek the upper beds of the formation comprise 30 feet of massive sandstone lying upon 100 feet of sandy shale and soft sandstone, 10 feet of harder sandstone, and 50 feet of soft sandstone and sandy shale with sandstone concretions. These rest upon 1,600 feet or more of the shale which underlies Jack Creek valley.

BRIDGER COAL BED.

Overlying the Montana sandstone are a few feet of sandy shale and sandstone containing the Bridger coal bed. The outcrop of this bed extends along the valley or shelf just west of the ridge of Montana sandstone. It passes a short distance west of Bridger, Fromberg, and Joliet, and extends along the ridge lying between Jack and Cottonwood creeks. The coal rarely appears at the surface, but it is opened at a number of mines at intervals through Tps. 4 to 8. The thickness of the coal bed from the vicinity of Bridger to Joliet ranges from 3 feet to 5 feet 8 inches. In the ridge between Jack and Cottonwood creeks the coal rapidly diminishes in thickness, and in an old mine in the northeast corner of T. 8 S., R. 23 E., it is, as reported,

only about 2 feet thick. To the north from Joliet also the coal thins rapidly, but owing to lack of exposures the thickness could not be ascertained. How far westward the Bridger coal extends is not known; to judge by the length of the deposit north and south, however, it may underlie a wide area west of the outcrop zone. The Bridger mine has been worked westward for more than half a mile and the coal shows no signs of diminution in thickness in that distance. In a diamond-drill hole sunk in the center of sec. 24, T. 6 S., R. 22 E., the coaly deposits were entered at a depth of 860 feet and continued to a depth of 980 feet. The log of the boring is as follows:

Log of diamond-drill boring in center of sec. 24, T. 6 S., R. 22 E.

	Ft.	in.
Sand and gravel	23	
Clay, hard	8	
Sandstone and soapstone	43	
Sandstone	14	
Sandstone and soapstone	77	
Sandstone	67	
Sandstone and soapstone	141	
Sandstone	63	
Sandstone and soapstone	76	
Soapstone, part coaly	9	4
Sand and soapstone	6	
Shale, coaly		8
Sandstone, coarse	58	
Sandstone, fine	20	6
Sandstone and soapstone	219	
Sandstone, fine	35	
Shale, in part coaly	18	
Shale, coaly	2	3
Sand, fine	6	9
Soapstone, with 10 inches coaly shale near base	13	
Soapstone, with thin coal and coaly shale	10	
Sandstone	17	
Shale, with thin curly bands	13	8
Soapstone, with 4 feet of sandstone	14	6
Coal	1	8
Sandstone and soapstone	24	
Sandstone, black	7	
Shale, coaly	1	2
Soapstone		6
Coal	1	11
Soapstone	3	
Sandstone	158	6
Soapstone, black	69	
Shale, light brown	4	
Soapstone, black	18	2
Conglomerate?	50	
	1,294	7

A shaft recently sunk at the foot of the sandstone bluff a short distance west of the tipple of the Bridger mine afforded the following section of Bridger coals and associated strata:

Section at Bridger shaft.

	Ft.	in.
Sand	12	
Rock, gray	57	9
Soapstone	6	
Coal	2	
Rock, white		2
Coal		4
Bone		8
Coal		4
Bone	1	10
Coal		6
Bone		4
Coal		11
Soapstone	7	
Coal	1	
Soapstone	2	
Rock, black	4	7
Coal		11
Bone		2
Soapstone		9
Sandstone	5	
Ironstone		8
Soapstone	8	8
Coal		8
Sandstone		2
Coal		2
Soapstone	3	9
Sandstone	2	6
Sandstone	12+	
	130	10

No evidence was obtained as to the age of the Bridger coal, and it may be either Montana or early Laramie.

LOWER BARREN MEASURES.

A wide area lying west of the outcrop of the Bridger coal is occupied by a succession of sandstones and sandy shales several thousand feet thick. These rocks are believed to be, in part, at least, of Laramie age, and they have the features generally associated with that formation. They consist of many extensive bodies of sandstone of gray to buff color, separated by deposits of clay and shale, some of which are carbonaceous and carry thin beds of coal. At the base of the formation, overlying the Bridger coal, is a thick mass of sandstone of considerable hardness, which gives rise to a prominent bluff or ridge. This bluff is especially conspicuous west of Joliet, Fromberg,

and Bridger, and along the divide between Jack and Cottonwood creeks. The sandstone is at least 300 feet thick, including some beds of sandy shale which occur at intervals. The succession is somewhat irregular. At Bridger the coal is overlain by a few feet of sandstone and shale merging upward into 100 feet of gray shale and thin sandstone, over which lies a thick body of sandstone constituting the high ridge. The bore hole that is described on page 179 passes through these beds, but owing to the expression "sandstone and soapstone" used by the driller the character of the rocks is not clear. On Cottonwood Creek the Bridger coal is overlain by 200 feet of heavily bedded, hard, buff sandstone. This is followed by several hundred feet of shales and sandstones, giving place above to a thick mass of hard sandstone which constitutes the high ridge east of Cottonwood Creek. Next above are shales, clays, and thinner-bedded sandstones, followed in turn by another thick sandstone series, which is prominent in high ridges in the center of R. 22, Tps. 5 and 6, and the center of R. 23, T. 8. This sandstone series is followed by a succession of sandstones and shales which extend to the base of the Red Lodge–Bear Creek coal-bearing rocks. The total thickness of the lower barren measures, as approximately determined on several cross-section lines, is at least 5,000 feet, and apparently it approaches 7,000 feet. The dips, however, are low, and the details of stratigraphy are not marked, so that it is difficult to ascertain the thickness precisely. Thin coal beds occur in this formation, but 2 feet appears to be the maximum thickness, and the deposits are not extensive. A 2-foot coal bed has been worked to a small extent in an opening $2\frac{3}{4}$ miles north of Red Lodge and on the bank of Clark Fork just below the mouth of Dillworth Creek. The latter locality is south of the area shown on the map. Some fossils obtained in the upper beds on Wolf Creek have been determined by T. W. Stanton as follows: *Physa* sp., *Hydrobia* sp., *Viviparus trochiformis* M. and H.?, and *Thaumastus limnæiformis* M. and H.? These are from beds about 600 feet below the top. From higher beds a very short distance below the coal-bearing rocks just east of Bear Creek the following forms were obtained: *Unio priscus* M. and H.?, *Viviparus raynoldsanus* M. and H.?, *Bulinus* sp. and *Goniobasis tenuicarinata* M. and H. Mr. Stanton states that both lots of fossils are suggestive of the Fort Union formation rather than the Laramie, although some of these, as well as other similar species, occur in the Laramie also.

RED LODGE-BEAR CREEK COAL-BEARING ROCKS AND OVERLYING BEDS.

The highest strata in the Carbon County basin consist of 2,000 feet or more of sandstones and shales containing in the lower 600 feet a local development of thick coal beds. Except for the coal the rocks

are similar to those of the barren beds which lie conformably beneath them. They consist largely of sandstones, gray to pale buff in color, and harder in the coal-bearing portion than in the upper part of the series. Shales and clays are interbedded at intervals in bodies from a few inches to 50 feet or more in thickness and they usually contain thin-bedded sandstones. The stratigraphy is variable, and probably there would be great difficulty in tracing individual beds from place to place.

The principal deposits are contained in about 700 feet of strata at Red Lodge, which comprise eleven workable coal beds, as shown by the following section:

Section of coal-bearing beds at Red Lodge.

	Ft.	in.
Slate	4	
Sandstone	10	
Slate	2	
Sandstone	20	
Slate, including 3 inches of bone	14	3
Sandstone	6	
Slate, including 3 inches of bone	18	3
Sandstone	8	
Slate, black	6	
Coal, bed No. 1	11	7
Sandstone	90	3
Shale	3	
Coal, bed No. 1½	4	6
Slate and shale	3	6
Sandstone	18	
Shale	11	
Sandstone	25	
Shale	2	1
Sandstone, gray	6	
Shale	3	
Coal, bed No. 2	6	10
Slate	5	2
Shale, sandy	5	6
Slate	10	
Sandstone	38	7
Slate and sandstone, including 6 inches of bone	8	4
Coal, bed No. 3	11	2
Slate, black	1	
Shale, sandy	20	
Slate, black	4	
Slate, gray	10	
Sandstone	60	
Shale, sandy	19	
Shale, black	1	
Coal, bed No. 4	11	8
Shale	2	6
Sandstone	13	
Shale		2

	Ft.	in.
Shale, sandy	17	
Coal, bed No. 4½	5	4
Slate		1½
Sandstone	40	
Slate, black	2	6
Sandstone	16	
Coal and slate		5
Slate with black dirt	4	6
Coal, bed No. 5	12	4
Shale	12	
Coal, bed No. 6	5	6
Sandstone, slate, and bone	14	
Coal, bed No. 7	2	2
Slate and sandstone	9	
Slate, black	5	
Sandstone	24	6
Slate, blue	10	
Sandstone, gray	6	
Coal, bed No. 8	25	2
Clay	1	
Sandstone, gray	15	
Slate, blue	25	
Bone, dirt, and clay	1	4
Shale, blue	24	
Coal, bed No. 9	11	10
Shale, sandy	4	6
Sandstone	10	
Slate, sandstone, and clay	3	6
Bone		6
	802	6½

The stratigraphy about Red Lodge is well illustrated by the records of diamond-drill borings that have been made in this vicinity. The following section represents a bore hole that was put down in the northern part of Red Lodge, beginning at or near the base of the coal-bearing beds:

Record of bore hole at Red Lodge, in the SW. ¼ NE. ¼ SE. ¼ sec. 27.

	Ft.	in.
Surface	12	
Shale	88	
Bone and coal	2	
Shale	133	
Sandstone	15	
Bone and coal		6
Shale	7	6
Sandstone	40	
Shale	20	
Bone and coal	2	
Shale	30	

	Ft.	in.
Sandstone	18	
Shale	29	
Coal, dirty	10	
Shale	10	
Coal, dirty	1	
Sandstone	25	
Coal, dirty	2	
Shale	55	
Bone and coal	1	
Shale	4	
Sandstone	18	
Coal and bone	10	
Shale	12	
Shale	34	
Coal, dirty	6	
Shale	62	
	647	

As stated on page 180, coal occurs lower down, for there is a small mine on a 2-foot bed $2\frac{3}{4}$ miles below Red Lodge station, on the west side of Rock Creek, and other thin beds are reported in the interval. The beds dip to the south at angles of 12° to 18° in this portion of the valley, so that several thousand feet of beds appear in a few miles.

The following section represents the strata passed through by a bore hole in the southeastern part of Red Lodge. The rocks penetrated lie in greater part, if not entirely, above coal bed No. 1 of the Red Lodge mines.

Record of bore hole in the SE. ¼ SW. ¼ NE. ¼ sec. 34.

	Ft.	in.
Surface	51	
Shale	118	
Bone and coal		6
Shale	108	6
Sandstone	10	
Shale	42	
Sandstone	10	
Shale	22	
Sandstone	8	
Shale	106	
Sandstone	12	
Shale	109	
Sandstone	18	
Bone and coal	1	
Shale	24	
Sandstone	25	
	665	

The next bore hole begins still farther up in the series overlying the Red Lodge coal beds, but penetrates the underlying coal-bearing

rocks. It is difficult, however, to recognize the individual beds in this record:

Record of bore hole in the SE. ¼ SE. ¼ SE. ¼ sec. 35.

	Ft.	in.
Surface	47	
Sandstone and shale	126	
Shale, hard	42	
Coal and bone	1	
Shale	4	
Sandstone	60	
Coal	1	6
Shale	3	6
Sandstone	14	
Coal, dirty	4	
Sandstone	12	
Shale	45	
Sandstone	44	
Coal, dirty	8	
Sandstone	53	
Coal and bone	1	6
Shale	101	6
Coal and bone	10	
Shale	99	
Coal, good	8	
Sandstone	5	
Shale	28	
Coal, good	3	
Shale	2	
Sandstone and shale	109	
Shale	7	
Coal	1	
Shale	3	
Coal, dirty	2	
Shale	5	
Coal, dirty	5	
Sandstone	5	
Shale	29	
Coal, dirty	5	
Shale	16	
Sandstone	28	
Shale	23	
Coal		6
Sandstone	1	6
Bone and coal	2	
Shale	5	
Sandstone and shale	68	
Coal		6
Sandstone	3	6
Shale	22	
Sandstone	11	
Shale	6	
Coal and shale	4	
Shale	55	
	1,140	

The coal measures of Red Lodge strike nearly due east across the divide lying between the head of Rock Creek and the northerly forks of Bear Creek. They are thickly covered by gravel on this wide, flat-topped divide, but appear again extensively in the Bear Creek basin. There is some variation in thickness and succession of the coal and inclosing beds, but the salient features persist for some distance. The dip decreases to 5° and less and its direction gradually changes more to the west. The succession in the vicinity of the Bear Creek mines is shown in the following section:

Section of coal measures on Bear Creek.

	Ft.	in.
Coal, No. 1, clean	6	
Sandstone with thin coal beds and fire clay	141	
Coal, No. 2, clean	6	6
Sandstone, mostly coarse	102	
Shale	6	
Coal	8	5
Fire clay, No. 3		10
Coal	2	
Sandstone, very hard	45	
Coal	2	2
Clay, No. 4		2
Coal	2	2
Clay	75	
Coal, No. 5, clean	4	6
Sandstone	40	
Coal, No. 6, clean	4	
Sandstone	80	
Coal, No. 7, clean	10	
Sandstone and shale	70	
Coal, No. 8, clean	5	
	610	9

The coal-bearing formation has a thickness of about 600 feet, in which there are about 50 feet of coal. There are eight principal beds, but above and below these are additional thin beds which have no value at the present time.

The coal beds are exposed at various places near the town of Bear Creek and present but little variation in their character and relations. To the south, however, they rapidly become thinner and more impure, so that in the vicinity of Grove Creek, where they pass under a thick mantle of alluvial wash, they are few in number and of greatly diminished thickness. In the next township south they are too thin to be workable under present conditions. In Foster Gulch, a mile and a half southwest of Bear Creek post-office, bed No. 3 is 8 feet thick, and consists entirely of clean coal of fine quality.

Fossils occur very abundantly in the roof of No. 3 coal bed in the Bear Creek mines. They comprise the following species, determined by Mr. Stanton: *Unio priscus* M. and H.?, *Sphærium formosum* M. and

H.?, and *Goniobasis tenuicarinata* M. and H. These forms suggest that the strata may be of Fort Union age, but they do not afford conclusive evidence. J. P. Rowe has obtained fossil leaves from sandstones separating the coal beds in the Red Lodge field, which he states are of Fort Union age.[a]

IGNEOUS ROCKS.

The coal-bearing rocks in the Red Lodge–Bear Creek field are traversed by several dikes of dark-colored igneous rock occupying vertical fissures. They average a foot in thickness and extend west-northwestward, rudely parallel to the course of the great fault which brings up the Madison limestone 2 to 3 miles farther southwest. Their contact relations are clearly exposed at some points, and they appear to have caused but little alteration in the sandstones and shales which they traverse. Their influence on the coal was not ascertained, but presumably they harden it and decrease the amount of volatile constituents for a short distance. On microscopic examination by Albert Johannsen the rock was found to be a camptonite, consisting of augite crystals in a groundmass of plagioclase, magnetite grains, and some apatite. It is of medium dark-green color and has a mottled appearance, due to the small scattered prismatic black crystals of augite, rarely 1 mm. in length, in an aphanitic decomposed groundmass. This groundmass consists of 50 per cent of minute crystals of augite, generally in laths and usually altered, 5 per cent of magnetite, and a small amount of apatite scattered in an aggregate of plagioclase. The minerals are greatly altered, some of the augite being changed to greenish-yellow serpentine.

STRUCTURE.

The coal field treated in this report is a monocline extending southwestward from the western slope of the Pryor Mountain uplift. On the southwest it is cut off by a fault having a throw of many thousand feet, which brings to the surface granite and some overlying Paleozoic rocks that constitute the Beartooth Mountains. In the eastern part of the area the dips are relatively steep, averaging 10°, but to the west and southwest they diminish to less than half that amount, and in some areas the strata are horizontal. A local anticline appears on Rock Creek, near Roberts, and extends some distance southeastward, as shown in section 1 on the map. In the coal mines west of Bridger the dip is approximately 6°; west of Fromberg and near Joliet it ranges from 4° to 5°. The structure of the Bridger coal is indicated by contour lines on the map. In the region about Belfry very low dips prevail and the strata are nearly horizontal along the lower portions of Wolf and Grove creeks. In the coal mines at Bear Creek the dips are to the southwest at low angles, the amount being 3½° in the

[a] Montana coal and lignite deposits: Bull. Univ. Montana No. 37, 1906, p. 24.

Bear Creek Company's mine and 9° at the Nelson mine. At the mine in the west-central part of section 8, a mile and a half southwest of Bear Creek, the direction is S. 18° W. and the angle 4°. At Red Lodge the coal beds dip toward the south at an angle of 18° (see section on Pl. XI, p. 176), but farther south this steep dip rapidly diminishes, the structure grading into a very shallow syncline in which the strata are horizontal for some distance and then apparently slightly upturned near the fault at the foot of the mountains. The strata dip at very low angles throughout T. 8 S., R. 20 E., but are not upturned adjacent to the fault except in the immediate vicinity of Rock Creek. North of Red Lodge the steep dips diminish gradually. Two miles north the rocks dip nearly due south at an angle of 12°. Six miles farther north they pass over a gentle anticline and for half a mile dip northward at an angle of 10°. Near Roberts they are horizontal, and farther northeast they are inclined at low angles to the southwest.

Faults are rare and only two were observed in addition to the great fault south of Red Lodge. One traverses the Bridger coal bed and adjoining strata southwest of Fromberg. It trends northeast and southwest and has a downthrow of several hundred feet on the north side. This causes an offset of nearly a mile and a half in the outcrop of the coal bed in the southeast corner of T. 5 S., R. 22 E.

COAL RESOURCES.

RED LODGE.

The mine at Red Lodge is owned by the Northwestern Improvement Company. It is in the bluff on the east side of Rock Creek in the eastern portion of the village. The first developments were made in 1887, three years after coal was discovered. The original operations were small, but in 1889 they had increased to 6,000 tons a year. There are ten coal beds at this place, and their aggregate workable thickness is about 85 feet, including thin partings in some of the beds. The sections of the principal beds are as follows:

Sections of coal beds at Red Lodge.

COAL BED NO. 1.

Shale.	Ft.	in.
Coal		4
Shale	2	
Bone and coal		7
Coal		6
Bone		4
Coal		4
Shale and coal	1	
Coal	2	6
Bone		4
Coal	3	6
Shale, black		2
Sandstone.		
	11	7

COAL BED NO. 1½.

	Ft.	in.
Coal, with thin parting	1	
Coal and shale		2
Coal	1	
Shale		¼
Coal		8
Bone		¼
Coal		10
Parting, thin		
Coal		4
Shale		½
Coal		5
Shale.		
	4	6

Sections of coal beds at Red Lodge—Continued.

COAL BED NO. 2.

	Ft.	in.
Shale.		
Bone		2
Coal		6
Bone and coal		4
Coal, with thin partings above center	3	4
Shale		3
Coal, with shale parting below center	2	3
Shale.		
	6	10

COAL BED NO. 3.

	Ft.	in.
Bone		6
Shale		3
Bone and coal	1	
Shale		1
Coal		10
Shale		1
Coal	1	4
Shale		1
Coal	1	2
Shale		2
Coal	2	
Shale		6
Coal		10
Shale		1
Coal		3
Shale		4
Coal	1	6
Shale	1	
Sandstone.		
	12	

COAL BED NO. 4.

	Ft.	in.
Shale	1	
Coal, with four thin partings	2	7
Coal and dirt		6
Coal	2	9
Bone		3
Coal		5
Shale		1
Coal, with three thin partings	4	1
Shale.		
	11	8

COAL BED NO. 4½.

	Ft.	in.
Sandstone.		
Coal	2	
Shale		1
Coal		5
Shale		2
Coal, much sulphur		7
"Sulphur"		1
Coal	1	2
Bone		2
Coal		2
Dirt		6
Shale.		
	5	4

COAL BED NO. 5.

	Ft.	in.
Shale.		
Bone		2
Coal	3	4
Shale		1
Coal, with one thin parting	1	10
Dirt		5
Shale		6
Coal	3	
Bone		1
Coal, with two thin partings	2	11
Sandstone.		
	12	4

COAL BED NO. 6.

	Ft.	in.
Sandstone.		
Coal, with two thin partings	5	6
Bone		4
Shale.		
	5	10

COAL BED NO. 8.

	Ft.	in.
Bone		6
Coal		5
Shale		1
Coal		3
Shale		1
Coal, with one thin parting	1	1
Clay	3	6
Coal	1	
Shale		1
Coal	1	
Clay	1	10
Coal, with three thin partings	3	
Bone		1
Coal	1	4
Shale		6
Sandstone	1	4
Coal	3	
Bone		2
Coal	1	
Bone		1
Coal		10
Coal and dirt		5
Coal		4
Shale		1
Coal		6
Clay		4
Coal	2	6
Clay.		
	25	4

COAL BED NO. 9.

	Ft.	in.
Shale, black.		
Coal	1	
Coal and shale		10
Coal		8
Bone		5
Coal	4	
Clay		6
Sandy shale	1	6
Coal, with two 2-inch partings	1	9
Sandy shale.		
	10	8

Beds Nos. 1, 1½, 2, 4, 5, and 6 are worked, but the most extensive operations are in bed 4. One level about half a mile down the slope runs eastward from the main slope more than 7,500 feet and has 110 rooms. There are numerous other levels both east and west. In bed No. 1 there are 10 rooms, in bed No. 1½ 31 rooms, and in bed No. 2 four east and three west levels, but some are not being worked. The mine is worked and lighted by electricity, generated by a plant erected by the company. It has a steel tipple with a capacity of 3,000 tons a day, revolving and shaking screens, picking tables, gravity box-car loader, 8 spiral separators, and a 600-ton Luhrig washer. About 500 miners and 100 outside men are employed. The production in ten months ending October, 1906, was 356,573 short tons in 209 working days.

BEAR CREEK FIELD.

The coal in the Bear Creek field has been known for nearly twenty years, but no mining was done until 1900, when the Montana Fuel and Iron Company opened a small mine and hauled its product to Red Lodge for shipment. The annual production was reported as 6,000 tons, at $3.30 a ton. During the last few years the construction of a railroad to the field has led to the development of several mines, and four companies now have extensive holdings. They are the Bear Creek Coal Company, the Montana Fuel and Iron Company, the Anaconda (Amalgamated) Company, and the Northwestern Improvement Company, the last being the owner of the Red Lodge mine. During 1906 the Yellowstone Park Railroad was completed from Bridger to the Bear Creek mines, so that the coal now has an outlet by way of the branch of the Northern Pacific Railway from Bridger.

The Bear Creek Company controls an area of approximately 10,000 acres. Its mines are in the NE. ¼ sec. 6, T. 8 S., R. 21 E., about a mile west of the new town of Bear Creek. The principal openings are in bed No. 2, having a thickness of 6½ feet, and bed No. 3, which yields about 10 feet of coal. The dip is to the southwest, at an angle of 3½°, and the workings are mostly toward the north, so that the mines drain easily. There is, however, but little water in them. In the autumn of 1906 the main gangway in bed No. 2 was 600 feet long, in bed No. 3, 1,000 feet, and in bed No. 4, 200 feet. The coal is hauled in the mines by electricity, which is generated in a large power house recently erected. It is reported that in September and October, 1906, about 3,000 tons were produced with a force of 75 miners and 8 outside men. With the completion of the tipple that was in course of erection in the latter part of 1906, a large increase in the production was expected.

The mine of the Montana Fuel and Iron Company is in the NW. ¼ sec. 6, half a mile west, or farther up the valley than the mines of the Bear Creek Company. It is on bed No. 2 and its main gangway runs

northward under the hillside. The coal bed is 6½ feet thick, with a 3-inch layer of bone 6 inches below the top. The roof is hard clay shale. A spur of the railroad extends to the mine, which is equipped with a tipple and other facilities for handling the coal. From 25 to 40 men are working in the mine.

A mine has recently been begun on the McCarthy properties on a northern prong of Bear Creek, in the NW. ¼ sec. 31 and the S. ½ sec. 36. The opening is in bed No. 2, which yields 6 feet or more of clean coal.

The following measurements of the coal beds in the Bear Creek mines were made by J. P. Rowe in the summer of 1906:

Sections of coal beds in Bear Creek mines.

COAL BED NO. 3.

Shale.	Ft.	in.
Coal	1	5
Parting, thin.		
Coal	1	4
Bone		2½
Coal	2	7½
Clay		8
Coal	1	7½
Fire clay.		
	7	10½

COAL BED NO. 4.

Sandstone.	Ft.	in.
Coal, dirty		2
Coal	1	9½
Bone		3½
Coal	1	5½
Clay, 4 inches, on sandstone.		
	3	8½

COAL BED NO. 5.

[150 feet in from mouth of entry.]

Clay.	Ft.	in.
Coal	3	5
Clay		7
Coal		10
Clay.		
	4	10

NELSON MINE.

The Nelson mine is a small opening on the south side of Taggart Gulch, in the SE. ¼ sec. 20, T. 8 S., R. 21 E., 3 miles south of Bear Creek. It is worked entirely by hand, and furnishes a small but steady product which is hauled to neighboring ranches. The coal is slightly more than 4 feet thick, with a few inches of clay parting in the middle. The dip at the Nelson mine is S. 55° W. at an angle of 9°.

Section at Nelson mine, 3 miles south of Bear Creek.

	Ft.	in.
Coal	1	
Clay	2	6
Coal	2	
Clay		3–8
Coal	2	6

BRIDGER MINES.

The mines of the Bridger Coal and Improvement Company are in the sandstone ridge a mile northwest of Bridger, the opening being in the SW. ¼ SW. ¼ sec. 17. The mines are connected by a long spur with the branch of the Northern Pacific Railway. They were opened in 1897, and the main entry now has a length of about 3,000 feet. The beds dip to the southwest at an angle of 6°, and the main entry is down the slope to the west-southwest. The coal bed is from 4½ to 5 feet thick, and consists of about 2½ feet of coal at the base and a foot or more at the top, separated by a parting of shale, clay, and bone which averages 8 inches, but in places increases to more than 2 feet in

thickness. The lower coal is generally the better. In the southwestern workings the upper coal is 21 inches thick, the parting 12 inches, and the bottom bench 2 feet, but the latter is partly bony. About 80 miners and 25 outside men are employed, and the product is about 150 tons a day. In the first ten months of 1906, with 220 working days, the output was 35,000 short tons. The coal is worked by the long-wall system and undercut by eight electric link-belt machines. The coal is hoisted up the incline and carried on a trolley line nearly three-fourths of a mile to the tipple. About 20 per cent is screened out and the screenings are used for fuel for an extensive electric plant operated by the company. This plant has two dynamos which run a 250-horsepower hoist, trolley line, pumps, a 30-horsepower fan, the town lights, and a 60-horsepower pump. The tipple is equipped with all conveniences, including a steam box-car loader.

McCARTHY MINE.

The McCarthy mine is in section 19, a mile south of west from Fromberg, and the coal is hauled in wagons to the railroad at that place. The section of the coal bed is as follows:

Section of Bridger coal bed at McCarthy mine, near Fromberg.

Bone and coal.	Ft.	in.
Coal	2	
Shale		2
Coal	2	10
	5	

The parting changes to coal in places. The beds dip gently south of west and the main gangway runs northward, so that there is a slight descent to its mouth. Twelve miners are employed and three outside men dump the coal over screens into wagons. In the first ten months of 1906 the mine worked 250 days and produced 9,000 tons of coal.

GEBO MINE.

The Gebo mine is a short distance west of Gebo, and is connected with the branch line of the Northern Pacific Railway by a spur from Fromberg. The section of the coal bed is as follows:

Section of Bridger coal bed at Gebo mine.

Shale.	Ft.	in.
Coal	2	3
Bone		2
Coal	3	3
	5	8

The beds dip 4° to 5° SW. and the workings are so arranged as to afford gravity drainage. The present extent of the workings is about 900 feet. Forty-five men are employed in the mine and twelve outside, and the product is about 200 tons a day. The tipple, which is of steel, is nearly a mile from the opening. Electric power is used for tram, hoist, drilling, and ventilation.

JOLIET.

The Bergen mine, belonging to the Joliet Coal and Fuel Company, is in the NE. ¼ NW. ¼ sec. 35, T. 4 S., R. 22 E., 2½ miles west of south of Joliet. The section of the coal bed in this mine is as follows:

Section of Bridger coal bed at Bergen mine.

	Ft.	in.
Sandstone.		
Coal and bone	1	2
Shale		8
Coal	1	
Bone		6
Coal	2	2
	5	6

The bone and shale afford a very satisfactory roof. The beds dip southwest, and the main entry, which runs westward, is about 600 feet long. A small force is employed, and the output is from 40 to 50 tons a day in winter and 15 tons in summer. Most of the coal is hauled by wagon to Joliet and to Wilsey station, but a small amount is sold at the mine for $2.50 a ton.

Two other small mines a mile and a half south of Joliet are worked intermittently. They have about 2 feet of coal at base, which is said to contain 26 to 27 per cent of ash. Several years ago a mine was worked on the south bank of Rock Creek, a mile above Joliet, but it is now fallen shut and a section could not be obtained. Doubtless the coal bed is similar to that in the mines above described. A small mine was once operated a mile north of Joliet in which the Bridger bed is about 4 feet thick, but not of satisfactory quality.

CARBONADO.

Several years ago a large shaft was sunk at Carbonado station to reach the Bridger coal bed. A preliminary drill hole was bored, which gave promise of a thick bed, but in the shaft the coal has a thickness of 4 feet with a parting, and occurs at a depth of about 980 feet. The enterprise belonged to the late Marcus Daly and was equipped for extensive workings. A very large amount of water was encountered, and as the bed was not satisfactory the project was abandoned.

CHEMICAL COMPOSITION OF THE COAL.

The composition of the Red Lodge, Bear Creek, and Bridger coals is shown by the following analyses made at the Geological Survey fuel-testing plant at St. Louis. This table shows the analysis of each sample as received and also after air drying. The former generally contains more moisture than the commercial coal, and the latter

probably shows less. For purposes of comparison, however, the analysis of the air-dried sample should be used. The samples for analysis were obtained by making a cut from roof to floor of the coal bed, excluding partings.

Analyses of coal samples from Carbon County, Mont.

	Red Lodge.						
Laboratory No.	3590.	3592.	3588.	3595.	3591.	3593.	3594.
Analysis of sample as received:							
Prox. Moisture	11.69	14.07	11.26	11.33	11.22	10.38	10.55
Prox. Volatile matter	36.14	33.46	34.08	34.22	36.43	35.98	36.39
Prox. Fixed carbon	40.19	42.51	43.26	44.04	45.38	40.62	43.02
Prox. Ash	11.98	9.96	11.40	10.41	6.97	13.02	10.04
Ult. Sulphur	1.05	2.05	1.14	1.59	.83	1.89	2.23
Ult. Hydrogen	5.26	.....	.....	.....	.....	.....	.....
Ult. Carbon	55.46	.....	.....	.....	.....	.....	.....
Ult. Nitrogen	1.20	.....	.....	.....	.....	.....	.....
Ult. Oxygen	25.05	.....	.....	.....	.....	.....	.....
Calorific value determined:							
Calories	5,437	.....	.....	.....	.....	.....	.....
British thermal units	9,787	.....	.....	.....	.....	.....	.....
Loss of moisture on air drying	4.70	5.60	4.00	4.40	4.00	4.20	3.90
Analysis of air-dried sample:							
Prox. Moisture	7.34	8.97	7.57	7.25	7.52	6.45	6.92
Prox. Volatile matter	37.92	35.45	35.50	35.80	37.94	37.56	37.87
Prox. Fixed carbon	42.17	45.03	45.06	46.06	47.28	42.40	44.77
Prox. Ash	12.57	10.55	11.87	10.89	7.26	13.59	10.44
Ult. Sulphur	1.10	2.17	1.18	1.66	.86	1.97	2.32
Ult. Hydrogen	4.97	.....	.....	.....	.....	.....	.....
Ult. Carbon	58.20	.....	.....	.....	.....	.....	.....
Ult. Nitrogen	1.26	.....	.....	.....	.....	.....	.....
Ult. Oxygen	21.90	.....	.....	.....	.....	.....	.....
Calorific value determined:							
Calories	5,705	.....	.....	.....	.....	.....	.....
British thermal units	10,269	.....	.....	.....	.....	.....	.....

	Bear Creek.			Bridger field.		
Laboratory No.	3620.	4007.	4008.	3955.	3956.	3954.
Analysis of sample as received:						
Prox. Moisture	10.05	8.97	9.60	8.47	8.70	8.93
Prox. Volatile matter	37.22	36.11	36.88	31.47	34.03	33.43
Prox. Fixed carbon	46.71	43.18	47.10	41.88	49.07	46.92
Prox. Ash	6.02	11.74	6.42	18.18	8.20	10.72
Ult. Sulphur	1.44	3.02	2.35	.84	.63	.61
Ult. Hydrogen	5.41	.....	.....	.....	.....	.....
Ult. Carbon	59.64	.....	.....	.....	.....	.....
Ult. Nitrogen	1.40	.....	.....	.....	.....	.....
Ult. Oxygen	26.09	.....	.....	.....	.....	.....
Calorific value determined:						
Calories	6,219	.....	.....	.....	.....	.....
British thermal units	11,194	.....	.....	.....	.....	.....
Loss of moisture on air drying	2.00	2.10	2.60	3.20	3.10	3.60
Analysis of air-dried sample:						
Prox. Moisture	8.21	7.02	7.19	5.44	5.78	5.53
Prox. Volatile matter	37.98	36.88	37.86	32.51	35.12	34.68
Prox. Fixed carbon	47.67	44.11	48.36	43.27	50.64	48.67
Prox. Ash	6.14	11.99	6.59	18.78	8.46	11.12
Ult. Sulphur	1.47	3.08	2.41	.87	.65	.63
Ult. Hydrogen	5.30	.....	.....	.....	.....	.....
Ult. Carbon	60.86	.....	.....	.....	.....	.....
Ult. Nitrogen	1.43	.....	.....	.....	.....	.....
Ult. Oxygen	24.80	.....	.....	.....	.....	.....
Calorific value determined:						
Calories	6,346	.....	.....	.....	.....	.....
British thermal units	11,422	.....	.....	.....	.....	.....

Sample with laboratory No. 3590 was from bed No. 1; 3592, bed No 1½; 3588, bed No. 2; 3595 and 3591, bed No. 4; 3593, bed No. 5; 3594, bed No. 6; 3620, bed No. 2, 1 mile northwest of Bear Creek; 4007, from Foster Gulch a mile farther west; 4008, from Taggart Gulch; 3955 and 3956, west of Bridger; and 3954, a mile southwest of Fromberg.

THE COAL FIELDS OF PARTS OF DAWSON, ROSEBUD, AND CUSTER COUNTIES, MONT.

By A. G. LEONARD.

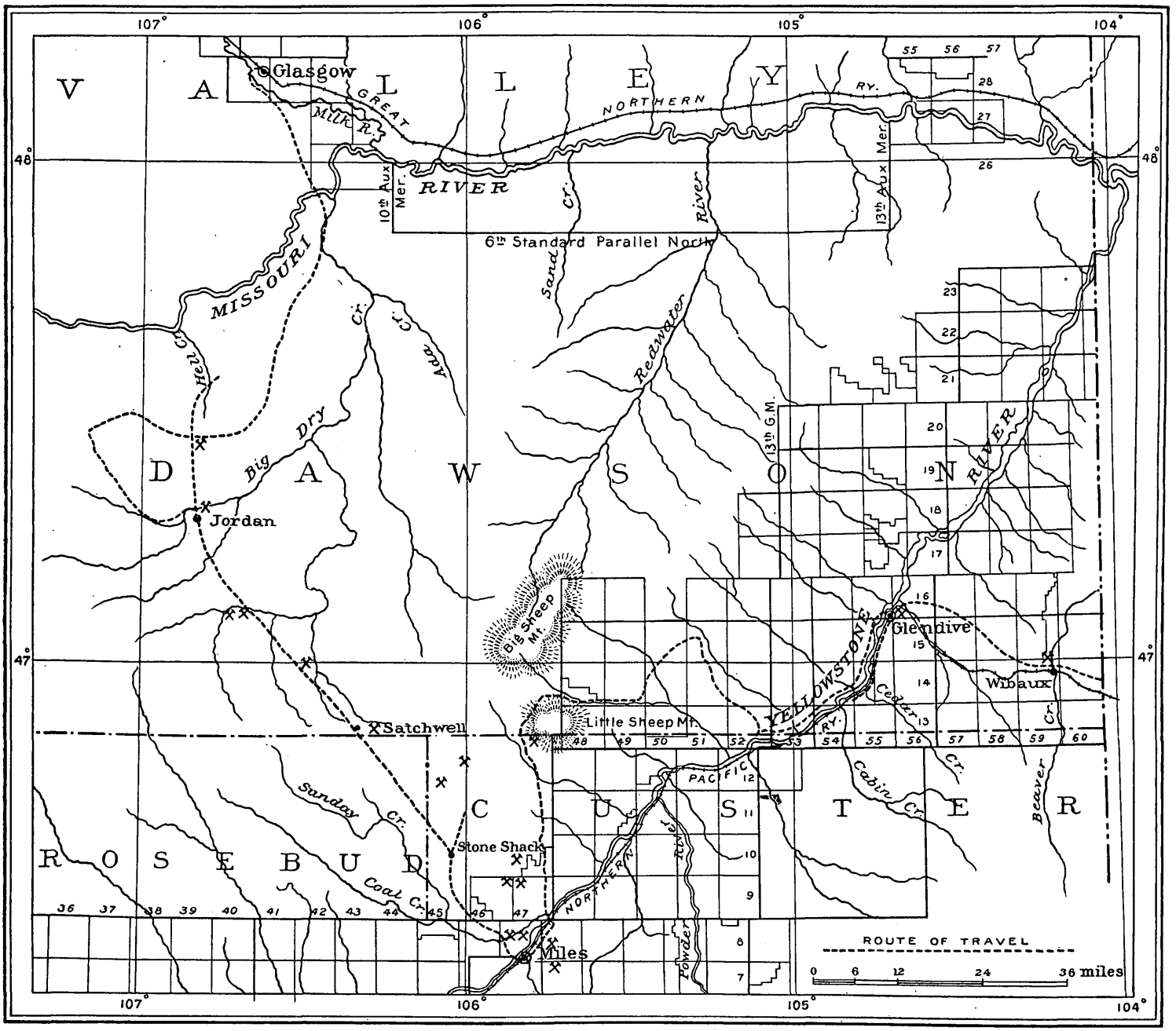
LOCATION AND EXTENT.

The Dawson-Rosebud-Custer County coal district forms part of a larger area which includes the greater portion of eastern Montana, most of the western half of North Dakota, and the adjoining parts of South Dakota and Wyoming; it also extends northward into Canada. Coal is known to occur as far west as Bighorn and Musselshell rivers in Montana and the Bighorn Mountains in Wyoming. In South Dakota the lignite is mostly confined to Butte County, in the northwest corner. Farther west in Wyoming the field extends southward in a tonguelike area between the Black Hills and Bighorn Mountains for more than 150 miles to North Platte River and includes parts of Sheridan, Johnson, Crook, Weston, and Converse counties. The area measures about 350 miles in an east-west direction, and at its widest part a greater distance in a north-south direction. It contains approximately 100,000 square miles and is equal to the area of Colorado or more than twice the area of New York State.

The coal of this great field ranges in quality from brown, woody lignite in the eastern part to black, shining subbituminous[a] coal in the western part. The transition from one to the other occurs near the eastern boundary of Montana, so in a general way the lignites are confined to North and South Dakota and the subbituminous coal to Montana and Wyoming.

That portion of the field which is described in this brief preliminary report includes parts of Dawson, Rosebud, and Custer counties, Mont. Custer County occupies the southeast corner of the State; Rosebud County is immediately west of it; and Dawson County, which borders the other two on the north, lies almost wholly between Yellowstone and Missouri rivers. The field work was confined largely to Dawson County, but included the portion of Custer and Rosebud counties lying north and west of Yellowstone River and a small area south of the river in the vicinity of Miles. The route traversed by the field party is shown on Pl. XII.

[a] The name subbituminous has recently been adopted by the United States Geological Survey for the class of coal above the brown lignites and below the bituminous coals—the class generally called "black lignite."



MAP OF PARTS OF DAWSON, ROSEBUD, AND CUSTER COUNTIES, MONT.

SURFACE FEATURES.

The greater part of the region may be characterized as a rolling plain, although there are extensive tracts of exceedingly rough badlands along Missouri and Yellowstone rivers and many of their tributaries. One of the largest of these badlands areas includes the 22 townships of Custer and Rosebud counties lying north of Yellowstone River. Another similar area, which is almost too rough to be traversed, occupies a broad belt on the south side of Missouri River, west of the mouth of Big Dry Creek, in northwestern Dawson County. Aside from these and similar smaller tracts the region as a whole is a wide-stretching, rolling prairie.

Big Sheep Mountain and Little Sheep Mountain, in southern Dawson County, are the highest points in the divide separating the drainage basin of the Missouri from that of the Yellowstone. These so-called "mountains," with bare clay sides, rise abruptly 150 feet above the gentle, grass-covered slopes of the divide and form a conspicuous landmark, which may be seen from a great distance. Cedar, Cherry, and Custer creeks, tributaries of the Yellowstone, are rapidly extending their valleys by headward erosion and encroaching on the upper branches of Redwater River and other tributaries of the Missouri.

Southeast of Miles, 5 or 6 miles back from the river, the Pine Hills rise 700 feet above the Yellowstone. The elevation of the divide between the Yellowstone and the Missouri is likewise about 700 feet above those streams. The broad valleys of these two rivers form natural highways followed by the railroads and wagon roads. The country lying between them is well drained by numerous streams, all but the larger of which run dry during the summer. The two most important are Big Dry and Redwater creeks, both tributaries of the Missouri. The creeks flowing into the Yellowstone are much shorter and include Sunday, Custer, Cherry, Cedar, and Bad Route creeks. Little Dry and Timber creeks are important tributaries of Big Dry Creek. (See Pl. XII.)

STRATIGRAPHY.

PIERRE SHALE.

The lowest member of the Montana group is the Pierre shale, which underlies the coal-bearing beds and appears at the surface at a number of localities within this field. One of these is on the Yellowstone, 12 miles above Glendive, at the mouth of Cedar Creek and extending downstream as far as Iron Bluff. The shale is brought to the surface by an anticlinal fold and the dipping beds on the southwestern flank of the fold can be seen on both sides of the river. The dip is 20° S. 52° W. and the strike is N. 38° W. The

dark-gray jointed shale contains numerous concretions of impure limestone, many of them rich in fossils. The following forms were identified by T. W. Stanton:

Avicula nebrascana M. and H.
Avicula linguæformis E. and S.
Inoceramus sagensis Owen.
Inoceramus cripsi var. barabini Morton.
Modiola meeki E. and S.
Veniella subtumida M. and H.
Callista deweyi M. and H.
Anchura americana E. and S.
Haminea occidentalis M. and H.
Pyrifusus newberryi M. and H.
Lunatia concinna M. and H.
Scaphites nodosus var. quadrangularis M. and H.
Scaphites nodosus Owen vars. brevis and plenus.
Limopsis parvula M. and H.
Yoldia evansi M. and H.
Lucina subundata M. and H.
Protocardia subquadrata E. and S.
Dentalium gracile M. and H.
Vanikoro ambigua M. and H.
Margarita nebrascensis M. and H.
Fasciolaria (Piestocheilus) culbertsoni M. and H.
Baculites ovatus Say.
Nautilus dekayi Norton.
Chlamys nebrascensis M. and H.

Along the extreme eastern edge of Custer County and continuing across the line into North Dakota is another area of Pierre shale which forms a belt extending many miles north and south on either side of the boundary. This shale also contains many calcareous concretions filled with fossils. The beds are well exposed on Little Beaver Creek, about 6 miles above its mouth, in secs. 23 and 24, T. 132 N., R. 107 W., Bowman County, N. Dak. From this locality the following fossils were collected:

Ostrea pellucida M. and H.
Avicula linguæformis E. and S.
Inoceramus cripsi var. barabini Morton.
Chlamys nebrascensis M. and H.
Yoldia evansi M. and H.
Nucula cancellata M. and H.
Lucina occidentalis Morton.
Protocardia subquadrata E. and S.
Callista deweyi M. and H.
Lunatia.
Anisomyon patelliformis M. and H.
Margarita nebrascensis M. and H.
Fasciolaria? (Cryptorhytis) flexicostata M. and H.
Pyrifusus.
Haminea? occidentalis M. and H.
Scaphites nodosus Owen var. brevis and plenus.
Nautilus dekayi Morton.

It is probable that the anticline so well shown on the Yellowstone has affected a wide area, since ammonites and other marine fossils are reported to occur on Cedar Creek 8 or 10 miles above its mouth and also many miles to the southeast on Cabin Creek. The Pierre shale thus extends a considerable distance toward the area on Little Beaver Creek, and the anticline, if continued in the direction of the strike of the beds (S. 38° E.), would include the latter area. The

Pierre shale exposed at the two localities is therefore probably brought to the surface by the same uplift and the two areas of outcrop are perhaps continuous.

There are extensive outcrops of the Pierre shale in northwestern Dawson County, where the beds are exposed along the Missouri and its tributaries. Southeast of Glasgow, at the mouth of Big Dry Creek, the shale in the river bluffs rises 200 feet above water level. No fossil-bearing calcareous concretions were observed at this point, although search was made for them, but otherwise the beds show all the characteristics of the Pierre. The shale was also observed on Hell Creek, a southern tributary of the Missouri, which empties into the river about 20 miles above the mouth of Big Dry Creek. At this place the shale has a thickness of at least 150 feet above creek level and contains calcareous concretions, with numerous fossils, among which ammonites and baculites are most common.

In the extreme southeast corner of Custer County, as the result of the Black Hills uplift, the Pierre shale outcrops over an area of considerable extent, overlying the Benton and Niobrara formations, which also appear at the surface.

FOX HILLS FORMATION.

The Fox Hills formation, lying above the Pierre, is the uppermost formation of the Montana group and the most recent of the marine Cretaceous strata. The relation of these beds to the Pierre below and the overlying rocks is well shown on Hell Creek, a tributary of the Missouri in northwestern Dawson County. In the section exposed along the sides of the deep valley of this creek, lying above the dark-gray shale with its concretions filled with Pierre fossils, are 100 feet of clay and sandstone that are believed to belong to the Fox Hills. The formation is composed largely of light-gray to buff, more or less sandy clay, with some layers of nearly pure sand. About 8 feet below the top there is a rather persistent bed of fine-grained yellow sandstone with a thickness of 11 feet. The beds as a whole are lighter in color and more sandy than the Pierre shale. Mr. Barnum Brown, in conversation with the writer, reports that they contain few fossils, but those that have been found were identified as probably belonging to the Fox Hills.

In the Glendive region there are no beds above the marine Pierre that correspond to the supposed Fox Hills clay and sandstones of Hell Creek. In fact, the line of contact between the Pierre and the overlying dinosaur-bearing beds, while not discordant so far as structure is concerned, may possibly represent a time break in which most of the upper fresh- and brackish-water beds of the Cretaceous are wanting.

DINOSAUR-BEARING BEDS.

Heretofore all the beds above the marine Pierre shale have been regarded as belonging to a single formation which carries the lignite and subbituminous coal beds of this field These rocks have been called, at various times, "Laramie" and "Fort Union," on the supposition that they composed but a single formation. The work of the last year, however, has shown that at Glendive the rocks above the Pierre shale apparently comprise two formations which seem to be reasonably separate and distinct, and that the upper formation only carries beds of lignite. The lower beds are well exposed between Glendive and Iron Bluff, where the following section was measured:

Section of rocks at Iron Bluff and vicinity.

	Feet.
8. Coal bed, burned, but probably 6 feet thick.	
7. Shale with a few thin beds of sandstone; abundant collection of fossil plants in sandstone bed 20 feet from base	150
6. Sandstone, massive, gray	40
5. Shale and sandstone; a few fossil plants at base	160
4. Sandstone, white, massive; most prominent stratum in the region	35
3. Sandstone, brown, fossil leaves in bottom part; forms summit of Iron Bluff	75
2. Shale and sandstone; fossil leaves in upper 20 feet	75
1. Shale, dark, Pierre, with limestone concretions containing abundant marine fossils; exposed to river level	100
	635

As noted in the section, fossil leaves were found at three horizons. The uppermost location (No. 7) is about 400 feet above the Pierre, and from this was obtained a fair collection of fossil plants which Knowlton regards as representing, approximately, the base of the Fort Union formation. The fossils obtained 75 to 100 feet above the Pierre (Nos. 2 and 3), as well as those from slightly higher horizons, were meager and not well preserved, so that their identification was difficult; they are, however, regarded by Knowlton as not Laramie, but possibly corresponding to the Livingston formation of the central part of the State, though showing decided Fort Union affinities. The beds are strikingly similar to the dinosaur-bearing beds on Hell Creek and presumably they are identical.

If the lowest principal coal bed is taken as the base of the Fort Union, then the dinosaur-bearing beds are 485 feet thick. If, however, the fossils found near the base of No. 7 are indicative of the base of the Fort Union, as thought by Knowlton, then the thickness of the dinosaur-bearing beds is only about 400 feet.

Perhaps the most favorable locality for the study of the dinosaur-bearing formation is the one already mentioned, in northwestern

Dawson County in the valley of Hell Creek. The section exposed there is as follows:

Section on Hell Creek.

	Ft.	in.
7. Clay and sand, light colored, light gray to buff; contains some massive sandstone and beds of coal 2 to 11 feet thick; many fossil leaves characteristic of the Fort Union are present; exposed to top of the ridges	115	
6. Clay and sand, similar in appearance to No. 4, but have yielded no dinosaur bones	100	
5. Coal, persistent; has been traced a distance of 25 miles	6	2
4. Clay and sand, mostly dark gray in color, with many brown, carbonaceous layers and some beds of coal. Two fairly persistent sandstone horizons, the lower about 15 feet and the upper about 20 feet thick, with 30 to 40 feet of clay between. These sandstones contain many large brown sandstone concretions. The beds yield dinosaur bones, such as *Triceratops*, *Claosaurus*, and *Tyrannosaurus;* also carry the remains of crocodiles, *Campsosaurus*, turtles, and ganoids, together with a few small mammal teeth	210–260	
3. Sandstone at the base of the dinosaur-bearing beds. Coarse grained and rather soft; characterized by its massiveness, absence of irregularity of bedding, the great number of large sandstone concretions, and its cross lamination; yellow or brown in color. Likewise contains dinosaur bones	50–100	
2. Clay, more or less sandy, and with some sandstone, light gray to buff, Fox Hills (?)	100	
1. Shale, Pierre, dark gray, with fossiliferous, calcareous concretions near the top; exposed above creek, about	150	

It will be seen from the above section that in this region between the top of the Fox Hills(?) and the base of the Fort Union, with its abundant and varied flora, there are only 400 feet of the dinosaur-bearing strata, even including the beds of No. 6, the age of which is not wholly beyond question.

In many places in northwestern Dawson County, particularly along the streams flowing into the Missouri, and in the badlands of the region, the dinosaur-bearing beds and overlying Fort Union are well exposed. At the head of Crooked Creek, which flows northward into the Missouri a few miles below Hell Creek, the following section was measured, beginning near the base of the Fort Union formation:

Section on Crooked Creek.

	Ft.	in.
46. Sand, yellow, with sandstone concretions to top of ridge	14	
45. Clay, gray	4	
44. Sand, gray	5	6
43. Sandstone yellow, persistent ledge	2–4	
42. Sand, fine, incoherent, yellow and gray	19	
41. Clay, sandy, gray	4	
40. Clay shale, brown	1	
39. Clay, gray	4	

	Ft.	in.
38. Clay, brown	1	3
37. Clay, gray	1	
36. Clay shale, brown, carbonaceous		6
35. Coal		3
34. Clay, gray, with plant stems	2	
33. Coal, impure; contains clay	1	8
32. Clay, gray, changing into brown above	1	
31. Sand, fine, argillaceous, yellow and gray	27	6
30. Coal, impure, and with seams of sand; this bed is continuous over a large area and forms a well-marked horizon 90 to 100 feet below the top of the dinosaur-bearing beds	5	6
29. Clay, brown, carbonaceous	1	6
28. Clay, gray	10	
27. Sand, fine, argillaceous, yellow, gray, shows cross lamination	13	
26. Sand, coarse, gray	18	
25. Clay shale, brown to black, carbonaceous	1	3
24. Clay, gray, sandy	11	
23. Clay, brown, carbonaceous, with several beds of coal, one 28-inch bed at top	10	
22. Clay, gray	2	6
21. Clay, more or less sandy, gray and yellow in alternating bands	1	6
20. Coal, impure, with three seams of sand	3	4
19. Clay, brown, carbonaceous	1	
18. Clay, gray, crumbles into flakes	2	
17. Sand, incoherent, yellow	1	6
16. Clay, gray	1	6
15. Sand, gray	5	
14. Clay, brown, carbonaceous	1	6
13. Clay, gray	2	6
12. Clay, brown, carbonaceous	1	2
11. Clay, sandy, light gray	5	6
10. Concretionary layer, brown, ferruginous		10
9. Clay, sandy, gray	5	
8. Clay, brown, sandy	2	6
7. Clay, gray	2	
6. Clay, brown, carbonaceous	1	
5. Clay, sandy, gray	24	
4. Sand, brown and yellow	6	
3. Sand, gray	5	
2. Clay, gray	2	
1. Clay, gray, sandy	7	
	245	3

Throughout the badlands which border the Missouri on the south, for a distance of over 50 miles above the mouth of Big Dry Creek, the dark-colored dinosaur-bearing beds, with many brown, carbonaceous layers, are overlain by the Fort Union.

FORT UNION FORMATION.

This formation presents a strong contrast to the underlying beds in this region and is readily distinguished by the light-gray and buff color

of its beds. The Fort Union contains thick beds of lignite and subbituminous coal, but brown carbonaceous clays seem to be rare. The sandstones of the formation abound in plants, which are exceedingly scarce in the underlying beds, but the latter contain dinosaur bones, as already stated, which are not found in the overlying Fort Union strata.

The following is a partial list of the plants collected from the Fort Union of this region and identified by F. H. Knowlton:

Onoclea sensibilis fossilis Newb.
Populus cuneata Newb.
Leguminosites arachioides Lesq.
Celastrus pterospermoides Ward.
Populus amblyrhyncha Ward.
Populus daphnogenoides Ward.
Populus arctica Heer (as identified by Lesquereux).
Populus smilacifolia Newb.
Populus nebrascensis Newb.
Populus genatrix Newb.
Populus speciosa Ward.
Cocculus Haydenianus Ward.
Platanus Haydenii Newb.
Platanus nobilis Newb.
Sequoia Nordenskiöldii? Heer.
Thuja interrupta Newb.
Glyptostrobus europæus (Brongn.) Heer.

In the vicinity of Miles, 100 miles to the south, the plants collected from several horizons are all considered by Knowlton to be undoubtedly Fort Union. Judged by their flora, practically all the beds about Miles are to be referred to this formation.

At Signal Butte, 5 miles east of Miles, the following section is exposed, extending from Tongue River to the top of the butte:

Section at Signal Butte, east of Miles.

	Ft.	in.
41. Clay, red from burning of coal bed; extending to top of Signal Butte	35	
40. Clay, sandy in part, crumbles readily in the hand, and some loose sand; light gray to buff in color and much lighter in appearance than the beds below; contains several thin, black streaks formed of black, carbonaceous dirt	160	
39. Clay, gray; contains large sandstone concretions and beds of sandstone near the top, containing plants	17	
38. Coal		2
37. Clay		9
36. Coal		9
35. Sand, gray	1	3
34. Clay, brown, carbonaceous		3
33. Sand and clay, light and dark gray in alternating bands	63	
32. Clay, brown, carbonaceous, with thin seams of coal		9
31. Clay, gray, with yellow, limonitic bands	11	
30. Coal, impure, contains clay seams	1	
29. Sand, with some clay, gray; contains many brown ferruginous nodules.	27	
28. Coal		8
27. Sand, with ferruginous nodules	11	
26. Coal		8
25. Sandstone, rather soft	20	
24. Coal, good quality, with three thin clay seams; the Weaver mine is in this bed	5	6
23. Shale, brown	5	6
22. Sand, loose, yellow	22	

	Ft.	in.
21. Clay, brown, with thin beds of coal	5	
20. Clay and sand, gray	25	
19. Coal, impure, with clay seam 2 inches thick	2	3
18. Clay and sand, gray	22	
17. Coal, good quality, has been mined	2½–3	
16. Clay and sand	39	
15. Coal		6
14. Clay, brown, carbonaceous		7
13. Coal, upper part impure, but lower 3 feet of good quality; has been mined	6	
12. Clay, yellow, containing sandstone beds and also concretions which break into yellow fragments. This member forms the top of the bluffs bordering the Tongue River Valley	17	
11. Clay, gray	2	
10. Coal, good quality	2	
9. Clay, yellow	8	
8. Clay, brown, carbonaceous, with some coal	1	
7. Clay, gray	2	
6. Coal	1	
5. Clay and sand, gray and yellow in alternating bands	66	
4. Sand, yellow, with sandstone concretions	5	
3. Clay, brown, carbonaceous	5	
2. Clay, gray	17	
1. Unexposed to river bank, estimated	75	
	702	1

At Signal Butte Fort Union plants were collected at only one horizon, No. 39 of the above section, which yielded the following species:

Taxodium occidentale Newb.
Sequoia Nordenskiöldii Heer?
Glyptostrobus europæus (Brongn.) Heer.
Populus? sp.? cf. genatrix Newb.
Populus, possibly P. acerifolia Newb.
Betula sp. new?
Corylus rostrata Aiton.
Corylus americana Walter.
Planera.
Hicoria antiquorum (Newb.) Knowlton.
Hicoria? sp. new?
Celastrus ovatus Ward.
Sapindus grandifoliolus Ward.

At a lower horizon in the bluffs of the Yellowstone at Miles other plants of Fort Union age were collected 115 to 125 feet above the river. The following species obtained from this locality were identified by F. H. Knowlton:

Populus cuneata Newb.
Populus amblyrhyncha Ward.
Populus nervosa elongata Newb.
Populus rotundifolia Newb.
Corylus americana Walter.
Hicoria? sp.
Platanus sp.
Cornus Newberryi Hollick.
Nelumbo n. sp.
Onoclea sensibilis fossilis Newb.
Trapa? microphylla Lesq., as identified by Ward.
Corylus rostrata Aiton.

The occurrence of the above plants at this horizon not far above the river is evidence that nearly all if not all the beds in the Signal Butte section belong to the Fort Union, and this formation thus has a thickness near Miles of 600 to 700 feet. The dinosaur-bearing beds

if present probably do not extend far above the level of the river, although if correlated solely on the basis of their close resemblance to the beds of the Hell Creek region, the lower 500 feet of the Signal Butte section would be referred to those beds. Only the upper 200 feet of the strata forming the butte resemble the Fort Union as it is developed 100 miles to the north.

STRUCTURE.

The geologic structure of the region under discussion is very simple, the beds for the most part being horizontal or with only a slight dip in certain localities. In the Hell Creek region, which is on the western margin of the field, the strata have a well-marked dip to the southeast, due no doubt to a general uplift to the west, which has brought the Pierre shale up to an elevation of at least 200 feet above Missouri River near the mouth of Big Dry Creek, southeast of Glasgow.

Reference has already been made to the anticline which shows so well on the Yellowstone at the mouth of Cedar Creek and on the opposite side of the valley. The dip is here 20° S. 52° W. and the strike is S. 38° E. This fold appears to be extensive, since it has brought the Pierre shale to the surface over a considerable area on Cedar Creek and it perhaps continues southeastward as far as Little Beaver Creek near the North Dakota line.

Smoke Butte, in western Dawson County, one of the most conspicuous buttes of the region, is composed of a mass of intrusive igneous rock forming part of a broad dike which can be traced for miles across the country. Smoke Butte stands at the junction of Smoke Butte and Big Dry creeks, 9 miles west of the town of Jordan. It rises 360 feet above Smoke Butte Creek. The dike has a width of 60 to 70 feet and its trend ranges from N. 48° E. to N. 53° E. Its course is marked by a line of ridges and detached buttes which owe their origin to the resistant character of the rock forming them. A smaller dike branching off from the main one has a width of 3 feet and shows columnar jointing, the columns being horizontal.

COAL.

GENERAL CHARACTERISTICS.

The coal beds are not confined to any particular horizon, but are distributed from top to bottom of the Fort Union formation. Sections in western North Dakota show that the lignite beds have a vertical range of 1,500 feet or more. Few exposures of 300 or 400 feet of strata do not contain at least thin beds of lignite. In some places but two or three such beds are present; in others there are ten or fifteen in a vertical distance of 250 to 500 feet, although many of the beds are only a few inches thick.

Over the field generally the coal beds range in thickness from a fraction of an inch to 14 feet. Beds 6, 8, and 10 feet thick are not uncommon, but those over 10 feet are comparatively rare.

The beds are usually not continuous over very large areas. A particular coal bed will pinch out within a mile or two and perhaps be replaced by another at about the same or a different horizon. Or two may overlap each other and while both appear at one point, at another point half a mile or so distant only one of them is present. In many places it is not possible to correlate beds on the opposite sides of the same valley and only 1 or 2 miles apart. On the other hand, here and there one coal bed can be traced 3 or 4 miles in the river bluffs and less commonly twice that distance, but sooner or later it thins out and disappears. This lack of persistence makes it unsafe to correlate coal beds whose outcrops are separated by more than a few miles.

Practically all the coal of this field is subbituminous (black lignite). Some of the beds, which are made up largely of the black variety, contain thin layers of brown lignite, but nowhere was the latter found to constitute the entire bed. The area is different in this respect from the North Dakota field, where the coal is entirely brown. In eastern Montana the coal is black and brittle and usually has a bright luster. Although some of it shows a woody structure, this is much less common than in the brown lignite, which is also generally tough rather than brittle.

On exposure to the air the coal loses part of its moisture, begins to crack, and finally breaks up into small fragments. This change takes place much more readily in the coal of some beds than in that of others. At some outcrops observed the material must have been exposed for many months, but back several inches from the face the coal still had the appearance of being fresh and unaffected by the weather. On the other hand, some beds, after no longer period of exposure, show the effects of weathering for a distance of several feet from the surface.

In many of the beds the coal is cut by one or two systems of joints, which are vertical, or nearly so, and from 5 or 6 inches to 1 foot and more apart. These joints are usually very clear cut and regular.

The following analyses show the composition of this subbituminous coal from several localities. Each sample was cut in the mine across a working face of the bed and then pulverized and quartered down to a quart sample, which was sealed air-tight in a galvanized-iron can and mailed to the chemical laboratory at St. Louis. Analyses were made under the supervision of N. W. Lord at the fuel-testing plant of the Geological Survey by F. M. Stanton, chief chemist.

Analyses of subbituminous coal samples from Montana.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Laboratory No	2424.	2429.	2425.	2426.	3701.	3782.	3783.	3842.	2423.	3812.	3816.
Analysis of sample as received:											
Prox. Moisture	26.84	28.47	30.25	33.53	29.13	31.29	35.16	31.33	34.94	34.55	34.89
Prox. Volatile matter	32.14	28.63	30.48	25.82	25.33	26.57	26.08	24.57	26.99	35.34	43.48
Prox. Fixed carbon	34.19	35.32	31.34	29.37	30.51	35.24	35.70	30.77	32.46	22.91	13.56
Prox. Ash	6.83	7.58	7.93	11.28	15.03	6.90	3.06	13.33	5.61	7.20	8.07
Ult. Sulphur	.31	.69	.60	.68	.55	.46	.31	.37	.74	1.10	1.33
Ult. Hydrogen	.....	.....	.....	.....	5.60	.....	.....	.....	.....	6.60	6.41
Ult. Carbon	.....	.....	.....	.....	40.09	.....	.....	.....	.....	42.40	41.66
Ult. Nitrogen	.....	.....	.....	.....	.54	.....	.....	.....	.....	.57	.56
Ult. Oxygen	.....	.....	.....	.....	38.19	.....	.....	.....	.....	42.13	41.97
Calorific value determined:											
Calories	.....	.....	.....	.....	3,701	.....	.....	.....	.....	3,939	3,880
British thermal units	.....	.....	.....	.....	6,662	.....	.....	.....	.....	7,090	6,984
Loss of moisture on air drying	17.50	20.30	21.90	25.60	16.50	14.80	22.30	20.30	27.40	15.50	14.20
Analysis of air-dried sample:											
Prox. Moisture	11.32	10.25	10.70	10.66	15.12	19.36	16.54	13.84	10.38	22.55	24.11
Prox. Volatile matter	38.96	35.92	39.02	34.70	30.34	31.18	33.57	30.83	37.18	41.82	50.68
Prox. Fixed carbon	41.44	44.32	40.13	39.48	36.54	41.36	45.95	38.61	44.72	27.11	15.80
Prox. Ash	8.28	9.51	10.15	15.16	18.00	8.10	3.94	16.72	7.72	8.52	9.41
Ult. Sulphur	.38	.86	.77	.91	.66	.54	.40	.47	1.02	1.30	1.55
Ult. Hydrogen	.....	.....	.....	.....	4.51	.....	.....	.....	.....	5.77	5.63
Ult. Carbon	.....	.....	.....	.....	48.01	.....	.....	.....	.....	50.18	48.55
Ult. Nitrogen	.....	.....	.....	.....	.65	.....	.....	.....	.....	.68	.65
Ult. Oxygen	.....	.....	.....	.....	28.17	.....	.....	.....	.....	33.55	34.21
Calorific value determined:											
Calories	.....	.....	.....	.....	4,432	.....	.....	.....	.....	4,662	4,522
British thermal units	.....	.....	.....	.....	7,978	.....	.....	.....	.....	8,391	8,140

1. On Clear Creek, 12 miles southwest of Glendive, Dawson County; bed 4½ feet thick.
2. Across the Yellowstone from Fallon, at mouth of Cottonwood Creek, Custer County; bed 6½ feet thick.
3. Five miles northeast of Miles.
4. In cut bank of Yellowstone at Fallon, Custer County; sample taken from face of outcrop of bed 4 feet 8 inches thick.
5. Five miles east of Miles.
6. At head of Youall Creek, T. 12 N., R. 45 E., Custer County; sample taken from outcrop.
7. Near head of Crow Rock Creek, T. 12 N., R. 45 E., Custer County; sample taken from outcrop, representative pieces of coal being selected near center of bed.
8. At Jordan, Dawson County; sample taken near face of outcrop.
9-11. Eight miles north of Glendive, Dawson County.

DESCRIPTION OF THE COAL BEDS.

Some of the coal beds of Dawson and Custer counties have already been described,[a] and only those which were examined during the last season (1906) will be considered here.

SHEEP MOUNTAIN REGION.

Big Sheep Mountain and Little Sheep Mountain are located in southern Dawson County, about midway between its eastern and western boundaries and almost due north of Miles. As already stated, they form the highest part of the divide separating the tributaries of the Yellowstone from those of the Missouri. Several coal beds occur in the vicinity of McMillan post-office in T. 14 N., R. 47 E., on West Fork of Cherry Creek. Four miles northeast of the post-office there is a 6-foot bed, and what is probably the same bed outcrops near the base of Big Sheep Mountain. Just south of Little Sheep Mountain, in a gully beside the stage road from McMillan to Miles, a bed 7 feet thick outcrops.

[a] Bull. U. S. Geol. Survey No. 285, 1906, pp. 327-329.

MILES DISTRICT.

North of Yellowstone River, on Sunday Creek and its tributaries, coal outcrops at many points in Tps. 8, 9, and 10 N., R. 47 E. It has been mined for several years just below the bridge over South Sunday Creek, in sec. 18, T. 8 N., R. 47 E. The bed outcrops in the cut bank along the stream for a distance of 300 feet and lies only 2 to 3 feet above the bed of the creek. It is from 4 to 4½ feet thick and the coal is of good quality. The section is as follows:

Section of coal bed on South Sunday Creek.

	Feet.
Sand and clay, washed from higher slopes	15
Sandstone, soft	8
Coal, with 1-inch seam of sand, 1 foot below top	4–4½
Clay, exposed to bed of creek	2–3

Mining is carried on here partly by stripping, the soft sandstone being blasted off in large blocks, and partly by drifting in along the bed. The coal is mined only during the winter and is sold in Miles. The same bed appears along North Sunday Creek and outcrops along the road about half a mile north of the bridge.

Several miles below the junction of the two creeks, in sec. 9, T. 8 N., R. 47 E., a coal bed 3 feet 4 inches thick is exposed on the north side of the valley.

In the high ridge 2½ miles northwest of the mouth of Sunday Creek, in sec. 22, T. 9 N., R. 47 E., a bed 7½ feet thick is present. It is badly weathered on the face of the outcrop and back several feet from the surface has crumbled to powder.

On Cow Creek, a tributary of Sunday Creek which crosses T. 9 N., R. 47 E., from northwest to southeast, a 10-foot bed of coal is exposed at a number of points from 5 to 10 miles above the mouth. The bed appears to be continuous over a considerable area and is only a few feet above creek level. In places the coal has burned and its horizon is represented by red clay, and much of the bed has been eroded by the branches of Cow Creek. At the outcrop the coal is overlain by only a few feet of clay, but it doubtless extends back from the creek and is present under the bluffs which rise abruptly at a distance of one-half to 1 mile.

Several beds of impure coal occur in the bluffs near the head of a small creek about 2 miles west of and nearly parallel with Cow Creek in T. 9 N., R. 46 E.

On South Sunday Creek, 5 or 6 miles above its junction with North Sunday and near the Reynolds ranch, a coal bed 3 feet thick is mined for use near by.

In the badlands about 18 miles north of Miles, or 9 miles from the ferry across the river near Tusler, a thick bed is exposed along the stage road to McMillan. The section is as follows:

Section of coal bed 18 miles north of Miles.

	Ft.	in.
Clay, yellow	9	
Coal	10	6
Clay and coal in alternating seams, the clay bands 1 to 8 inches thick	5	6
Coal	2	6
Clay, exposed to creek	4	
	31	6

Including the several clay seams the bed has a thickness of over 18 feet. It appears at intervals for more than half a mile, one outcrop being 300 feet long. The coal is of good quality.

Two thin beds of coal are exposed in the steep bluffs of the Yellowstone opposite Miles. The lower, which is only 27 inches thick, can be followed by its outcrops for a distance of at least 2 miles. It has been mined at many points by running short drifts in along the bed.

By far the greater part of the coal used in Miles comes from the Kircher and Weaver mines on the south side of the river. The former is located 5 miles northeast of town, and the latter about the same distance to the east, near the base of Signal Butte.

The Kircher Brothers' mine, in sec. 19, T. 8 N., R. 48 E., is working a bed ranging in thickness from 4 feet 2 inches to 4 feet 6 inches and lying about 75 feet above the river. The coal is reached by a slope 136 feet long and lies 58 feet below the entrance of the slope. The coal is cut by vertical joints, 18 inches to 2 feet apart, which serve to block it out and assist in mining, the coal coming out in good-sized pieces. A main entry extends in opposite directions from the bottom of the slope for a distance of about 400 feet. From this entry rooms 200 feet long are turned and 6-foot pillars are left between the rooms. Several inches of coal are left at the top and little timbering is necessary, since this forms a secure roof. The mine is worked during the entire year, 25 to 30 men being employed during the winter. The coal is of excellent quality, black, brittle, and with bright luster.

The Weaver mine is on a higher bed, 330 feet above the Yellowstone, and the section here is as follows:

Section of coal bed at Weaver mine.

		Ft.	in.
11.	Sandstone, gray and rather soft, but forming good roof	20	
10.	Clay, brown, carbonaceous, with some plant fragments		10
9.	Coal, good quality	2	2
8.	Clay		1
7.	Coal		2
6.	Clay		3

	Ft.	in.
5. Coal	1	5
4. Clay, brown, carbonaceous		4
3. Coal	1	2
2. Clay, brown, carbonaceous	5	7
1. Sand, soft, yellow	22	
Total coal bed	5	7

Nos. 5 to 9, inclusive, are removed, 4 feet of coal and the included clay seams being mined. The bed is exposed at a number of points in the sides of Signal Butte and probably underlies the entire butte. Two lower coal beds which outcrop below the mine have also been worked by Mr. Weaver in past years. They are shown in the Signal Butte section on pages 201–202. One lies about 130 feet below and has a thickness of 6 feet, but the upper half of the bed is a poor, impure coal; the other, 2½ to 3 feet thick, contains good coal, but has a poor roof.

Thick coal beds occur in the Pine Hills east of Miles, which have an elevation of 700 feet above Yellowstone River. One of these beds, 12 to 15 feet thick, is exposed at numerous points about 10 miles from town, in secs. 9, 10, 12, 14, 15, 22, and 23, T. 7 N., R. 49 E. The coal lies not far below the top of the hills and has burned out over large areas, as shown by the abundance of red clay.

REGION BETWEEN MILES AND JORDAN.

The town of Jordan is located on Big Dry Creek, in western Dawson County, and is 92 miles northwest of Miles. Between these two places there are many coal beds within a few miles of the stage road. The most important of these will be described in the order of their occurrence northward from Yellowstone River.

In the bad lands on Grimes Creek, a tributary of North Sunday Creek, in T. 10 N., R. 45 E., a bed of coal 2 feet 6 inches thick outcrops for a distance of several miles in the bare clay slopes of the bluffs. A bed of the same thickness appears on Alkali Creek 3 miles above its junction with Grimes Creek at the Stone shack.

One or more thick beds of coal occur in T. 12 N., R. 45 E., the extreme northwestern township of Custer County. They are exposed in the deep ravines near the heads of Youall and Crow Rock creeks, both of which flow north into Little Dry Creek. About 4½ miles east of Sim Robert's ranch a bed of coal 10 feet thick outcrops at the head of Youall Creek, in sec. 20, T. 12 N., R. 45 E. It is of excellent quality, black and with a bright luster. The coal is jointed, the joint cracks being from 10 to 18 inches apart. The bed is overlain by 40 to 50 feet of buff clay. About 5 miles farther northeast, near the

head of Crow Rock Creek, what is perhaps the same bed outcrops. It is 8½ to 9 feet thick and is overlain by 8 to 10 feet of buff sandstone and 20 to 30 feet of yellow clay, mostly wash from higher slopes. The coal, though black and brittle, shows plainly the woody structure.

Several miles southeast of Satchwell post-office, near the northern border of Rosebud County, a bed of coal 2 feet 6 inches thick occurs under a cover of 3 or 4 feet of clay. It is near the top of the divide separating the Missouri from the Yellowstone drainage.

At Joe Greer's place, on Thompson Creek, 4 to 5 feet of coal is exposed and is mined close beside the house by drifting in along the bed. A spring flows from the bottom of the bed.

There are two beds of coal in the vicinity of Cohagen post-office on Little Dry Creek. One of these is well exposed for 300 yards in a cut bank along the stream. The section here is as follows:

Section of coal beds at Cohagen.

	Feet.
5. Clay washed from higher slopes.	
4. Coal	5
3. Clay	6
2. Coal, upper 5 or 6 feet of poor quality from admixture of clay; also contains iron pyrites in nodules; lower 3 or 4 feet of good quality	9
1. Clay, exposed to creek bed	1
	21

In places the upper part of the coal bed has suffered erosion and is overlain by several feet of sand and gravel upon which rest 3 to 10 feet of wash clay.

About 1½ miles southwest of Cohagen, on Phillips Creek, a tributary of Little Dry Creek, another bed is exposed, the section being as follows:

Section on Phillips Creek.

	Ft.	In.
10. Sand and clay	9	
9. Coal		6
8. Clay, brown	1	6
7. Coal		1
6. Clay, brown	1	2
5. Coal		5
4. Sand seam, brown		1½
3. Coal	3	6
2. Clay, gray	6	
1. Unexposed to creek	15	
	37	3½

The coal of the 3½-foot bed (No. 3) is a good subbituminous coal, with bright luster and brittle. It is well jointed, the joint cracks being from 1 to 4½ inches apart.

Two beds appear on Sand Creek near the road crossing, as shown in the following section:

Section on Sand Creek.

	Ft.	in.
8. Clay, alluvial, and silt	9	
7. Gravel and sand	4	
6. Clay, brown	1	
5. Coal, impure, dull	1	6
4. Clay, jointed, gray	15	6
3. Coal, mostly black, with bright luster, shows bedding plainly, being composed of layers one-half to 4 inches thick	2	
2. Sand, gray	2	
1. Clay, gray, exposed to creek level	4	
	39	

The upper bed outcrops at intervals along the creek for a distance of 1 to 2 miles.

The section which follows is exposed in the steep cut bank of Big Dry Creek at Jordan:

Section at Jordan.

	Ft.	in.
13. Clay, washed from upper slopes	2	
12. Clay, gray, jointed	9	
11. Clay, brown, carbonaceous, with some coal		4
10. Coal, impure, with 1-inch clay seam	1	9
9. Clay, brown, carbonaceous		6
8. Coal, good quality except upper 3 or 4 inches	2	2
7. Sand seam, brown		2
6. Coal, good quality	1	8
5. Clay, gray	1	6
4. Sand, gray	2	
3. Clay, gray	3	
2. Coal		6
1. Clay, blue, to bed of creek	1	
	25	7

The beds have a slight dip to the east. The outcrops appear in the banks of the creek for over half a mile and the coal doubtless extends back under the slopes south of the stream. At the lower end of the exposure the bed is cut out by erosion and is replaced by alluvial clay. Nos. 6 and 8 of the above section together form a 4-foot bed of coal of excellent quality, with a 2-inch seam of sand near the center. The coal, which is black and has a bright luster, is in distinct layers and breaks readily along the bedding planes.

REGION NORTH OF JORDAN.

At Percy Williamson's ranch, about 13 miles north of Jordan, a bed of good black subbituminous coal is mined on its outcrop for use on the ranch. Only 3 feet is exposed, but the bed is said to be 5 to 6 feet thick. A massive sandstone with a thickness of 30 to 40 feet occurs over the coal.

Beds of coal occur in the dinosaur-bearing beds and the Fort Union formation of the Hell Creek district. A very persistent bed about 6 feet thick lies 100 feet below the Fort Union, and this has been traced at least 25 miles.