TWO MONTANA COAL FIELDS.

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1. THE GREAT FALLS COAL FIELD.

INTRODUCTION.

Near the rapidly growing city of Great Falls, Montana, the Missouri river emerges from the Belt mountains and begins its long eastward course through the great plains. The rapidly flowing stream soon com-

mences to cut through the nearly horizontal strata of the plains, and near Great Falls plunges over a series of sandstone ledges in a succession of cataracts collectively known as the "Great falls of the Missouri." Below the falls the sandstones gradually pass beneath the dark carbonaceous shales so well exposed at Fort Benton, from which place they take their name. These sandstones, with their interbedded shales, now known as the Great Falls formation, have long been known to all geologists visiting the region, but until recently failed to reveal any fossil remains and were referred to the Dakota epoch, whenever mentioned, on account of their inferior position to the well developed Fort Benton shales. Their true age was first made known by Professor J. S. Newberry,* who identified a number of fossil plants from the Great Falls formation and found

FIGURE 1.—Sketch Map of Montana showing Location of Coal Fields.

The shaded zone extending from the headwaters of Musselshell river to the international boundary includes the coal fields.

them to be species characteristic of the Kootanie rocks of the Canadian geologists.

South of Great Falls, a few miles nearer the mountains, this formation holds a thick seam of excellent bituminous coal, which is being extensively mined at Sandcoulée and has been opened at a number of other localities along the base of the mountains. The area underlain by coal has been called the Great Falls coal field, and as these strata constitute the only occurrence of the Kootanie rocks yet recognized in our territory they possess a decided interest apart from their economic importance.

In prosecuting a study of the coal fields of Montana for the United States Geological Survey, a visit was made to this field in the spring of

*School of Mines Quarterly, vol. viii, no. 4, July, 1887, p. 327.

1891, and the facts then observed are believed to be of sufficient interest to present to the Society. They prove—

1. The identity of the fossiliferous strata near Great Falls with those of the coal field ;

2. The position of the formation relative to the Carboniferous and to the Fort Benton rocks, as established by a carefully measured detail section ;

3. The occurrence of fresh-water shells above the coal ;

4. The absence of recognizable Dakota strata ;

5. The termination of the Carboniferous deposits in a series of shales and impure limestones, stratigraphically and lithologically the equivalent of the *Myacites* beds of the Jura-Trias of southern Montana, but carrying lower Carboniferous (Spergen hill) fossils.

The eastern portion of the field was examined by the geologists of the Northern Transcontinental Survey in 1880. Professor W. M. Davis, in studying the relation of the coal to the older rocks, measured two sections from the Cambrian to the horizon of the coal, of which detailed notes are not given. A graphic representation of these sections was published, with lists of fossils determined and an interesting account of the adjacent mountain region, in the reports of the Tenth census.*

In the investigation of the coals from an economic standpoint for the same survey, the coal seam was traced by G. H. Eldredge from the Judith basin to Belt creek, and sections of the seam, wherever opened at that time, will be found in his report.† Somewhat later Professor J. S. Newberry made an examination for the Great Northern railway of that part of the field now worked, and mentioned the general relations of the coal rocks to the underlying Paleozoic terranes, in a paper on the geology and botany of the country bordering the Northern Pacific railroad.‡

LOCATION AND EXTENT OF THE FIELD.

The Great Falls coal field, as already indicated, is situated at the base of the Rocky mountains in central Montana, and takes its name from the town to which it is tributary. Its proximity to Helena, the state capital, and to the great mining center Butte, with the increasing market afforded by the smelters and other industries of Great Falls itself, makes the field of the first importance in the future development of Montana.

Coal has been found in the Kootanie rocks all along the base of the mountains from the vicinity of fort Shaw eastward to the Judith basin.

* Tenth Census: Mining Industries, vol. xv, Washington, 1886, p. 697.

† Ibid., p. 739.

‡ Annals of the N. Y. Academy of Sciences, vol. iii, 1884, no. 8.

The seam has been opened at several places, and desultory working for the local supply has been attempted on St. Johns creek, west of the Missouri, and on Bird creek, Hound creek, Smith river, Dry Arrow creek, Willow creek, and Sage creek. The more extensive workings of Belt creek are sufficient to prove the value of the seam; the mines at Sandcoulée have an average daily output of 1,300 tons. It will be seen from the localities cited that the field embraces a strip of country a few miles in width, but extending along the base of the mountains for 125 miles, its extreme limits being yet undetermined (see figure 1).

CONFIGURATION AND STRUCTURE.

Throughout its entire extent the coal field is an open, grassy plateau or prairie country, but rarely presenting low buttes or eminences left by the erosion of higher strata, and cut by numerous drainages whose coulées show sections of the rocks. To the southward the Belt mountains form a rugged range whose higher slopes are dark with a heavy growth of pines, the lower slopes presenting that park-like character that forms one of the chief charms of Rocky mountain scenery. The plateaus of the coal field extend northward, forming the western limit of the great plains. In the center of the field, Belt creek has cut a narrow valley whose groves of cottonwood and alders are in pleasant contrast to the monotonous grasslands of the plateaus. Belt butte, a conical hill of horizontal shales and sandstones, forms a conspicuous landmark, the girdle of sandrock about its slopes giving it the name. To the eastward the Highwood mountains break the continuity of the plains, rising abruptly as an isolated cluster of picturesque peaks. The drainage of the coal field, at least that part of it which was visited, is peculiar: The level plateaus are trenched by narrow coulées, which are frequently partially filled with drift and are now occupied by streams of relatively small size, streams that even in flood are not proportionate to the valleys they occupy. The evidence seems to show that a period of depression, when the plateaus were cut, was followed by a short time of relatively high elevation accompanying the advance of local glaciers and a vigorous drainage, which was followed in turn by the present period of scanty precipitation.

The abundance of glacial drift on the plateaus was noted by Professor Newberry. It is conspicuous when the glacial gravels fill pre-existing hollows and drainage channels, but on the mesas forms but a thin and widely spread mantle in which the bowlders are seldom of large size. The material points to local origin of the drift, coming from the Little Belt range. In the coal field proper no true moraines were observed.

The gently inclined strata of the Great Falls coal field rest conformably upon the Paleozoic terranes flanking the granitic axis of the Belt mountains, the easternmost range of the Rocky mountain cordillera of this locality. In these steeply upturned and folded Paleozoic strata the Cambrian, Silurian, Devonian and Carboniferous rocks have been recognized by means of fossils. The massive white limestones of the Carboniferous form the foothill country and pass beneath a series of gypsiferous red sands and limy shales long thought to represent the Jura-Trias but recently found to contain Carboniferous fossils, and these are in turn overlain by the sandstones and shale belts of the Great Falls formation. To the northward these coal rocks are in turn covered by a heavy series of strata that pass into typical Fort Benton beds as identified by Professor Newberry.*

The Highwood mountains, whose proximity to the chains formed by the uplifts of the eastern Cordillera would suggest a similar origin, are really a remnant of still higher Cretaceous beds, preserved during the erosion of the surrounding country by a network of dikes and sheets whose injection produced an induration of the strata that has left them as a record of the sediments once covering this part of the plains. Toward the east and west this same general structure, with local modifications, continues along the base of the Rocky mountains.

THE GEOLOGICAL COLUMN.

Sections.—The entire geological column, from Archean gneiss to the shales of the Fort Benton group, is well exposed along the course of Belt creek. This stream, rising in the Belt mountains, flows for several miles westward along the strike of the Paleozoic limestones, and then turning northward has cut the picturesque Sluice-box canyon through massive Paleozoic beds, and reaches the more readily eroded clays and sandstones of the Mesozoic. At the lower end of Sluice-box canyon, near Riceville, the Paleozoic limestones dip deeply northward beneath the arenaceous beds of the Gypsum series and the overlying gray shales. Starting at this point, a continuous section was measured from the massive mountain limestones of the Carboniferous to the beds of supposed Fort Benton age which overlie the coal-bearing strata and form Belt butte. These measurements are given in the natural order.

The following table shows, in considerable detail, the section (represented graphically in figure 2) exposed in Belt butte:

*School of Mines Quarterly, vol. viii, 1887, p. 327.

Belt Butte Section.

		Feet.
26.	Sandstone, gray, slaty and hard, forming cap of the butte.....	80
25.	Slate, black.....	20
24.	Limestone, white and hard; forms upper "belt"....	20
23.	Sandstone, gray, irregularly bedded, breaks into shelly detritus.....	90
22.	Shale, black and earthy.....	100
21.	Sandstone, unevenly and thinly bedded, usually light earthy brown, holding carbonaceous layers of 1 to 3 inches; principal "belt" of the butte.....	50
	Sandy shales, black and iron-stained but hard and shelly.....	20
	Sandy shales, gray, more arenaceous than those beneath.....	40
20.	Sandy shales, fissile and carrying $\frac{1}{3}$ proportion black shale; facies decidedly Benton.....	25
	Shale, black.....	75
	Shale, sandy, gray, breaking into cubical bits.....	50
	Limestone.....	10
	No good exposures, but slopes show débris of white vitreous quartzite resembling novaculite.....	75
	Shale, black and earthy.....	10
	Sandstone, marked by fucoidal rolls.....	$\frac{1}{2}$
	Shale, black and earthy, with one 6-inch band of sandstone.....	25
19.	Sandstone.....	2
	Shales, red and purple to purple-black, with rare layers of harder sandy rock whose splinters strew slopes.....	140
18.	Sandstone, gray, weathering light brown; forms top of a broad bench extending back to the base of Belt butte.....	20
17.	Gasteropod bed; <i>Goniabasis</i> , <i>Neritina</i> , <i>Corbula</i> (?)....	10
	Sandstone, dense, lilac-colored, weathering purple-brown.....	10
16.	Series of thinly bedded sandstones and limestones with alternating beds of shale, well exposed in coulée, but not of sufficient interest to warrant more detailed section, viz:	
	k. No exposure.....	21
	j. Sandstone, gray, cross-bedded.....	10
	i. Shale.....	
	h. Sandstone, buff, dense, uniform.....	
	g. Sandy lilac-colored ledge.....	2
	f. Sandstone.....	5
	e. Lilac-tinted freestone.....	20
	d. Sandstone, fissile, gray, quartzose, very hard and iron stained.....	17
	c. Ledge of pink and lilac rock.....	30
	b. Red and gray sandstones and shales....	45
	a. Shale, sandy, buff, with red blotches... 10	
15.	Sandstone ledge, prominent stratum that throughout the valley lies over coal.....	50
14.	Coal.....	10
		1,092 $\frac{1}{2}$

FIGURE 2.—Section at Belt Butte.

The Belt butte section is supplemented by that exposed on Belt creek, which comprises the following sequence (represented graphically in figure 3):

Belt Creek Section.

		Feet.
	Overlying beds of Belt butte section	1,192½
14.	Coal	10
13.	Shaly sandstones	100
12.	Sandstone belt	25
11.	Shales, limy	50
10.	Sandstones, white	150
9.	Limestone, gray and red, rusty	25
	Sandstone, white	5
	Sandy shales, the lower 40 feet very ferruginous and brown	95
8.	Sandstone, white, cross-bedded; forms persistent ledge	6
	Sandstone, shaly and iron stained	10
	Sandstone; ledge forming bluff	50
7.	Limestone, dense, light earthy gray	5
6.	Conglomerate and sandstone, Jurassic fossils	215
5.	Limestone, white, red earthy patches, Paleozoic facies	90
4.	Otter Creek shales; alternating gray, purple, green and black shales and earthy limestones yielding Carboniferous fossils; comprising—	
	x. Shales, dark gray and black alternating with purple and green	45
	w. Limestone	5
	v. Shale, gray	30
	u. Limestone, white	3
	t. Shales, green and purple, limestone lenses	25
	s. Limestone, white, conchoidal fracture	6
	r. Shale, gray, green and red	8
	q. Limestone, hard, dense, purplish-brown	1½
	p. Shale	1½
	o. Limestone, pebbly, containing gasteropod shells	2
	n. Shale, gray	3
	m. Limestone, gray, weathering creamy, usually brecciated	2
	l. Shales, carrying <i>Rhynchonella</i> , etc.	15
	k. Limestone, irregularly bedded and of varying tints of gray	5
	j. Shale, black and earthy	½
	i. Limestone	15
	h. Shale, earthy dark gray	8
	g. Limestone, soft, crystalline	3
	f. Shale, purple-gray	8
	e. Limestone	3
	d. Shale, black	16
	c. Gypsum	2½
	b. Limestone conglomerate	2
	a. Shale, dark gray	2
	Black chert belt	8
3.	Limestones and shales	80
	Gypsum	3
	Sands, gray and white	12

FIGURE 3.—Section on Belt Creek.

		Feet.
Red sands and gypsum layers made up as follows:		
2.	f. Sands, red.....	10
	e. Gypsum, pure.....	5
	d. Sands, green-gray, shaly.....	35
	c. Gypsum, impure.....	1½
	b. Sands, reddish, soft, 3 belts of gypsum, 3 to 6 inches.....	25
	a. Sands, crumbling, red and white or gray.....	25
Limestones, granular, earthy.....		7½
Sandy clays, red and green mottled.....		30
1.	Carboniferous limestones *	200
		<hr/> 2,572½

The Carboniferous.—The series of red sandy gypsiferous beds overlying the massive limestones of the Carboniferous and so closely resembling the "Triassic" red beds were diligently searched for any traces of fossil remains, but without success. This series (number 2 of the section) consists of crumbling sands, soft and often incoherent, generally red in color, though also white and gray, containing numerous seams or beds of gypsum. The series corresponds in position and general characters to the "red beds" which overlie the Carboniferous in Wyoming.

Overlying these gypsiferous red sands, there is commonly seen a series of gray beds, also characterized in this section by layers of gypsum, one of which is 3 feet in thickness. The gray shales and earthy limestones of this series (number 3 of the tabular section) is capped by a belt of black chert 8 feet thick, which was found at this horizon in several parts of the field. The earthy limestones and shales resemble the Jurassic of southern Montana, but are barren of fossils.

The series of alternating red or purple and gray shales and limestones (number 4 of the section) are characterized by abundant fossil remains. The thin beds of limestone, often but a few inches in thickness, contain a number of small serpulæ and the shales contain a variety of fossils. These fossils have been seen by Dr. C. A. White and unhesitatingly referred to the Carboniferous age. They have been identified by Mr. C. D. Walcott, who reports the following species, viz, *Retzia verneuilliana*, Hall; *Rhynchonella osagensis*, Swallow; *Athyris subtilita*, Hall; *Bellerophon carbonarius*, Cox; also lamellibranch shells belonging to the genera *Allorisma*, *Schizodus*, and *Aviculopecten*; as well as two species of *Fenestella*, shown on thin fragments, and two species of coral of the genera *Chætetes* and *Lophophyllum* (?). Mr. Walcott reports that "the species appear to have lived in a sea not favorable to their full growth or development."

The section made by Professor Davis a few miles farther eastward has already been noted. I have examined the rocks at this locality and

* Characteristic Carboniferous fossils were found in the uppermost strata of number 1, establishing its age beyond any doubt.

found a close correspondence with the section made by myself on Belt creek. Fossils collected by Davis from these same shales, supposed by him when in the field to be Jurassic, were reported to be Spergen hill types by Professor Whitfield; this places them in the lower Carboniferous. The list given by Professor Whitfield is as follows:

<i>Rhynchonella mutata</i> , H.	<i>Terebratula turgida</i> .
<i>Productus tenuicostatus</i> , H.	<i>Allorisma</i> , sp.?
<i>Athyris trinucleata</i> , H.	<i>Lingula</i> , sp.?
<i>Eumetria verneuilliana</i> .	<i>Stictopora</i> , sp.?

These species and those enumerated above do not include a single characteristic Jurassic type. Notwithstanding the wide range of many of the species, and in general of the molluscan fauna so abundant in the Carboniferous, rendering such paleontologic evidence by itself of little value in determining exact horizons, it is noteworthy that fossils characteristic of the lower Carboniferous should be found in beds formed during the very close of the Carboniferous period. It should be noted in this connection that fossils from a very much lower horizon in the section made by Professor Davis are described by Whitfield as upper Carboniferous. The stratigraphic position and lithological character of the limestones and shales from which the fossils collected by myself were obtained correspond closely to those of the beds found in southern Montana to be characterized by an abundance of Jurassic fossils.* Such a decided change in the upper part of the Carboniferous from that observed elsewhere indicates a local modification of prevailing conditions and nearness of a shore line.

The Jurassic.—This shaly series is overlain by a bed that is characteristic of the Jurassic throughout central Montana. In its lower portion it is frequently a good crystalline limestone, passing gradually into a coarse sandstone, frequently a conglomerate closely resembling the Dakota but carrying large numbers of Jurassic shells in both the sandy and limestone portions of the bed (number 6 of the section).

The Belt creek section gives a total thickness of 538 feet of beds between the white limestone of the Carboniferous and the Jurassic.

The Kootanie.—Overlying the Jurassic conglomerate bed (number 6 of the section) there is a series of rather thinly bedded sandstones of varying degrees of coarseness and induration. Near the mountains these rocks are ferruginous and bright red in color, but farther away from the uplift they are white and contain intercalated beds of shale and ferruginous sands. A 5-foot bed of dense yellow sandstone, quite impure and argillaceous, forms a recognizable division of this sandstone series. The

* Cf. W. H. Weed, Cinnabar and Bozeman Coal Fields: Bull. Geol. Soc. Am., vol. 2, 1891, pp. 352-360.

coal occurs above this sandy belt, 1,479 feet above the mountain limestone of the Carboniferous and 520 feet above the conglomerate carrying Jurassic fossils.

No plant remains whatever have been found in the shales resting upon the coal. Careful search was made at every opening of the seam for traces of plants, but with the same lack of success that attended the efforts of previous investigators. Slabs containing indeterminate shells of *Unio* were once sent to Professor Newberry as coming from the roof of the seam, but I found no fossils of any kind.

Overlying the coal seam there is a prominent ledge of massive and dense coarse sandstone capped by a series of rapidly alternating beds of lilac-tinted or pink sandstones and red and purple shales. Like the same beds at Great Falls, the sandstones form an excellent building stone. This series is capped by an impure yellow limestone full of gasteropod shells, which were forwarded to Dr. White for examination. His assistant, Mr. T. W. Stanton, reports that these fossils consist of three forms of fresh or brackish water types, viz, (1) *Neritina*, sp., resembling *Neritina* (*Neritella*) *nebrascensis*, M. and H., from supposed Jurassic beds at the head of Wind river, though the specimens (casts) are not well enough preserved for positive identification; (2) *Goniabasis* (?), sp., some of the more distinctly carinated forms very much resembling *Goniabasis tenuicarinatus*, a Laramie species, though it is probable that all the elongate gasteropods in this collection represent a single variable undescribed species belonging to that section of *Goniabasis* which includes *G. tenuicarinata* and *G. aultortuosa*; and (3) some fragments of a small bivalve that may belong to the genus *Corbula*.

The beds from which the plant remains determined by Professor Newberry were obtained are similar to those lying above the coal seam and between it and this limestone, and they form the northern extension of the same horizon.

The section above given represents the general characters of the Kootanie formation throughout the field; briefly described, it is a series of rapidly alternating sandstones and clay-shales, with few and thin beds of impure limestone. Individual beds are inconstant, the heavy ledges of firm sandstone passing laterally into arenaceous clays, and *vice versa*.

The Dakota.—No definite recognition of the Dakota has been made, and therefore only an arbitrary upper limit of the Kootanie rocks can be assigned to the section on Belt creek. The gasteropod-bearing limestone just alluded to is capped by a massive and rather coarse sandstone bed 25 feet thick, which forms the top of the table-land 200 feet above Belt creek. This is covered by a series of shale beds, black, purple and red, carrying thin beds of sandy limestones and passing upward into a

decidedly arenaceous shale that resembles the shales frequently found in the Dakota of this region; but the typical Dakota conglomerate of more southern localities is entirely wanting, nor is there any distinct sandstone zone of sufficient importance to replace it. The section of 780 feet to the top of Belt butte shows a series of black carbonaceous shales with sandy and flaggy shales and thin beds of sandstone. Number 21 of the section is a bed of massive, coarse sandrock, 50 feet thick, that forms the "belt" about the butte, and number 24 is a white and hard limestone that forms the upper belt or crown. The top rock is a gray sandstone underlain by black carbonaceous shales. Careful search was made for fossils, but nothing whatever could be found.

As noted farther on in this paper, the coal seam passes under the creek (at the mouth of Little Belt creek); and beyond this point to its confluence with the Missouri, Belt creek cuts higher strata, the bluffs of the Missouri at fort Benton belonging to the Fort Benton group.

DESCRIPTIVE GEOLOGY.

As it was deemed quite important to establish the exact horizon of the coal seam relative to the shales from which the leaf remains were obtained, the beds were traced continuously by means of ledges exposed along the Missouri river and the walls of Sand coulée from Black Eagle falls to the coal mines at Sandcoulée and across the plateau from the latter place to the mines of Belt creek.

At Black Eagle falls, the first of the series of cascades below the city of Great Falls, the river bluff is about 150 feet high, exposing a good natural section, the rocks of which were even better exposed in the cuttings made for the dam and for the foundations of the smelter on the western side of the river. Arranged in tabular form, this section is as follows:

	Thickness in feet.
Hill top, on which the smelter chimney is erected.	
21. Sandy shale, greenish.....	20
20. Sandy shale, red and purple.....	15
19. Sandrock ledge, fissile, not prominent.....	5
18. Clay and red shale.....	15
17. Clay and sands, green and gray.....	3
16. Clay, red and leafy shale.....	5
15. Ironstone forming caps to sandstone pillars.....	1
14. Sandstone, crumbling, weathering into pillars and buttes; this is but a lens of sandrock in a clay series.....	10-30
13. Clays.....	10
12. Sandstone ledge; forms top of river bluff.....	25-30
11. Clay-shales, red and gray on weathered slopes, blue-gray in fresh exposures.....	50

	Thickness in feet.
10. Sandstone ledge, gray and hard.....	2
9. Shales, gray or red.....	15-20
8. Gray sandstone.....	5
7. Limestone, decomposed, brown, splintery.....	2½
6. Shale, easily crumbled, green-gray.....	5
5. Sandstone, passing into shales at base.....	7
4. Shale and shaly sandstone, rotten, red-brown.....	9
3. Sandstone, massive ledge, forming fall of river.....	7
2. Flagstone, purple and lilac sandrock.....	12
1. Sandstone, massive, square block jointing.....	5

At the top of the section there is a sandy series (numbers 16-21) whose erosion has formed most picturesque and brilliantly colored miniature badlands. The beds change rapidly horizontally, passing into the lilac sandstone (freestones) and clay-shales, the sandstone being an excellent building material and easily quarried and much used. The clay-shales interbedded with them hold the beautiful ferns identified by Professor Newberry. These beds rest on a massive layer of buff sandrock containing thin seams of lignite which, traced southward, is found to correspond to the sandrock above the coal seam. This ledge illustrates the difficulty of following a particular ledge of sandstone any considerable distance, for it passes into clays and sands a few miles to the northward, and is not a decidedly recognizable horizon at the south. Beneath this sandrock, forming the top of the bluff, there is an alternating series of clay-shales and sands, which are blue and gray where freshly cut for the walls of the new smelter, but generally weather reddish or brown; beneath these shales, a ledge of soft granular sandstone caps a series of soft clay-shales, resting upon the lilac-colored or pinkish sandstones forming the falls—rocks that pass laterally into red clays half a mile down stream.

Traced southward, the upper members of the section are seen to form the slopes about the city of Great Falls, the city dam being built on a sandstone ledge corresponding to number 12 of the foregoing section. South of the city the eastern bank of the Missouri shows exposures of red clays with freestones and shales that are quarried at a number of points between the city and Sandcoulée. At the mouth of the valley known as Sand coulée, where the creek empties into the Missouri, a ledge of white quartzose sandstone outcrops on the slope some 25 feet above the river; it corresponds in horizon to that on which the city is built, and forms a readily traceable ledge, extending up the coulée to the coal mines. It is capped by rather thinly bedded, square-jointed, lilac or pinkish sandstones and alternating slate beds, which form excellent building stone. Following these beds up the coulée the coal seam does not appear until reaching a branch of Sand coulée known as Straight coulée, on

which the Sandcoulée mines open, where the coal appears beneath the massive sandstone ledge traced up the valley. At the mines it is about 20 feet thick and is a hard white quartz rock. The coulée slopes are generally drift-covered, but a natural section is exposed where the wagon road ascends the plateau, showing the following beds:

	Feet
Sandstone	30
Shaly beds	25
Sandstone, square-jointed, buff; really a pebbly grit	3
Shaly beds, purple and red, crumbling	(?)
Shaly beds, pebbly, gray and green, crumbling	(?)
Sandstone ledge, same as that over coal; no coal seen.	

Where the wagon road descends into Straight coulée, near the coal banks, the following strata are exposed:

	Feet

Sandstone, forming summit of plateau.	
Sandstone and sandy shales, red and gray, alternating beds.	50
Shales and clays, red and buff.	50 to 75
Sandstone, forming bed above coal seam.	20
Coal seam.	12

FIGURE 4.—Section
on Sand Coulée.

The plateau summits are quite gently undulating surfaces, well grassed but bare of trees or shrubs, with a covering of glacial drift not of sufficient thickness to produce a marked drift topography but filling preglacial hollows. Boulders are not common but include a variety of rocks—granite, limestone, etc—found in the Belt mountains.

SANDCOULÉE BASIN.

Structure.—That portion of the Great Falls coal field adjacent to the Sandcoulée mines can best be alluded to as the Sandcoulée basin. In prospecting the field it has been found that the seam thins out toward both the north and the south from the mines. Toward the west the seam splits into two beds, separated by 25 feet of shale, but probably is continuous, if not workable, to the bluffs of Smith river, though the prospecting indicates a shallow basin.

The following section represents the strata exposed on McGriffin coulée, a branch of Sand coulée, near the coal mines:

FIGURE 5.—Section at Sandcoulée.

The only working within this basin and the chief mine of the entire field is that of the Sandcoulée Coal company. In the prospecting of the basin by this company several drill-holes were driven, which furnish complete sections of the strata above the coal seam. By the kindness of President Cocker* I have been placed in possession of the records of these drill-holes, sections of which are presented in the accompanying table. Though sections of precisely identical strata, they differ somewhat in detail and show the local changes of particular strata. The three borings, designated respectively as numbers 1, 2 and 3, lie in a north-and-south line at intervals of half a mile.

*I am under obligation to him and to Superintendent Burrill for many courtesies and for valuable information.

Diamond Drill Records at Sandcoulee.

FIGURE 6.—Sections revealed by Drilling at Sandcoulee.

NUMBER 1.	NUMBER 2.	NUMBER 3.
Soil 1' 6"		Soil 2'
Ironrock. 6' 6"		Sandstone..... 6'
Red shale..... 5'		Red shale..... 6' 6"
Sandrock..... 14'	Soil 1' 6"	Yellow sandstone 10'
		Pink shale 6'
		White sandrock 20'
		Hard yellow sandrock..... 5'
Clay and shale..... 10'	Light shale 9'	Light yellow sandrock..... 16'
Yellow sandstone..... 7'	Sandrock 4' 6"	
	Black slate..... 21'	Clay..... 3'
Black slate and mud..... 41'	Gray and black slate and clays..... 14'	Sandstone..... 4'
	Blue clays..... 18'	Black slate and mud.. 20'
		Limestone..... 3'
		Cream-colored shale... 12'
Blue clay..... 14'	Sandy yellow clay.. 15'	Yellow clay..... } 18'
Sandstone..... 22'	Limestone 7'	Limestone }
Clay-shale and mud. 10' } 20'	Sandy red shale..... 3'	Sandstone and conglomerate 6'
Light shale..... 10' }	Gray shale ("soapstone"). 32'	Slate, running into above... 33' 6"
Sandstone..... 19'	Sandstone..... 15'	Sandstone..... 12' 6"
Black slate and coal 2' } 8' 5"	Coal..... 0' 10"	Coal 6' 8"
Clay and slate 1' 6"		Slate 1' 5"
Dark slate and coal. 1' 4"		Coal 0' 11"
Slate..... 1'		
Slate and coal..... 2' 7"		
Black slate..... 3'		Slate 1' 5"
Clay 4' 6"		Clay..... 2' 1"

Sandcoulée Coal Mines.—The Sandcoulée coal mines are twelve miles from Great Falls by rail and six miles east of the Missouri river. Like the rest of the coal field, the country about the mines is a rolling plateau, locally cut by the numerous branch coulées tributary to Sand coulée. The mines are opened in the banks of one of these tributaries called Straight coulée. The coal lies beneath a sandstone ledge that generally outcrops upon the coulée banks, the slopes above it being generally grass-covered and showing no exposures. There is a slight dip of the beds to the northward, affording easy drainage and haulage.

The property now being worked shows an excellent fuel coal that can be economically mined and is near enough to the point of consumption to avoid excessive freight charges. Unfortunately for the early reputation of the product, the working was begun in an area of "dead" coal. Experience has shown that where tributary coulées have cut down the overlying strata the coal has lost its virtue and is high in ash and low in volatile carbon, and its physical constitution is such that it is of very inferior quality. It was in such an area that the early working was done; and this, combined with the fact that in mining the entire seam, as was formerly done, a large amount of slate got into the coal from the parting above the lower bench (a parting that is now used as a floor in the rooms), led to unmerited prejudice against the coal from this mine.

Throughout the workings at Sandcoulée the seam shows a considerable variation in thickness, the upper benches now worked being from 3½ feet to 7 feet thick. The quality also varies with the proximity to the surface of the overlying ground in the manner already stated, and appears also to depend somewhat upon the thickness of the slate roof between the coal and the overlying sandrock. For the first 1,000 feet from the main entry the coal is "dead," the gases having escaped through seams in the sandstone roof; and the coal east of this entry is similarly affected.

The following average section of the seam shows its character:

Top coal.....	23-28 inches.
	Parting.....	$\frac{3}{4}$ "
	Coal.....	10 "
	Parting.....	1 "
	Coal.....	24 "
	Parting.....	6- 8 "
	Coal.....	24 "

FIGURE 7.—Section
of Sandcoulée
Coal Seam.

On account of the thick parting above the bottom bench the coal is not mined except in driving entries. The top coal consists of an upper layer of 10 to 15 inches of dull and quite hard coal called "anthracite," but carrying quarter-inch streakings of bright coal. Below it the coal is mixed, dull and bright, down to the uppermost parting. The second bench is a bright bituminous coal and, like the bench below, is an excellent fuel, but carries balls of pyrite that cause much annoyance in mining and prevent the use of the coal for many purposes.

Samples representing the average quality of the different benches of coal were collected and have been analyzed for me by Dr. Stokes, of the chemical laboratory of the United States Geological Survey. The analysis of the top coal shows—

H ₂ O.....	3.66
Volatile hydrocarbon	30.88
Fixed carbon	55.50
Ash	9.96
	<hr/>
	100.00

A sample of the coal from the middle of the seam shows a very large amount of ash, and is evidently the cause of so much complaint that the coal output is dirty. The analysis gave—

H ₂ O.....	2.68
Volatile hydrocarbon	26.36
Fixed carbon	44.02
Ash	26.94
	<hr/>
	100.00

A third sample, from the lower bench, shows a cleaner coal, low in ash and higher in volatile combustible matter, possessing coking qualities that fit it for many uses for which the coals of the upper bench are not available. This bottom coal should be economically mined and separated with present methods of working. Under the present management the large amount of ash experienced in using this fuel must be charged to the coal itself and not to dirt from the partings.

An examination of the seam as exposed throughout the workings shows that the thin partings in the upper portion are quite variable in thickness and position and are occasionally wholly absent. Their maximum thickness is about 2 inches. The lower parting is always present and can be counted upon as to both position and thickness. As a rule the roof is good, there being from 6 to 18 inches of slate over the coal. When this slate is but 6 inches thick it is difficult to keep the roof up, but when it reaches 18 inches the roof is perfectly safe. Throughout the mine the roof rolls in gentle undulations.

The floor of the newer workings is the thick parting of slate over the bottom bench of coal. In driving the entries this lower coal is extracted, and there is some 3 feet of slate between the coal and the underlying sandrock. The floor rolls up and down a good deal but runs into regular strata.

The mine at present is worked by the pillar-and-room system. Two main entries are run, with side entries driven at right angles to them. The main entries are 24 feet wide, timbered where the roof slate is thin, but usually having a line of pillars in the center only. The right-angle entries are driven 12 feet wide at the roof and no timbering is necessary. The usual 30 feet of coal is left between the air entry and the main entries. The rooms are 24 feet wide, with a 12-foot pillar, and cross-cuts every 100 feet; but where the coal-cutting machines are used the rooms are 50 feet wide with a 15-foot pillar, and 20 feet between belts.

The miners are, as usual, paid by the amount of lump coal delivered, weighed as it is dumped over screens into box cars, an automatic scatterer being used for loading. The nut coal averages 15 per cent of the output, and there is 10 per cent of slack. The nut coal meets with a ready sale, and the slack is hauled away by the Great Northern railway and used as ballast. The cost of ordinary outdoor labor is \$2.50 per day. The miners are paid at the rate of \$1.00 per ton.

BELT CREEK BASIN AND MINES.

As the plateau summit between Sand coulée and Belt creek is drift-covered, no continuous ledge can be traced; but the low inclination of the beds and the exposures seen on Box Elder creek and its tributaries are sufficient to establish the identity of the coal strata of Belt creek with those of Sand coulée. The prominent features of the topography are the flat table-lands which extend eastward to the slopes of the High-wood mountains and southward to the uplands of the Belt range. Natural sections of the strata are found in small drainage cuttings trenching the plateau walls. These are sufficiently illustrated in the general section already given, which was made here.

The strata of the Belt creek basin possess a gentle northerly dip with an extremely gentle local anticlinal fold in the center of the basin. The rocks of the coal measures are the same as those found along Sand coulée. The coal lies beneath a cap-rock of hard quartzose sandstone 60 to 75 feet thick in the southern part of the basin, though but 25 feet thick at the Armington mines. It is a coarse gray, very massive sandstone, having a prominent outcrop tinted pink by the wash from the shales above. The slopes above this ledge are usually grassy and show

no exposures up to the summit of the table-land, 200 feet above the valley bottom at Armington; but sections of the rocks forming the table are seen in small lateral drainage cuttings.

The rocks beneath the coal are seldom exposed, as the seam is generally but 50 feet or so above the creek. Where the beds are cut by the railway line in the northern part of the basin the following rocks were found exposed:

FIGURE 8.—Section
near Belt Creek.

At Armington similar rocks are exposed near the railway bridge.

The largest opening is the Castner mine, which was formerly worked to supply the Fort Benton demand. The main entry is some 600 feet long, of which 115 feet only is timbered. In the rooms, pillars and caps are used to support the roof. The seam shows a total thickness of 12 feet, the uppermost 3 feet being too slaty and dirty to work and showing but 12 inches of coal. The bottom bench shows 20 inches of clean coal that is used for blacksmithing purposes.

On the eastern side of Belt creek is the Millard claim. The section of this seam is essentially the same as that of the Castner mine, as will be seen by the diagram (figure 10). In the room now being worked the seam shows the following section:

FIGURE 9.—Section
in Belt Field.

The coking coal is separated in mining and sold separately for black-smiths' use. The second parting is not separated.

Examinations of the coal bed, made at the various openings of the Belt basin and other parts of the Great Falls field, show the following sections:

Sections of Coal Seams of the Great Falls Field, Montana.

	Castner mine.	Millard mine.		Watson mine.	Armington mine.	Sand Coulee.
		Entry.	Room.			
Roof, sandrock ..						Sandrock Slate 9"
Slate	5"	10"	0	0	16"	Coal 28"
Coal	20"	20"	26"	24"	21"	3"
Slate parting	6"-10"	2"	4"	6"	6"-10"	10"
Coal	12"-15"	10"-12"	9"	12"-16"	10"	1"
Slate parting	4"	6"-8"	4"	6"-8"	3"-4"	24"
Coal	20"	24"	18"	30"-36"	14"	6"-8"
Floor						24"

FIGURE 10.—Sections of Coal Seams of the Great Falls Field.

The Belt creek mines are now worked only for household fuels, but their consolidation has already been effected and their further development is likely to be accomplished in the near future, now that railroad facilities are afforded by the Neihart road.

The coal seam thins rapidly north and south of Belt. On the north it is but 2 feet thick some two miles below Belt, and thins out near the mouth of Little Belt creek, where the coal dips beneath the creek bed. Toward the south the seam thins out and deteriorates in quality toward Otter creek, and although it has been found on Otter creek and opened near Mann post-office (Otter), the seam is but 3½ feet thick, the bottom bench only being workable.

An average sample of this coal taken by the writer and analyzed by Dr. H. N. Stokes, of the United States Geological Survey laboratory, shows the following composition :

H ₂ O.....	3.05
Volatile hydrocarbon.....	41.01
Fixed carbon.....	52.31
Ash.....	3.63
	<hr/>
	100.00

The roof here shows 10 inches of slate between the coal and the sand-rock, and the roof rolls slightly, pinching the seam. The two partings are always present, the upper one varying, the lower very constant. The top coal is long grained down to the lowest 4 inches, which breaks into dicey bits.

The Castner and Millard mines are in the center of the Belt basin. About a mile north of the latter the Watson mine shows the seam to be 11 feet thick, the upper 3 feet being too dirty to work. The section shows the seam to be quite dirty and the coal, particularly the lower bench, sulphurous. The roof is uniform and flat. The structure is as follows :

FIGURE 11. — Section at Watson Mine.

North of this mine the seam is not worth working, so far as shown by the prospects yet driven.

South of Belt there are several openings at Armington, which show the seam to be constant in character and to hold an excellent free coal. In the old entry of the Armington mine, abandoned on account of a roll of the seam, the following section of the coal was obtained 500 feet under cover :

FIGURE 12. — Section at Armington.

Similar sections at the other openings show that the seam, though less free from parting dirt than at Sandcoulée, is yet a valuable property. The coal from many of the openings shows peacock tints and, like that of Sandcoulée, holds pyrite balls. The openings at this part of the field show generally a firm sandrock roof over the coal.

OTHER PARTS OF THE GREAT FALLS COAL FIELD.

The Otter Creek coal has already been mentioned. The seam is too thin to pay working, and whether it thickens to the south in a continuation of the Belt Creek basin, as present indications appear to point, can be determined only by drill prospecting, as natural exposures are wanting.

Nothing is known of the eastern extension of the Great Falls field about Dry Arrow, Sage and Willow creeks and the Judith basin, save the notes made by Eldridge for the Northern Transcontinental survey, though the country has been prospected for several parties by local experts; but the seam shows a workable thickness that will be of value when the Judith basin is traversed by a railroad.

The western extension of the Great Falls field shows a promising thickness of coal at several points. The coal seam outcrops in the bluffs of Smith river and at Hound creek, but the openings are of small extent and are not worked at present. The coal seam is in a steep bluff some 300 feet above the river and shows a thickness of 5 feet 9 inches. Its character is much like that of the Sandcoulée coal—a roof of hard slate caps a dull coal, which lower down is streaked with bright coal. A thick parting of sandy shale separates this upper bench from a good coking coal below.

A mile and a half up Hound creek the seam is said to be but four feet thick and to thin rapidly toward the south. To the northward the seam thins out to four feet in the bluffs of Mings coulée, where it dips toward the south, showing a shallow basin.

The seam is also reported to outcrop at the base of the mountains at the head of Bird creek, near Chestnut, and but a few miles beyond.

As further exploration of the field is made in the search for special grades of fuel better fitted for metallurgical purposes, there will be more information available concerning the extent of the field and the geology of the Kootanie formation.

AGE OF THE GREAT FALLS COAL.

To Professor J. S. Newberry belongs the honor of first establishing the age of the Great Falls formation. The fossil plant remains upon which this identification rests have been obtained from two localities: (1) a

railroad cutting 5 miles above the mouth of Sun river; and (2) a ravine exposing the plant-bearing shales on the northern side of the Missouri opposite the city of Great Falls. At the first locality ferruginous concretions were obtained containing well-preserved leaf impressions. The following species have been reported from this locality by Professor Newberry:

Zamites montana, Dawson.

Podozamites latepennis, Heer.

Sequoia smittiana, Heer.

S. fastegata (?), Heer.

Professor Newberry says, "These plants prove beyond question that the Great Falls coal basin is of the same age with those that have been described north of the boundary line by Dr. George M. Dawson in what he has designated as the Kootanie series." "The strata here dip to the north, the coal passing under the barren sandstones and shales which form the falls of the Missouri, and all the bedded rocks are concealed by drift as far as observation has extended northward of the river." Detailed observations by the writer having confirmed this statement, the plant remains found in the rocks north of the Missouri and opposite Great Falls afford evidence of the Kootanie age of the coal measures, as well as proof of the age of the barren strata.

A small collection of plant remains obtained for the writer by Mr. H. S. Williams, of Great Falls, the discoverer of the first fossils found in the formation, was submitted to Mr. F. H. Knowlton and by him sent to Professor W. M. Fontaine, together with a collection made by himself. Professor Fontaine has written an interesting report upon these fossils, which will appear in the proceedings of the United States National Museum. The collections consist mainly of well preserved impressions of ferns, many of them new species, besides a number previously identified from this locality by Professor Newberry. There are in addition a few conifers and an equisetum.

The most interesting feature of Professor Newberry's latest paper was the correlation of the Great Falls, Kootanie and Potomac formations, the fossil floras of all three having many species in common. This is sustained by the later collections mentioned above, though most of the species identified by Professor Fontaine have not been identified in the Great Falls formation before.

2. NOTES ON THE ROCKY FORK COAL FIELD OF MONTANA.

LOCATION AND GENERAL FEATURES.

The Rocky Fork coal field lies at the foot of the Beartooth mountains and south of Yellowstone river, Montana. The quality of coal, the thickness and great number of the seams, with the unproved extent of the field, make it of great importance notwithstanding the distance to the larger centers of consumption. A branch line leaves the Northern Pacific railway at Laurel, 13 miles west of Billings, and runs up Clarkes fork of the Yellowstone and its tributary, Rocky fork, to the mines and the mining town of Red Lodge.

The topography of the field is of a type common along the eastern base of the mountains. Very gently sloping plains abutting sharply against the steep rocky slopes of the mountains stretch out for many miles northward. These plains are trenched by longitudinal drainages, the larger streams from the mountains flowing in rather broad gravel-filled valleys, the smaller streams heading in the plateau cutting down the benchland slowly and exposing the tilted and eroded rocks which form the mesa. Toward the south the mountains rise abruptly in rocky, buttressed slopes to the crest of the Beartooth range, an unexplored glacier-crowned mountain mass having the highest peaks in Montana. Toward the north the table-land fades into the benchland and rolling hills of the Crow reservation, a well watered country with broad alluvial bottom lands and well grassed uplands, greedily coveted by the settlers of the surrounding country. The mountain slopes and valleys are wooded with a heavy growth of pine timber, but the table-lands of the coal field are bare of trees and shrubs, save along the water-courses, though well grassed and bright with the colors of innumerable flowers.

The general features of the geology of the region are simple; a section shows a series of sandstones resting on the marine cretaceous in the valley of the Yellowstone, dipping gently from 3° to 5° toward the mountains but disturbed by gentle warping of the beds. These sandstones, which near the mountains dip more steeply (averaging 15°) and carry the coal seams, are faulted against the Paleozoic limestones which form the mountain flanks; the latter weather in great combs and ledges, dipping away from the mountains at high angles.

The benchlands which form so conspicuous a feature of the coal field are covered by a thick mantling of more or less rounded drift, sometimes to a depth of 160 feet. This gravel effectually conceals the truncated

edges of the underlying coal measure sandstones and makes it extremely difficult to outline the extent of the field.

A very brief but comprehensive account of the coal seams of this field was published by J. E. Wolff,* who visited the locality before the mines were opened.

EXTENT OF THE FIELD.

Very little is thus far known of the extent of the Rocky Fork field. Prospecting has been confined to the vicinity of the Red Lodge mines, being chiefly done in the broken country to the eastward, where the deep trenches of streams have exposed the coal seams. The coal has been traced and found to be workable at least as far eastward as the Clarkes fork bottom. Westward no prospecting whatever has been done, and therefore the presence of the coal is not proved; but the same geological structure and the same rock series has been found by the writer to extend for many miles westward, and there is no reason to doubt the continuity of the coal measures in this direction, although prospecting with drills will be necessary to prove the value of the land.

The southern boundary must perforce be the fault line that runs along the base of the mountains; the northern boundary of the field is at a variable distance of 3 to 4 miles from this fault line, according to the dip of the beds.

THE COAL MEASURES.

Structure.—The coal seams occur interbedded with coarse gray and buff sandstones and thin clayey shales, such as characterize the coal rocks of the Bozeman field. Fossil leaf remains are found in these sandstones and rather well preserved shells of *Unio* in the slates over the coal. The total number of coal seams is not known, but nineteen have been examined, of which six have been mined at Red Lodge. Of the nineteen seams examined, eleven show over six feet of coal.

About the town of Red Lodge the coal measures outcrop as heavy sandstone ledges and shale belts on the eastern bluffs of the valley. The prevailing dip is 15° southward or toward the mountains. The eroded edges of the beds are covered by gravels known to be from 20 to 160 feet thick in the vicinity of the town and forming the surface of the level benchlands in which the valley is cut. On the south the beds flatten out toward the fault that brings the coal measures against the white limestones of the Paleozoic. The coal rocks are cut by a dike of igneous rock a mile above the town, a prominent ledge that was traced for several miles to the eastward, trending southeasterly. The creek, issuing

* Tenth Census, vol. xv, Washington, 1886, p. 755.

from the mountains through a sharp cut in the upturned limestones above the town, flows through the boulder-filled channel, whose well grassed valley slopes show no exposures until the town is reached.

To the westward, crossing the broad benchland cut by shallow grassy drains, the low ridge about 3 miles from the town forms the terminal edge of a rising alluvial or wash slope or cone, the drift being wholly local and mainly limestone from the neighboring mountain slopes. About the head of a considerable drainageway that has cut down into the soft sandstones overlying the coal measures, the strata are seen to dip gently southward toward the fault. The rocks are mainly sandstones, rather soft, and weathering into loose sands that form smooth grassy slopes, with intercalated clayey shales and more rarely thin beds of limestone. Westward the country is more broken and the slopes show similar southward-dipping beds, while toward the north the broad benchlands continue for many miles. East of Red Lodge the branches of Bear creek, a lateral tributary of Clarkes fork, have cut back the bench, forming a deeply gullied and hilly country, locally called "badlands." Here the coal measures lie much flatter than at Red Lodge, and the coal seams have been prospected at a great number of points. It is a promising part of the field, but is dependent upon a railroad for its development.

Red Lodge Mines.—The only mines now operated in the Rocky Fork field are those of the Rocky Fork Coal company at Red Lodge; to Dr. Fox, the manager, and the other officers of this company, I am indebted for many courtesies and much information. Six seams have been worked, three of which are not being mined at present, owing to their inferiority to the others. The seams have an average thickness as follows: Number i (most southerly seam mined), 6 to 7 feet; number ii, 7 to 10 feet; number iii, 6 to 7 feet; number iv, 12 to 13 feet; number v, 12 feet; number vi, 5 feet.

Number vi is geologically highest of those worked, but 120 feet above it there is a 3-foot seam of coal, and 600 feet farther up the creek an 18-inch seam of coal. Below number vi there are nine seams outcropping in the creek bluff, of which five show over 6 feet of coal, the best being perhaps number viii. The farthest seam is about a mile below the mines and is opened by a drift 100 feet long. The coal is 6 to 7 feet thick, strikes east-and-west magnetic, and dips 10° southward. The rocks between this seam and the mines are sandstones and gray shelly shales, barren of fossils and strictly conformable. No outcrops occur below this seam.

Number i is no longer mined. It is the original "Yankee Jim" seam, and is a good coal; but the other seams are worked cleaner. The tunnel was not safe to enter, owing to gas, so that no section was obtained.

Seam number ii is opened by an entry main 2,000 feet in length. Cross-sections of this seam, made at the end of this entry, and of seam number

iii, show the benches and partings represented in the first two columns of the accompanying table and figure 13. Seam number ii dips southward 15° . The upper bench of coal, 24 inches thick, is left up in the rooms to form the roof. The sandstone lying above the seam occasionally cuts out the slate over the coal. The thickness of coal is 7 feet 8 inches; coal worked, 5 feet 2 inches. The roof of seam number ii is a soapstone. This seam, though showing several thick benches, is not worked on account of the partings. If worked in the future it will be by the long-wall method.

Coal Seams of Red Lodge Mines.

FIGURE 13.—Coal Seams of Red Lodge Mines.

<i>Number ii Section.</i>	<i>Number iii Section.</i>	<i>Number iv Section.</i>	<i>Number v Section.</i>
Sandstone roof.			
Slate 6"		Coal 18"	Coal 6"
Slate 2"		Clay 3"	Parting 1 1/2"
Coal 6"	Coal 36"		Coal 4"
Slate 2"	Slate 2"	Coal 36"	Parting 1"
	Coal 7"	Coal 40"	Coal 2"
Coal 24"	Slate 1 1/2"	Parting 6"	Parting 1 1/2"
	Coal 5"	Coal 13"	
Parting 2"	Slate 2"	Parting 3/4"	Clay 2"
Coal 18"	Coal 6"	Coal 17"	Coal 10"
Dirt 6"	Clay and } 6"	Parting 1"	Parting 1"
Coal, clean, } 40"	dirty coal }	Coal 24"	Coal 4"
shackly, } 40"	Coal, clean ... 24"	Parting 1/2"	Parting 1"
fractured.. }	Fire-clay... 6"-18"	Coal 18"	Coal 30"
Parting 1"		Coal 17"	Fire-clay 8"
Coal 4"	Coal 48"	Parting 1/2"	Coal 9"
Fire-clay 6"		Coal 8"	Coal dirt 5"
Sandstone.	Slate.		Coal 24"
			Dirty coal ... 10"
			Coal with } 30"
			lenses of } 30"
			parting. }

The fourth and fifth seams show the structure indicated in the diagram. The sections of seam number iv do not, of course, give the entire width of the seam, but only the portion worked. The roof is a firm sandstone, so that only the main entry, 18 feet wide, is timbered, and the slope the same. The seam is opened by a half mile of entry and a slope of 600 feet. These workings show the seam to have a dip of 18° at outcrop and 16° at the bottom of the slope, the roof being very constant. The floor is a soft gray shale having a slight roll. The lower partings of the seam are very constant, but the uppermost parting is quite variable in thickness. The seam has a nearly uniform thickness of 12 feet, of which 20 inches is left to form the roof over the rooms. The roof of this seam rolls considerably.

A 5-foot seam of coal lies between seams number iv and v, with 35 feet of rock between it and number iv; but the seam has too many partings to be workable.

Number v is but little worked, the mine being abandoned on account of the partings and the prevention of economical working by the bottom coal. The roof rolls but very little, not so much as number iv. The coal above the 30-inch bench is all one bench, or has but thin partings, of no consequence farther in.

Seam number vi is 5 to 6 feet thick and shows a clean bench of coal having only one parting of an inch in thickness about midway. The coal is bright and breaks into prismatic masses with hackly fracture. The roof rolls in strong waves and the floor also rolls. No timbering is done in the entries of seams numbers v and vi, but though the roof of number vi is a hard sandstone it is crushing in the rooms and is held up by timber cribs.

While the seams numbers i, iii and v are not mined at present, owing to the greater profit of mining the other seams, they are valuable for future supply.

The Rocky Fork Coal company holds 3,440 acres of property, being a strip about two miles wide (the entire width of the outcropping seams of the field) and some three miles long, comprising the high benchland and broken country about the head of Bear creek, east of Rocky Fork creek. To the eastward the seams flatten out to a dip of 5° , with low arching of the beds.

Bear Creek Mines.—In this eastward extension of the field the area available for mining has a much greater width, as the beds flatten out gradually toward Clarkes fork. In general the trend of the field is toward the southeast. Numerous locations have been made and short prospect entries driven on the seams that outcrop in the sides of the gulches. The most extensive working has been made by agents of Butte capitalists,

who opened a 7-foot seam of coal, but abandoned it after a year's working. Coal taken out of the old prospect entry near by, that has been exposed for three years, is hard and firm.

Taggart's claim, 4,500 feet in altitude by aneroid, shows a dip of 1° to 2° toward the south. A short entry shows the following section, which was taken at the outcrop and does not, therefore, fairly represent the seam :

Solid sandrock.....	
Decomposed brown clay.....	36''
Coal	24''
Lignite bone.....	42''
Coal, forming entry roof.....	12''
Bony, dirty coal.....	12''
Clean coal.....	4''
Slaty dirt parting.....	2½''
Coal, clean.....	23''
Carbonaceous slate parting.....	5''
Coal.....	24''

This part of the field can be mined cheaply, owing to the flatness of the seams ; but the narrow gulches give no dumping ground. The lack of transportation is the only great obstacle to the rapid development of the mine.

Near Clarkes fork the ridge shows a heavy outcrop of sandstone composed of granitic grains and forming ridges 150 to 175 feet high, the beds dipping southward 4° , and coal seams lying beneath the sandstones. East of Clarkes fork the soft clays of the Tertiary (?) appear, the river cutting through a low synclinal arch.

The continuity of the coal field toward the southeast is interrupted by the river valley and the eroded basin of Grove creek, now a broad wash-plain. At the head of this gravel plain the Cretaceous sandstones and clays, carrying lignites, dip 5° toward the mountains, the summit being about 5,320 feet in altitude, and the ledges abutting against a Carboniferous conglomerate dipping northward 75° and underlain by massive limestone cut into picturesque, castellated forms by the mountain torrents. The fault line extends southeastward, so far as can be seen, at least a couple of miles beyond here. From this point to the most westerly spot visited, some eight miles in all, the structure is the same. East of Clarkes fork, Pryer mountain shows beds dipping southward.

AGE OF THE ROCKY FORK COAL.

Below seam number i there is some 60 feet of sandstone weathered down to a slope, with a bold outcrop of massive sandstone some 30 to 40 feet in thickness below it. This rock is coarse, formed of granite débris,

and is cross-bedded and pitted. It shows poorly preserved leaf remains. Fossil leaf remains occur in a better state of preservation in the sandstones between numbers iv and v, where they have been quarried for building purposes. A collection made by the writer has been studied by Mr. F. H. Knowlton, who reports the species to present a decidedly Fort Union facies.

The remains of *Unio* obtained from the roof of seam number iv have been examined by Dr. C. A. White, who reports them to belong to two species, *Unio senectas*, White, and *Unio danæ*, M. & H. These species are of too widespread occurrence in the fresh-water Cretaceous rocks to fix any definite horizon.

In the lack of definite structural evidence of the age of the coal measures, we must therefore rely upon the plant remains. These are of Fort Union types and belong to a flora quite distinct, so far as studied, from that of the true Laramie, or that of the Livingston beds of the Bozeman coal field farther westward.