THE SOUTHERN EXTENSION OF THE MILK RIVER COAL FIELD, CHOUTEAU COUNTY, MONTANA.

By Leon J. Pepperberg.

INTRODUCTION.

Field work.—During the summer of 1908 the writer,[1] assisted by V. H. Barnett, surveyed about 2,000 square miles of the Milk River coal field in Montana. The present paper describes the southern extension of that part of the field lying between the Bearpaw Mountains and the Fort Belknap Indian Reservation. The results given are based on a detailed survey in 1909 by J. H. Bridges, L. V. Arbogast, P. L. Hall, jr., and the writer. As the object of the investigation was the classification of the public lands with respect to coal, the work was conducted primarily with the view of ascertaining the extent of coal areas and their relation to land subdivisions. Planetable-stadia methods were used for tying coal outcrops and prospects to section corners, mapping geologic boundaries, carrying levels, triangulation, and general mapping. The field work was done on a scale of 2 inches to the mile.

Previous reports.—The Milk River coal field has not been examined in detail by previous workers. The most important work published prior to the investigation of 1908 is that of T. W. Stanton and J. B. Hatcher.[2] Their report, which deals with the geology and paleontology of the Judith River formation, contains a review and bibliography of publications relating to this formation in Montana and Canada. Brief mention of this field is made in a report by J. P. Rowe [3] and the field is referred to in several reports of the inspector of coal mines of the State of Montana and in the "Mineral Resources of the United States."[4] The glacial geology of the region has been briefly discussed by F. H. H. Calhoun,[5] and papers describing the prominent features of the Bearpaw Mountians with special reference

[1] The Milk River coal field, Montana: Bull. U. S. Geol. Survey No. 381, 1910, pp. 82–107.

[2] Geology and paleontology of the Judith River beds, with a chapter on fossil plants by F. H. Knowlton: Bull. U. S. Geol. Survey No. 257, 1905.

[3] Montana coal and lignite deposits: Bull. Univ. Montana No. 37 (Geol. series No. 2), 1906, pp. 39–40.

[4] Mineral Resources U. S. for 1908, pt. 2, U. S. Geol. Survey, 1909, p. 140.

[5] The Montana lobe of the Keewatin ice sheet: Prof. Paper U. S. Geol. Survey No. 50, 1906.

to igneous rocks have been prepared by W. H. Weed and L. V. Pirsson.[1]

The writer[2] has described the cement materials near Havre, Mont., and has also written a paper on the principal mineral deposits of the Bearpaw Mountains.[3]

Location and extent.—The part of the Milk River coal field herein described is located in Chouteau County, north-central Montana, and embraces the following six townships: Tps. 31 N., Rs. 16 to 19 E., Tps. 30 N., Rs. 17 and 18 E. It is bordered on the west by the Fort Assinniboine Military Reservation and lies about 7 miles south of Milk River and the Great Northern Railway.

TOPOGRAPHY AND GEOGRAPHY.

The area under consideration is situated in the northwestern part of the Great Plains region. For the most part it is covered with a fair growth of grass and scattered patches of sagebrush. Trees are noticeably absent, except along the larger creeks, where cottonwood, willow, and underbrush grow close to the drainage ways, and along some of the lava-covered ridges, where there are scattered scrub cedars, aspens, and here and there a pine or fir. When viewed from the highlands the country has a rolling aspect, exhibiting no abrupt changes except where cut by the larger tributaries of Milk River and where ridges and buttes due to geologic structure or the occurrences of igneous rock stand out prominently in comparison to the surrounding flat treeless plains. This area has an average elevation of about 3,000 feet above sea level.

The region is drained by a few large creeks which head in the Bearpaw Mountains and flow northward and northeastward into Milk River. The tributaries of Milk River are for the most part intermittent streams, but the drainage ways contain local water pockets and a few springs which afford watering places for stock. As a rule, this water is too alkaline for domestic use. The bench land is studded with numerous small intermittent lakes which occupy shallow depressions in the glacial drift. The water in these lakes, especially in the smaller ones, contains salts leached from the soil and is therefore alkaline. The field season of 1909 was unusually wet, and Boxelder, Clear, Bean, and Snake creeks carried a large amount of water throughout the summer.

The principal railroad towns near this area are Havre and Chinook, situated along the main line of the Great Northern Railway, which lies about 7 miles north of the northern boundary of the tract examined during 1909.

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[1] The Bearpaw Mountains, Montana: Am. Jour. Sci., 4th ser., vol. 1, 1896, pp. 283-301, 351-362; vol. 2, pp. 136-148, 188-199.

[2] Cement materials near Havre, Mont.: Bull. U. S. Geol. Survey No. 380, 1909, pp. 327-336.

[3] Notes on the mineral deposits of the Bearpaw Mountains: Bull. U. S. Geol. Survey No. 430, 1910, pp. 135-146.

GEOLOGY.

STRATIGRAPHY.

The sedimentary rocks which outcrop in the part of the Milk River coal field under discussion consist of sandstones and shales belonging to the Montana and Colorado groups of the Cretaceous system, with the exception of a small infaulted Tertiary area in the southwest part of T. 31 N., R. 19 E. These rocks are largely covered by glacial materials on the bench-land areas and by alluvium in the larger valleys. In a few places they are cut by igneous intrusions or are covered by lava flows.

The following formations outcrop in the Milk River coal field:

Stratigraphy of the Milk River coal field, Montana.

System.	Series.	Group.	Formation.	Thickness (feet).	Description.
Quaternary.	Recent.				Alluvium.
	Pleistocene.				Glacial drift.
Tertiary.	Eocene.		Fort Union formation.	60+	Massive gray to buff sandstone, with thin beds of gray shale, containing many fossil plants and beds of subbituminous coal.
Cretaceous.	Upper Cretaceous.	Montana.	Bearpaw shale.	80-100	Leaden-gray shale, with thin beds of sandstone and large concretions, usually fossiliferous.
			Judith River formation.	480	Alternating beds of light-colored sandstone and shale, with important subbituminous coal beds in the upper 150 feet.
			Claggett formation.	350+	Dark-gray shale, with thin beds of buff sandstone near top and bottom, and large concretions, some of them fossiliferous.
			Eagle sandstone.	250	Massive, slightly calcareous white to cream-colored sandstone, locally cross-bedded; at top dark-gray shale, with intercalated beds of gray to buff sandstone.
			Colorado shale.	1,000+	Drab or lead-colored clay shale carrying round or oval concretions of gray limestone.

CRETACEOUS SYSTEM.

UPPER CRETACEOUS SERIES.

COLORADO SHALE.

The Colorado shale is the oldest formation outcropping in the area examined during 1909. It consists of drab or lead-colored clay shale carrying round or oval concretions of gray limestone, thin beds of calcareous sandstone, and in places thin strata of impure limestone. This shale, though similar in color to the Claggett formation and Bearpaw shale, differs from them lithologically in being slightly more calcareous and compact and containing more limestone members. Fossils collected from this shale have been examined by T. W. Stanton and found to be of Colorado age.

MONTANA GROUP.

Eagle sandstone.—The Eagle sandstone overlies the Colorado shale conformably. Only the lower portion of the formation is exposed in this area, and the following description is given in order to show the character of the formation where good and continuous exposures are found in the Milk River field. The lowest member of this formation is a massive, calcareous, white to cream-colored, persistent, usually hard, and locally cross-bedded sandstone about 100 feet thick. Wherever the base of the Eagle is exposed it constitutes a horizon marker that is easily recognized. In the upper 30 feet of the formation are numerous concretionary lenses of hard sandstone, some of which are highly stained by iron. These harder parts resist the effect of weathering much better than the rest of the sandstone and stand out as prominent knobs or cap thin rounded or angular spires of the underlying softer material. In places the entire massive stratum forms a steep cliff several miles in length and about 100 feet in height.

In the upper part of the Eagle sandstone, which has a thickness of about 150 feet, the sandstone strata are thin and more friable than those in the lower part. Sandy shale and carbonaceous layers with streaks of coal predominate in the lower half, but the upper half is principally dark-gray shale with a few intercalated beds of gray to buff sandstone. The difference in composition of the two members of the Eagle is very pronounced. Overlying the massive white bed of sandstone are a number of coaly beds and layers of carbonaceous shale which give this zone a dark color. The upper member, being much softer than the lower, weathers into long, rounded slopes. Coal beds 6 to 8 inches in thickness were observed, but the greater part of the carbonaceous matter consists of black shale interbedded with fine laminæ of coal.

Claggett formation.—The Claggett formation does not outcrop in the area under consideration, but as it forms a part of the geologic column of the Milk River coal field, the following description is given to show the character of the formation as it appears where exposed. The Claggett consists chiefly of dark leaden-gray shale intercalated with thin beds of buff sandstone near the top and bottom. It overlies the Eagle conformably. It is very similar lithologically to the Bearpaw shale, from which, without the aid of stratigraphic or paleontologic evidence, it is often distinguished with difficulty.

Gypsum flakes or crystals are scattered throughout the soft shale. Hard concretions of different sizes up to several feet in diameter are numerous, especially near the top. The concretions are calcareous and are usually traversed in all directions by cracks filled with amber-colored calcite or gypsum crystals. Invertebrates are found in the shale, but more often in the calcareous concretions, although they are not so abundant in this formation as in the Bearpaw shale. Coal does not occur in this formation, although there is some thin carbonaceous shale near the top. The Claggett in this field has an estimated thickness of 350 feet.

Judith River formation.—The Judith River formation overlies the Claggett conformably and is composed of beds of sandstone, shale, and coal. The Judith River is the important coal-bearing formation of the Milk River field. It is almost entirely of fresh-water origin, but some brackish-water beds are included at the top in the transition zone between the Judith River and the marine Bearpaw shale, and also at the base in the transition from the marine Claggett to the fresh-water Judith River formation. There is no persistent bed in the entire formation which can be followed for any great distance. The sandstone is ash-colored, is locally cross-bedded, and contains iron-stained concretionary bands. In some places it is hard and massive; in others it is soft and friable. The shales, sandstones, and coals of this formation are very lenticular, and it is common to find a massive sandstone grading into a soft shale or a sandstone or shale grading into a carbonaceous shale or thin coal bed within a comparatively short distance horizontally. In the same manner a coal bed which consists of clean coal of considerable thickness may pinch out altogether and be replaced by a sandstone at the next exposure half a mile away. A coal bed from 1 to 12 inches thick was observed in the base of the Judith River, but the most important coal beds occur in the upper 150 feet of the formation. It has a total thickness of about 480 feet.

Bearpaw shale.—The Bearpaw shale overlies the Judith River formation conformably and consists of dark leaden-gray shale containing thin beds of sandstone and large concretions, many of which are highly fossiliferous. These round and oval bodies are fissured and the cracks are usually occupied by calcite. Selenite or gypsum flakes are scattered throughout the formation.

As previously stated, the Bearpaw and Claggett are very similar lithologically. Both are leaden gray in color, both contain similar concretionary masses and thin beds of sandstone and both weather into long, rounded slopes and form barren patches of loose weathered shale. The Bearpaw, which is represented by observed outcrops 80 to 100 feet thick in this field, has a known thickness of 350 to 900 feet in other parts of Montana.

TERTIARY SYSTEM.

EOCENE SERIES.

Fort Union formation.—Abundant fossil plants, which are, according to F. H. Knowlton, of Fort Union age, were collected from a sandstone stratum beneath a coal bed in the SW. ¼ NW. ¼ sec. 28, T. 31 N., R. 19 E. The Fort Union outcrops along a branch of Bean Creek in a faulted zone close to a small igneous intrusion, where it occupies only a small area. From the few outcrops observed it was impossible to determine which part of the formation is present in this locality, but it may possibly correspond to the yellow beds of the formation as developed in northeastern Montana and northwestern North Dakota. Lithologically the Fort Union is notably different from the Judith River formation; it consists chiefly of massive strata of gray to buff sandstone, which are very persistent, and of thin beds of gray shale. The Fort Union is an important coal-bearing formation and in the area under consideration contains a thin bed of good coal. The position of the Fort Union in the geologic column is several hundred feet above the coal-bearing Judith River and its occurrence in this area is accounted for by a fault having an estimated throw of not less than 500 feet.

QUATERNARY SYSTEM.

Among the features which should be fully described in any complete account of the region are several types of glacial and alluvial deposits, such as ground and recessional moraines, kames, eskers, drift, till, and river and lake deposits, which cover the greater part of the area. These features of recent glaciation and erosion can be only mentioned here.

IGNEOUS ROCKS.

Igneous rocks of both intrusive and extrusive types make up a number of prominent ridges and buttes in the area examined in 1909. These rocks, which are of post-Eocene age, in general have had little or no effect on the coal of the region.

STRUCTURE.

As the Milk River field is largely covered by glacial and alluvial material and continuous exposures for great distances are lacking, the geologic structure is very obscure. Except in a few places where the glacial cover is extremely thin, the only outcrops present in the field are along the lines of drainage where erosion has removed the glacial mantle. At these places the sedimentary rocks outcrop in small patches or long, narrow strips on either side of the coulees and along well-drained slopes. These rocks, which were originally approximately horizontal, have been disturbed by numerous faults and folds which make the determination of the stratigraphy rather difficult. A vivid idea of the abundance of these disturbances is given by Hayden [1] as follows:

> The most remarkable feature of this basin is the wonderful disturbance of the strata. So much are the beds disturbed and blended together by forces acting from beneath that it seems almost hopeless to obtain a section showing with perfect accuracy the order of superposition of the different strata.

The faults of the Milk River field are too numerous to be described individually. They are in general closely associated with folds and for the most part are of the thrust type, although a few normal or tension faults were observed. The faults are best developed in the regions where the folding has been greatest. The larger thrust faults were probably produced at about the same time as the folds with which they are associated.

The disturbances mentioned have caused lateral and vertical offsets of the coal beds, in many places tilting them to high angles.

THE COAL.

OCCURRENCE.

The coal of the Milk River field is a fair subbituminous ("black lignite") grade. Most of the beds are lenticular in shape, showing a variation in thickness from a fraction of an inch to 8 feet at different points on the outcrop. Generally there is one bed, in some localities two, and in others three beds of considerable thickness. Most of the coal occurs in the upper part of the Judith River formation, from 10 to 150 feet below the base of the Bearpaw shale, the only exception being the coal in the SW. ¼ NW. ¼ sec. 28, T. 31 N., R. 19 E., which is of Fort Union age.

On account of the small number of mines and prospects in the area it was necessary to study the coal largely from the weathered outcrops of the beds, the method employed being as follows: A careful search for outcrops of coal beds was made in coulees and ravines over the whole area. All coal beds thus found were traced by planetable-stadia traverse until they pinched out, were covered by glacial or alluvial material, or were cut out by faults. In the vicinity of the mines and prospects visited and all coal outcrops traversed the topography was sketched and tied to the nearest Government land corners and all coal beds were measured. Samples for chemical analysis were taken from the principal beds at the mines and prospects throughout the area.

The examination showed that the land surveys were well made and the section and quarter section corners were so well established that

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[1] Hayden, F. V., Proc. Acad. Nat. Sci. Philadelphia, 1857, p. 116.

no difficulty was experienced in locating a corner when it was desired to tie a coal outcrop, prospect, or other feature to a known point. About 98 per cent of all section and quarter section corners looked for during the examination were found.

The extensive glacial and alluvial covering in this field and the slumping of talus obscures the outcrop of coal over large areas, making the continuous tracing of coal beds impossible. All the localities in this area where coal is exposed are given below with the detailed descriptions. Future exploitation of the field must depend largely upon drilling.

DETAILED DESCRIPTIONS.

The sections given in the following pages show the thickness and contents of coal beds examined at the localities indicated.

T. 31 N., R. 19 E.

Locality 1,[1] NW. ¼ SW. ¼ sec. 1:

Section at locality 1.

	Ft.	in.
Drift	10±	
Coal	1	6
Shale, brown.		
Total coal	1	6

Dip 20°–25° NW.

Locality 2, NE. ¼ SE. ¼ sec. 2:

Section at locality 2.

	Ft.	in.
Drift and alluvium	8±	
Coal	1	4
Bone	1	
Total coal	1	4

The top of this bed has been cut by erosion; the bottom was not uncovered.

Locality 3, SE. ¼ SE. ¼ sec. 2:

Section at locality 3.

	Ft.	in.
Sandstone, concretionary		6
Shale	1	6
Shale, carbonaceous	1	3
Coal		3
Shale, carbonaceous		1
Shale		9
Coal	1	1
Bone		1
Coal		1
Shale, blue	3+	
Total coal	1	5

[1] The locality numbers refer to locations on Plate XXVIII.

Locality 4, NE. ¼ NE. ¼ sec. 11:

Section at locality 4.

	Ft.	in.
Shale, carbonaceous, thin coal seams		4
Coal, with thin bony streaks	1	10
Shale, carbonaceous	2±	
Total coal	1	10

The sections given above are located in an area of very complicated structure, where the strata of the Judith River and Bearpaw formations are tilted at high angles in various directions.

Locality 5, SW. ¼ SW. ¼ sec. 2:

Section at locality 5.

	Ft.	in.
Shale, black and brown, carbonaceous, containing very little coal	2	7
Shale, estimated	5±	
Shale, carbonaceous	1	2
Coal, very dirty		6
Shale, carbonaceous	1	
Shale	3	
Shale, black, carbonaceous, containing very little coal	2	6
Total coal		6

Dip 25° S. 30° E.

Locality 6, NE. ¼ NW. ¼ sec. 3:

Section at locality 6.

	Ft.	in.
Drift	5	
Coal	1	8
Shale, carbonaceous, estimated	2	
Total coal	1	8

Locality 7, SW. ¼ SW. ¼ sec. 3:

Section at locality 7.

	Ft.	in.
Drift, part of coal bed eroded.		
Shale, carbonaceous		6
Coal, dirty, containing thin bone and shale		8
Coal	1	
Bone and clay		2
Coal, fairly clear	2	2
Shale, carbonaceous, with thin coal		6
Shale, carbonaceous, brown		5+
Total coal	3	10

This bed outcrops on the brow of a hill and shows as a smut through the thin glacial cover. The top of the bed has been planed off by the glacier. The cover is thin, consequently the bed is probably badly weathered.

Locality 8, SE. ¼ SE. ¼ sec. 4, near section corner:

Section at locality 8.

	Ft.	in.
Drift, thin, smut showing through.		
Coal, top of bed planed off by glacier.		
Coal, slightly bony	2	
Shale, carbonaceous and bone		4
Coal	2	2
Bone with coaly streaks		8
Shale, carbonaceous.		
Total coal	4	2

Locality 9, SW. ¼ SE. ¼ sec. 4:

Section at locality 9.

	Ft.	in.
Drift	3	
Shale, carbonaceous		10
Coal, dirty, poor	1	
Coal, slightly dirty	1	5
Bone		2
Coal, good	2	6
Shale, carbonaceous, and bone to bottom of pit.		
Total coal	4	11

About 50 feet north of the place where the above section was measured the bed has been burned, leaving red clinker and ash.

Locality 10, Henry Rader prospect, SW. ¼ SE. ¼ sec. 5: Coal, 3 feet 8 inches. This bed consists of almost clear coal. The entry was only 15 feet long when visited. Mr. Rader has opened five other prospects on the west side of this coulee, but all have been abandoned on account of water. At the time the locality was visited these abandoned prospects were caved in and could not be examined.

Locality 11, an abandoned prospect opened by H. Rader in the SW. ¼ NW. ¼ sec. 5:

Section at locality 11.

	Ft.	in.
Shale, gray, slightly carbonaceous.		
Coal, clear	1	1½
Clay, parting constant		2–4
Coal		3
Bone		1–2
Coal		6
Bone		4
Coal, slightly bony		3
Coal, clear	1	4
Bone		3
Coal		10
Shale, carbonaceous.		
Total coal	4	3½

This bed was sampled (No. 9150) for analysis about 105 feet from mouth of entry. (See p. 381.) The coal is hard, bright, and of good quality, but contains considerable bone which would be difficult to separate in mining. The roof is soft and requires timbering.

The bed lies almost flat in the prospect, with a slight dip southward. It has been burned for a distance of 25 feet at the mouth of the entry, forming clinker, ash, and tilelike material.

Locality 12, NE. ¼ NE. ¼ sec. 7:

Section at locality 12.

	Ft.	In.
Drift	15±	
Shale, carbonaceous		10±
Coal		3
Bone and shale, carbonaceous		4
Coal, clear	1	5
Clay		1–3
Coal		9
Bone, with thin coaly streaks	1	2
Shale, carbonaceous.		
Total coal	2	5

There may be more coal below and above this bed. The bed is almost flat, probably dipping 1°–2° S. The cover is thin.

Locality 13, NE. ¼ NE. ¼ sec. 7:

Section at locality 13.

	Ft.	In.
Drift.		
Sandstone, massive	3±	
Shale, carbonaceous, with thin coal seams		4
Sandstone, massive	3	
Sandstone, friable	4	
Shale, carbonaceous		8
Coal		2
Bone		8
Coal	1	
Bone		2
Shale, carbonaceous	2	
Shale, gray		8
Shale, carbonaceous, plant fragments	2	
Coal		8
Clay		½–1
Coal, slightly bony	1	3
Bone, with coaly streaks	1	
Coal		3
Bone and clay		6
Coal	1	2
Coal, with bony streaks	1	10
Shale, carbonaceous, partly covered		6±
Coal, with bony streaks	2	4
Bone.		
Total coal	8	8

A fault traverses Black Coulee west of this outcrop and is accountable for the local change of dip. A small east-west fault cuts the coal bed north of the point at which the section was measured. The general dip at this place is west and southwest. This bed presumably underlies the greater part of sec. 8, T. 31 N., R. 19 E., and is probably of good quality under cover.

Locality 14, NE. ¼ SE. ¼ sec. 7:

Section at locality 14.

	Ft.	in.
Sandstone, massive, buff	3–4	
Shale	1	4
Shale, carbonaceous, brown		3
Coal, clear		6
Shale, carbonaceous		10
Coal, clear		6
Shale		10
Coal, slightly bony	1	8
Shale, carbonaceous		7
Coal, slightly bony		8
Clay		1
Bone, carbonaceous shale, and thin coal streaks	2	
Coal		4
Bone and clay parting		4
Coal		3±
Bottom covered by water, probably more coal and bone.		
Total coal	3	11±

The above section was measured on the east side of the main coulee near the mouth of an abandoned prospect. This prospect is on the lower coal bed, which is covered by water in the coulee. The roof has caved in, but it is reported that a bed of fair coal more than 3 feet thick was worked at this place.

Locality 15, SE. ¼ SE. ¼ sec. 7:

Section at locality 15.

	Ft.	in.
Shale, slightly carbonaceous	1	
Shale, with gypsum bands		6
Shale, slightly carbonaceous		8
Bone		2
Coal, slightly bony	1	10
Coal, with bony streaks		11
Bone, with coaly streaks		9
Shale, carbonaceous, and clay	1	
Coal	2	6
Bone		2
Clay		½–1
Coal		5
Bone		1–3
Coal, clear	1	1
Shale, carbonaceous.		
Total coal	6	9

Dip 18° S. 85° W.

Locality 16, NW. ¼ SE. ¼ sec. 8:

Section at locality 16.

	Ft.	in.
Shale, carbonaceous, and thin coal	1	2
Shale and sandstone	5	
Sandstone	1–3	
Shale	1	4
Coal		2
Shale, carbonaceous	3	3
Sandstone, friable	2	
Shale, carbonaceous	1	5
Coal	1	3
Shale, carbonaceous, and bone		4
Sandstone, sandy, partly covered	2	2
Sandstone, containing plant fragments and mineral charcoal	3	7
Shale, carbonaceous		7
Coal		7
Clay		1–2
Coal		5
Shale, carbonaceous		4
Shale, slightly carbonaceous	1	3
Coal		7
Shale, black, carbonaceous		4
Shale, brown, carbonaceous	1	8
Shale	2	4
Shale, carbonaceous		2
Coal, clear	2	2
Shale, containing coaly streaks partly covered	2	2
Coal, clear		5
Coal, slightly bony	1	10
Shale, carbonaceous		1–2
Coal, clear, black		8
Clay		1–3
Bone		1
Coal, with a few thin bony streaks	1	
Shale, carbonaceous.		
Total coal	9	1

Locality 17, NE. ¼ NE. ¼ sec. 20:

Section at locality 17.

	Ft.	in.
Top of coal bed eroded.		
Bone		2
Coal	1	7½
Bone and shale, carbonaceous	1	1
Clay, gypsiferous		6+
Total coal	1	7½

The bed probably represents a coal zone of considerable thickness. The glacial cover in secs. 16, 17, and 20 is thin and many outcrops of smut were observed. The coal is badly weathered but shows coaly structure and under cover would probably prove to be of good quality.

Locality 18, an abandoned prospect in the SE. ¼ NW. ¼ sec. 17:

Section at locality 18.

	Ft.	in.
Drift.		
Coal, with thin bone and shale		10
Shale, carbonaceous, with thin coal and bone streaks		7
Coal, dirty, with bony streaks		10
Coal		10
Bone		2
Coal, clear		7½
Clay and bone, constant		1–3
Coal, clear	1	5
Bone		4
Shale, carbonaceous.		
Total coal	4	6½

The above section represents a bed from 5 to 7 feet thick (estimated). The top of the bed has been removed by glaciation. The clay parting is constant throughout the bed. The coal lies east of a thrust fault which brings the Bearpaw shale down on the west side of the coulee. It is also north of a small igneous intrusion. The bed has been burned along the outcrop north and south of the prospect, leaving a clinker from 2 to 3 feet in thickness.

Locality 19, NW. ¼ SW. ¼ sec. 19: Coal, dirty, 1 foot 4 inches. This coal outcrops in the bed of the coulee. It probably represents one of the upper coal beds of Judith River. As it lies directly south of extensive Bearpaw exposures it is probably underlain by important coal beds. Neither the top nor bottom of the bed is exposed at this place.

Locality 20, NW. ¼ SW. ¼ sec. 22:

Section at locality 20.

	Ft.	in.
Sandstone, hard		8
Sandstone, soft	3	
Shale	4	6
Shale, carbonaceous, with coaly streaks		10
Coal		1
Shale, carbonaceous, brown	1	1
Shale, carbonaceous, brown, and thin coal streaks	1	9
Coal, weathered (apparently good), with few thin bony streaks	3	9
Shale, carbonaceous.		
Total coal	3	10

Dip 17° S. 10° E.

This bed outcrops east of a fault which is not exposed on the south side of the creek. The main coal (3 feet 9 inches) is weathered but shows a few bright streaks interbedded with thin bony layers. Although it is poor at the outcrop, development might show good coal.

Locality 21, NW. ¼ NW. ¼ sec. 23:

Section at locality 21.

	Ft.	In.
Sandstone, friable	1	
Sandstone, hard		6
Shale, gray, sandy	3	
Shale, black, slightly carbonaceous		3
Clay		2
Shale	1	3
Gypsum		1
Shale, carbonaceous, with thin coal streaks		7
Coal, with a few bone streaks	1	6
Shale, black, carbonaceous		4
Shale, brown, carbonaceous	2±	
Total coal	1	6

The coal in the above section is exposed about 100 feet south of a fault which brings the Bearpaw down on the north. Bearpaw shale outcrops through thin glacial cover in the hill north and west of this locality and is probably underlain by important coal beds.

Locality 22, NE. ¼ SW. ¼ sec. 23:

Section at locality 22.

	Ft.	In.
Sandstone, massive	12±	
Coal	1	4
Shale, black		4+

Locality 23, SW. ¼ SW. ¼ sec. 23: Coal, bone, and carbonaceous shale 3 feet 4 inches thick. The bed contains many partings.

Locality 24, SW. ¼ NW. ¼ sec. 28, on northwest side of coulee:

Section at locality 24.

	Ft.	In.
Sandstone	2	
Shale and covered	3	
Shale		4
Coal, slightly bony		11
Bone		2–4
Coal	1	
Shale, carbonaceous	1	
Shale and sandstone, covered	10±	
Sandstone, massive, tan; many Fort Union plants collected	6–9±	
Total coal	1	11

The coal in the above section is of Fort Union age. It is slightly metamorphosed by igneous intrusion and pressure caused by folding and faulting. The lower 12-inch bench is of good quality, whereas the upper 11-inch bench contains more bone and carbonaceous shale.

Locality 25, SW. ¼ NW. ¼ sec. 28, on southeast side of coulee:

Section at locality 25.

	Ft.	in.
Sandstone, massive	15–20	
Shale and covered	3±	
Coal, slightly bony (interbedded coal and bone)	1	2
Bone		2–4
Coal	1	6
Shale, carbonaceous.		
Total coal	2	8

The coal in this section represents the same as that given in the preceding measurements but does not show metamorphism. It is also of Fort Union age. The lower bench of coal (1 foot 6 inches) is of good quality, but the upper bench (1 foot 2 inches) is too dirty for commercial use.

T. 31 N., R. 18 E.

Locality 26, SE. ¼ NW. ¼ sec. 6:

Section at locality 26.

	Ft.	in.
Sandstone, massive, concretionary	3±	
Shale, sandy	4±	
Sandstone, soft	6±	
Shale, blue, sandy		6
Coal	1	10
Sandstone		3
Coal	2	
Shale, sandy.		
Total coal	3	10
Dip 27° S. 75° W.		

Locality 27, NW. ¼ SE. ¼ sec. 12:

Section at locality 27.

	Ft.	in
Igneous sill	6	
Shale, carbonaceous, black, containing thin coal streaks	2	
Coal		9
Bone, with thin coal streaks		6
Coal	1	
Bone and shale, carbonaceous, with thin coal streaks		11
Coal, slightly bony		11½
Coal, with many bony streaks	1	4
Bone, with thin coal streaks	3	4
Coal		7
Bone	1	3
Coal, clear	1	10
Shale, carbonaceous, and bone, with thin coaly streaks	1	8
Total coal	6	5½
Dip 24° S. 54° E.		

Locality 28, SE. ¼ NW. ¼ sec. 23:

Section at locality 28.

	Ft.	in.
Sandstone, friable, light buff	5	
Shale, black, with thin coal streaks up to 2 inches	1	2
Shale, carbonaceous		4
Coal, bony, weathered	1	4
Sandstone		6
Bone		10
Coal		6
Bone		6
Coal, with thin bony streaks	2	
Bone		4
Sandstone and shale, containing some thin brown carbonaceous shale streaks	40	
Total coal	3	10

Dip 8° S.

T. 31 N., R. 17 E.

Locality 29, Staton mine, SE. ¼ NE. ¼ sec. 4:

Section in Staton mine.

	Ft.	in.
Roof, soft clay shale	4±	
Coal, left in roof	1±	
Coal	3	1
Coal, bony		10
Coal	1	10½
Floor not exposed.		
Total coal	6	9½±

A sample (No. 6478) for analysis was taken in 1908 in this mine, 250 feet from the mouth of the entry. (See p. 381.)

In 1909 this property was actively developed and two of five prospects were worked. Another section is as follows:

Section in mouth of new opening, Staton mine, SE. ¼ NE. ¼ sec. 4.

	Ft.	in.
Roof, coal.		
Coal, clear	6	4
Floor, coal.		

Mr. E. L. West, mine superintendent for the Staton Co., reports that the coal in the new opening is from 4 feet to 6 feet thick, clear coal, with pockets in places 8 feet thick.

The roof of the mine is a soft gray clay shale, making timbering necessary. About 8 to 12 inches of coal is left in the roof. About 18 feet below the above section is a bed of good coal 18 inches in thickness. About 12 feet above the Staton coal and one-half mile south of the mine the following section was measured:

Section one-half mile south of Staton mine.

	Inches.
Coal	10
Shale, carbonaceous, black	9
Shale, carbonaceous, brown	7

At a number of places in Staton Coulee the coal has been burned, but drifting 30 feet has demonstrated that the coal behind the burned-out places is of good quality. The dip of the coal bed at the mine is about 3½° N., whereas in the coulee south of the mine the dip is about 2° SE.

The following section shows the stratigraphic position of the Staton coal with reference to the Bearpaw shale:

Section of strata near Staton mine.

	Ft.	in.
Bearpaw shale.		
Sandstone, shaly	1	
Sandstone, soft	4	
Covered	53	
Sandstone, soft	4	
Shale, sandy, olive and drab	10	
Coal	1	5
Shale, carbonaceous		5
Shale and sandstone	9	
Sandstone, soft	5	6
Shale, carbonaceous		6
Staton coal bed.		
	88	10

Locality 30, Clack mine, SE. ¼ NE. ¼ sec. 5:

Section in Clack mine.

	Ft.	in.
Clay shale.		
Coal, left in roof	1±	
Coal, good	2	8
Bone	1	
Coal	1	6
Floor, bone.		
Total coal	5	2±

A sample (No. 6640) for analysis was taken in this mine. (See p. 381.)

A miner reports the following section in an abandoned caved-in room in the mine:

Section in abandoned room in Clack mine.

	Ft.	in.
Coal	3	
Bone		8
Coal	3	
Total coal	6	

The miner also reports that drilling in the floor of the mine has demonstrated that the following coal bed lies about 12 feet below the bed now being worked:

Section of coal bed below the bed being worked in Clack mine.

	Ft.	in.
Coal	1	6
Bone	1±	
Coal		8

T. 31 N., R. 16 E.

Locality 31, a prospect opened by Dan Anderson, of Havre, Mont., located in the NW. ¼ NW. ¼ sec. 4:

Section in the Anderson prospect.

	Ft.	in.
Shale, sandy, with seams of carbonaceous shale	3	
Coal		2
Shale, carbonaceous		10
Sandstone	5	
Coal	1	10
Shale, carbonaceous	2	8
Sandstone	4	
Shale	2	
Shale, black, carbonaceous		4
Coal		8
Bone		2
Coal	1	4
Bone		6
Coal	1	3
Bone		4
Coal	1	
Total coal	6	3

The upper part of the section was measured at the mouth of the entry; the main bed was measured 225 feet from the mouth of the entry.

Locality 32, SW. ¼ SW. ¼ sec. 4:

Section at locality 32.

	Ft.	in.
Shale, black, carbonaceous	1	3
Sandstone	1	5
Coal		4
Bone		4
Coal	1	6
Shale, black, carbonaceous.		
Total coal	1	10

The section given above was measured in a 25-foot prospect on the south side of the coulee. The base of the coal-bearing beds is not exposed at this place. The outcrop probably represents the zone exposed in the NW. ¼ sec. 4.

Locality 33, NW. ¼ SE. ¼ sec. 18 (unsurveyed), located in the Fort Assinniboine Military Reservation:

Section at locality 33.

	Ft.	in.
Sandstone	2	8
Coal, containing mineral charcoal, tough, woody		4
Coal, good	1	6
Bone		8
Coal, covered		6+
Total coal	2	4+

This section was measured in a 3-foot pit sunk on the west side of a small coulee. The outcrop indicated on Plate XXVIII as occurring southeast of the prospect represents a lower coal bed that was covered by water at the time of examination.

T. 30 N., R. 18 E.

Locality 34, NE. ¼ SE. ¼ sec. 5, 40 feet from the mouth of the entry of the Tiger Ridge prospect:

Section at locality 34.

	Ft.	in.
Shale, carbonaceous		10
Coal		4
Bone		1
Coal		4
Bone with coaly streaks		6
Coal	1	8
Bone		2
Shale, carbonaceous.		
Total coal	2	4

At locality 35, in the same prospect as given above, at the breast of the drift 60 feet from the mouth of the entry, a sample (No. 8622) was taken for analysis. (See p. 381.)

Section at locality 35.

	Ft.	in.
Sandstone and shale	50±	
Shale, carbonaceous	1	1
Bone, with thin coal streaks		4
Coal		4
Bone		1
Coal, with bony streaks		6
Bone		4
Coal	1	9
Bone, with coaly streaks		5
Shale, carbonaceous		4
Shale		4
Total coal	2	7

The bed in this opening lies almost flat and is cut by an east-west fault at the breast of the drift 60 feet from the mouth of the entry. The throw is about 2½ feet (downthrow on the north). The dip of the beds on the north side of the coulee, in a prospect almost opposite the one where the sample was taken, is 4°–7° N. 55° E.

There are no natural outcrops in the coulee. The coal has been prospected at eight places, but all except one of these prospects has been abandoned on account of the difficulty in mining due to small faults.

T. 30 N., R. 17 E.

Locality 36, NW. ¼ NW. ¼ sec. 1:

Section at locality 36.

	Ft.	in.
Coal and shale worked over by glacier		2
Shale, carbonaceous, and bone	1	9
Coal		1
Shale, carbonaceous, and bone	1	
Coal, very bony	1	
Shale, carbonaceous	2	7
Total coal	1	3

Locality 37, NW. ¼ NW. ¼ sec. 1:

Section at locality 37.

	Ft.	in.
Coal and carbonaceous shale worked over by glacier	1	8
Shale and thin coal and bone seams		8
Shale, carbonaceous, and bone		8
Shale, carbonaceous, and thin coal seams		11
Coal		9
Clay, slightly carbonaceous	1	8
Coal		½
Shale, carbonaceous		3
Shale, sandy.		
Total coal	2	5½

The section given above was measured in an abandoned prospect pit. Dip almost zero.

Locality 38, 150 feet southwest of the above section, on the south side of a coulee in the NW. ¼ NW. ¼ sec. 1:

Section at locality 38.

	Ft.	in.
Sandstone	1	8
Shale, sandy		10
Coal		10
Total coal		10

Dip 35° N. 10° E.

The entire township was examined in a reconnaissance way, but no coal of value was discovered.

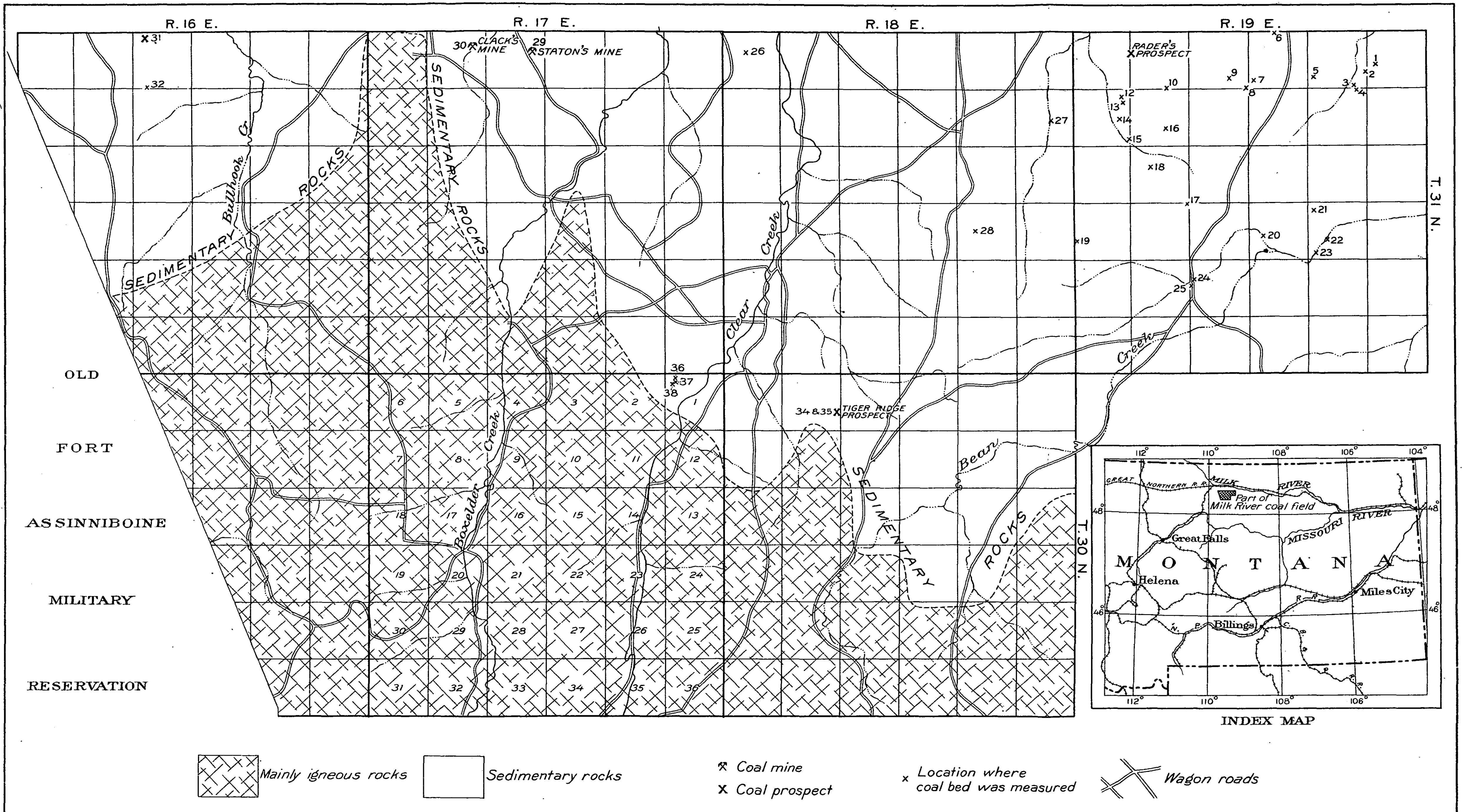
CHARACTER OF THE COAL.

Physical properties.—The coal is brownish black to pitch black and has a dark-brown streak. Two poorly defined systems of joints at right angles are usually present, and the coal splits readily along the bedding planes. The most pronounced physical property of the coal is that on exposure to the atmosphere it air-slacks and tends to fall to pieces. This is due to the fact that it contains a large percentage of water, which evaporates on exposure to the air, causing shrinkage and the development of an irregular network of cracks along which the coal disintegrates. This property prevents stocking the coal in the open, makes shipping in box cars desirable, and necessitates careful handling. Best results in burning are obtained by the use of grates with bars close together, which minimizes the loss of fine coal.

Chemical composition.—The composition of four samples of coal from the area under consideration is given in the table on page 25. The analyses represent mine samples collected and analyzed under uniform conditions.[1]

Comparison of these analyses with those of coal from the northern part of the Milk River field[2] shows a general similarity. The product of the Milk River field is classed as a fair grade of subbituminous coal.

[1] Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, pp. 174 et seq.
[2] Bull. U. S. Geol. Survey No. 381, 1910, p. 105.



MAP OF THE SOUTHERN EXTENSION OF THE MILK RIVER COAL FIELD, CHOUTEAU COUNTY, MONTANA

By Leon J. Pepperberg

Scale $\frac{1}{125,000}$

0 1 2 3 4 5 6 Miles

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

Analyses of coal samples from the Milk River coal field, Montana.

[F. M. Stanton and A. C. Fieldner, chemists in charge.]

Laboratory No.	Location. Quarter.	Sec.	T. N.	R. E.	Thickness. Coal bed.	Part sampled.	Air-drying loss.	Form of analysis.	Proximate. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Heat value. Calories.	British thermal units.	Reference.
					Ft. in.	*Ft. in.*														
6640	NE	5	31	17	6 3	4 8	14.2	A	25.6	27.9	39.2	7.27	0.58	6.19	49.08	1.03	35.85	4,605	8,290	P. 376 (Clack mine).
								B	13.2	32.6	45.7	8.47	.68	5.39	57.20	1.20	27.06	5,370	9,670	
								C		37.6	52.6	9.77	.78	4.50	65.96	1.38	17.61	6,190	11,140	
								D		41.7	58.3		.86	4.99	73.10	1.53	19.52	6,860	12,350	
6478	NE	4	31	17	6 9½	4 11½	22.9	A	29.2	26.7	37.4	6.74	.67	6.39	46.04	.94	39.22	4,355	7,840	P. 375 (Staton mine).
								B	8.2	34.6	48.5	8.74	.87	4.99	59.72	1.22	24.46	5,645	10,160	
								C		37.7	52.8	9.52	.95	4.45	65.02	1.33	18.73	6,145	11,070	
								D		41.6	58.4		1.05	4.92	71.86	1.47	20.70	6,795	12,230	
9150	NW	5	31	19	5 3	4 3½	14.7	A	21.4	28.0	41.6	8.99	.58	5.84	51.96	1.22	31.41	4,965	8,940	P. 368 (Rader prospect).
								B	7.9	32.8	48.8	10.54	.68	4.94	60.91	1.43	21.50	5,820	10,480	
								C		35.7	52.9	11.44	.74	4.40	66.11	1.55	15.76	6,315	11,370	
								D		40.2	59.8		.84	4.97	74.65	1.75	17.79	7,135	12,840	
8622	SE	5	30	18	3 1	2 4	8.8	A	16.8	27.9	43.8	11.50	1.19	5.58	54.37	1.14	26.22	5,315	9,510	P. 378 (Tiger Ridge prospect).
								B	8.8	30.6	48.0	12.61	1.30	5.04	59.62	1.25	20.18	5,825	60,490	
								C		33.5	52.7	13.83	1.43	4.46	65.38	1.37	13.53	6,390	11,500	
								D		38.9	61.1		1.66	5.17	75.86	1.59	15.72	7,415	13,340	
6319	NW	5	31	19	4 7	3 2	12.1	A	23.1	26.6	40.5	9.8	.56					4,760	8,570	P. 368 (Rader prospect).
								B	12.5	30.3	46.1	11.1	.64					5,415	9,750	
								C		34.6	52.7	12.7	.73					6,195	11,150	
								D		39.7	60.3		.84					7,095	12,770	
6801	SW	29	33	16	5 2	3 6	18.0	A	24.6	27.9	35.4	12.06	.88	5.80	46.00	.85	34.41	4,410	7,930	(a)
								B	8.1	34.0	43.2	14.71	1.07	4.64	56.10	1.04	22.44	5,375	9,680	
								C		37.0	47.0	16.01	1.17	4.06	61.07	1.13	16.56	5,850	10,530	
								D		44.1	55.9		1.39	4.83	72.71	1.35	19.72	6,965	12,540	
7156	SW	29	34	19	5 0	4	14.2	A	23.6	26.7	37.2	12.46	.55	5.56	45.62	.98	34.83	4,265	7,670	(a)
								B	11.0	31.1	43.4	14.52	.64	4.64	53.17	1.14	25.89	4,970	8,940	
								C		35.0	48.7	16.31	.72	3.85	59.71	1.28	18.13	5,580	10,040	
								D		41.8	58.2		.86	4.60	71.35	1.53	21.66	6,670	12,000	
6381	SW	29	34	19	5 0	3 4	18.5	A	26.7	26.4	40.0	6.90	.68	6.09	49.23	.91	36.19	4,690	8,440	(a)
								B	10.0	32.4	49.1	8.47	.83	4.94	60.41	1.12	24.23	5,755	10,560	
								C		36.0	54.6	9.41	.93	4.27	67.13	1.24	17.02	6,395	11,510	
								D		39.8	60.2		1.03	4.71	74.10	1.37	18.79	7,060	12,710	

[a] Not in that part of the field examined in 1909.

Analysis No. 6801 represents a sample of coal from the Olcott mine, 2½ miles north of Havre. The sample was taken in the mine 100 feet from the entrance, where the coal bed has the following section:

Section of coal bed in the Olcott mine.

	Ft.	in.
Coal[1]		6
Bone		2
Coal[1]	2	
Bone	1	6
Coal[1]	1	
	5	2

Analysis No. 7156 is of a sample of coal taken from the outcrop at the mine of Henry Leabo, 6 miles north of Chinook. It was taken for the purpose of determining the effect of weathering, and in that respect should be compared with No. 6381, which is an analysis of a sample of fresh coal obtained in the mine 45 feet from the entrance. The section of the coal bed at the place sampled is as follows:

Section of coal bed in Leabo mine.

	Ft.	in.
Coal		8
Bone	1	
Coal[1]	3	4
	5	

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form is not well suited for comparative purposes, for the amount of moisture in the sample as it comes from the mine is largely a matter of accident, and consequently analyses of the same coal expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted for general comparisons. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated. Analysis D represents the coal after all moisture and ash have been theoretically removed. This is supposed to represent the true coal substance, free from the most significant impurities. Forms C and D are obtained from the others by recalculation. They should not be used in comparison, for they represent theoretical conditions that never exist.

In the analytical work chemists generally recognize that it is not possible to determine the proximate constituents of coal or lignite with the same degree of accuracy as the ultimate constituents. Therefore the air-drying loss, moisture, volatile matter, fixed carbon,

[1] Parts sampled.

and ash are given to one decimal place only, whereas the ash (in an ultimate analysis), sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. It is also understood that calorific determinations to individual units are not reliable; therefore, in the column headed "Calories" the heat values are given to the nearest five units, and in the column headed "British thermal units" they are given to the nearest tens (the value of a British thermal unit being about one-half that of a calorie).

THE LIVINGSTON AND TRAIL CREEK COAL FIELDS, PARK, GALLATIN, AND SWEETGRASS COUNTIES, MONTANA.

By W. R. Calvert.

INTRODUCTION.

This paper is a statement of results obtained in certain coal fields of southern Montana during the summer of 1908 by a party of the United States Geological Survey in charge of the writer. In this work he was assisted by F. H. Kay and E. F. Schramm, and the former has given further material aid in the office in the compilation of field notes and maps. As no adequate topographic map of the area surveyed was available, one was made in the field, and in this mapping a Land Office base was adopted, the primary object of the survey being to ascertain the relation of coal areas to land subdivisions in order to classify those areas still a part of the public domain. Wherever practicable, therefore, land lines were traversed and ties were made frequently to land corners, even in those districts where the nature of the topography made it more feasible to base horizontal control on a system of triangulation rather than on direct traverse of lines established by Land Office surveys. Aneroid barometers, checked by railway profiles, were employed for vertical control. The land lines on the map (Pl. XXIX) are plotted from data given on the original township plats of the General Land Office.

In previous publications in which reference is made to the coal-producing area west of Livingston the term "Bozeman coal field" is used. When this name was first adopted, Bozeman was the principal town of the region and naturally the field was called by its name. It seems advisable now, however, to disregard previous usage and to term this area the Livingston coal field, as coal-bearing rocks are not exposed in the vicinity of Bozeman but are well developed near Livingston. The former town is not within the area mapped, whereas the latter is located centrally. Moreover, the term "Bozeman field" is not used locally to designate the productive areas, so that the adoption of another name will cause no misunderstanding in the field itself.

The term "Trail Creek field" has become well established in the literature in referring to the producing area in Trail Creek valley, and there seems to be no reason to adopt another term, although the primary reason for applying a name to differentiate it from the Livingston field is no longer valid. It has been believed that the two areas are entirely separate and that the coal measures do not extend from one to the other. It was ascertained in the course of work in 1908, however, that the coal-bearing rocks can be traced continuously from one to the other, so that they do not constitute distinct geologic units. Because of this fact any boundary separating them must of necessity be arbitrary. It seems most natural, however, to separate the Livingston and Trail Creek fields on the basis of drainage areas, and the line of division is placed therefore at the watershed between Meadow and Trail creeks, as the former stream belongs to the Missouri River drainage system, whereas Trail Creek flows eastward to join the Yellowstone.

GEOGRAPHY.

LOCATION AND EXTENT.

The area described includes about 300 square miles and lies in the southern part of Montana to the north of Yellowstone National Park. In general land lines were adopted arbitrarily as boundaries, and the area thus comprises a single row of townships with an extension to the south at the western end in order to include the Trail Creek field. Mapping was begun near Boulder River and extended westward within 6 miles of Bozeman. The geographic relations are shown on the Kay map, Plate XXIX.

DRAINAGE.

The greater part of the area belongs to the drainage basin of Yellowstone River, which enters the field through a narrow canyon near the southeast corner of T. 2 S., R. 9 E., flows northeast for several miles, and then turns sharply to the east just north of the area mapped. It reenters the field in R. 11 E., continues in an easterly direction a short distance, and then turns again to the north. Its principal tributary is Boulder River, which with its affluents drains the southeastern part of the Livingston field. Between Boulder River and the Yellowstone are several small streams which flow northward. From the west the main stream joining the Yellowstone is Billman Creek, up whose valley the Northern Pacific Railway passes into Gallatin Valley, to the west of the field. Trail Creek, from which one of the coal fields derives its name, is also tributary to the Yellowstone. In the northwestern part of the area shown on the map the streams flow westward to join the Missouri.

RELIEF.

Most of the area is very hilly and it is bordered by mountains on the south and southwest. The semirugged character of the topography is due to the influence of structure and to the fact that the surface rocks throughout much of the area are resistant to weathering and erosion, so that the streams tend to flow in deep, narrow valleys. Yellowstone River valley is carved below the 4,500-foot contour, whereas the hills near the south and west borders of the area rise to over 7,000 feet above sea level. The average altitude of the country is more than 5,500 feet. As a consequence of this broken surface the area is not traversed by many roads and the main lines of travel are confined almost entirely to the stream valleys.

CULTURE.

Livingston is the principal town of the area and has a population of about 7,000. It is on the main line of the Northern Pacific Railway and is the terminus of a branch line extending 40 miles south to Gardiner, at the north entrance of Yellowstone National Park. A branch extends also from Chestnut, a small coal-mining town in the western part of the Livingston field, southeast to the coal mines on Trail Creek. Storrs, about 2 miles southeast of Chestnut, was formerly a town of several hundred inhabitants but is now deserted. Cokedale, 6 miles west of Livingston, is almost deserted also. Timberline, formerly a coal-mining camp, situated in the south-central part of T. 2 S., R. 8 E., has been abandoned for a long period.

GEOLOGY.

STRATIGRAPHY.

The sedimentary rocks of the area comprise a great thickness of strata ranging from Cambrian quartzite, which rests on Archean granite, up to beds which are stratigraphically only a short distance below the Fort Union. The total thickness of these sedimentary rocks is about 12,000 feet, the greater part of which occurs above the base of the Cretaceous. As the geologic work of 1908 was largely economic in character, study was confined chiefly to the coal measures and associated formations, and mapping seldom included rocks older than Upper Cretaceous.

The general region of which the area shown on Plate XXIX is a part was mapped by Weed, and the results of his work appear in several publications, the chief of which, so far as the area under discussion is concerned, is the Livingston folio.[1] Although the strati-

[1] Iddings, J. P., and Weed, W. H., Livingston folio (No. 1), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

graphic succession as described by Weed agrees with that of the writer so far as the thickness and lithologic character of the various formations is concerned, the age determinations and the general interpretations placed upon the stratigraphy are radically different. According to Weed, Jurassic rocks are overlain by the Dakota sandstone, comprising three members, the most characteristic of which is a conglomeratic sandstone near the base. This is overlain by beds of reddish clay, and the top member of the formation is a massive quartzite. Regional study by the writer covering a period of four field seasons has convinced him that the formation termed Dakota sandstone by Weed is the Kootenai formation as described in various reports[1] on Montana geology, for in lithology and stratigraphic relations the formation is similar in every way to the Kootenai, as developed elsewhere in the State.

Above the Kootenai formation is a mass of shale and thin beds of sandstone, the lower half of which was considered to be Colorado by Weed, whereas the upper half was mapped and described as the Montana group. This entire mass, which apparently measures 3,700 feet near Livingston, is now known to be of Colorado age throughout, as distinctive fossils have been found practically to the top. That the thickness of the Colorado is in reality so great is considered doubtful, for, although accurate measurements could be obtained elsewhere in the field, no estimate assigned such an amount. Whatever its true thickness, however, the point which should be emphasized is that the strata from the base of the dark shale up to the overlying coal measures are not separable lithologically and carry a Colorado fauna from bottom to top.

The upper part of the Colorado passes by gradual transition into the overlying coal measures, which constitute the most important formation, economically, of the entire geologic column. The coal measures are prevailingly sandy, are 750 to 900 feet thick, and contain several coal beds of commercial importance. In previous publications this sandstone has been assigned to the Laramie, partly on the evidence of fossil plants and partly on its conformable relations to the underlying rocks, which were supposed to be Montana. At present, however, there seems to be justification for considering the coal measures as the lower portion of the Montana group instead of the Laramie. They are conformable on Colorado shale, thus occupying the stratigraphic position of the lower Montana, and even in previous publications have been correlated with a sandstone north

[1] Fisher, C. A., Geology and water resources of the Great Falls region, Montana: Water-Supply Paper U. S. Geol. Survey No. 221, 1909. Fisher, C. A., Geology of the Great Falls coal field, Montana: Bull. U. S. Geol. Survey No. 356, 1909. Stone, R. W., Coal near the Crazy Mountains, Montana: Bull. U. S. Geol. Survey No. 341, 1909, pp. 78-91. Calvert, W. R., Geology of the Lewistown coal field, Montana: Bull. U. S. Geol. Survey No. 390, 1909.

of the Crazy Mountains, now proved beyond question to be the lowest member of the Montana group. Furthermore, poorly preserved marine shells that have been found at the top of the coal measures, although not absolutely determinative, strongly suggest a Montana age. Elsewhere in the State the Montana group has the Eagle sandstone as its lowest member, but there is some question regarding the propriety of thus designating the coal measures of the Livingston field. The Eagle sandstone where typically developed seldom attains a thickness greater than 300 feet, whereas the coal measures at Livingston are 750 feet or more thick. To the writer the most plausible explanation of this variation in thickness between the coal-bearing sandstone and the typical Eagle is that the Livingston area represents the northern limit of the Mesaverde formation of the Montana group as developed in Colorado and Wyoming. Conditions in the Electric coal field, 40 miles to the south, apparently bear out this assumption. There the coal measures, which have always been correlated with those at Livingston, are 1,000 feet or more thick and, moreover, carry a scanty fauna similar in form to Mesaverde types. That there should be such a change from the well-known typical Montana section represented by the Eagle sandstone and overlying formations of the Upper Cretaceous into an undifferentiated Montana section is normally to be expected. Such a transition is well illustrated in the Bighorn Basin of Wyoming, at the northern end of which the formations can be distinguished, but at the southern end a thick undifferentiated mass of sandstone and sandy shale immediately overlies the Colorado. The coal measures at Livingston are not, however, entirely comparable to the typical Mesaverde formation, because of the fact that the lowest beds in the Livingston field rest on strata of Colorado age, thus demonstrating that the basal portion of the formation is older than Mesaverde. The term undifferentiated Montana is therefore more applicable and will be adopted in this report in referring to the coal-bearing formation.

This interpretation of the age of the coal measures at Livingston is not in accord with the evidence furnished by fossil plants, which are abundant and represent many forms. According to the paleobotanists these plants are of post-Montana types, so that further work is needed in order to bring the various lines of evidence into complete harmony. All the evidence either in favor of or opposed to the opinion held by the writer can not be presented here, however, and the reader interested in the stratigraphic phase of the question is referred to a paper [1] in which details are given.

[1] Stone, R. W., and Calvert, W. R., Stratigraphic relations of the Livingston formation, Montana: Econ. Geology, vol. 5, Nos. 6, 7, and 8, 1910.

Overlying the coal measures is a formation 5,000 feet or more thick consisting of shale and sandstone, both largely tuffaceous in character, together with local intercalations of conglomerate. On Boulder River a local member of volcanic breccia and agglomerate about 2,000 feet thick occurs about the same number of feet above the base of the formation. This entire mass is known as the Livingston formation, and it has been supposed to represent sediments derived from one or more areas of volcanic activity and laid down in post-Laramie time. Furthermore, there was supposed to have been an interval of erosion and orogenic movement between the deposition of the coal measures and that sedimentation which resulted in the Livingston formation. It has already been shown that the evidence at hand points to the correlation of the coal measures with the lower Montana, and it is now believed the Livingston formation as originally defined represents in reality a shore phase of several formations and has no definite age value. On following the peculiar andesitic strata of the Livingston formation from the type locality north around the Crazy Mountains it was found that they feather out and merge with normal sedimentary rocks, some of fresh-water and some of marine origin, separable into the several formations of the Montana group above the Eagle sandstone. Thus it appears that the deposition of andesitic material at Livingston began immediately after the coal measures were laid down and continued uninterruptedly into the Tertiary. North of Livingston similar material was deposited in Colorado time, but the great mass of andesitic débris was not laid down until after the deposition of the Eagle sandstone.

In the Livingston folio the agglomerate member of the Livingston formation is shown in one locality as unconformable on older rocks down to the Colorado as defined by Weed. This unconformable relation is now explained by the presence of a fault in the southeast corner of the area mapped. (See Pl. XXIX.) Throughout this area no evidence of an unconformity was found between the coal measures and the Livingston formation, and in general there is every appearance of transition from one to the other. Although in general lithologic character the two are materially different, one being quartzose sandstone and the other tuffaceous material, the line of demarcation is not sharply defined. It is usually about 180 feet stratigraphically from the highest coal to typical Livingston beds, but in the interval between there is in many places an alternation of white quartzitic sandstones and brown tuffaceous beds. The following table expresses graphically the previous and present interpretations of the stratigraphy at Livingston:

Geologic formations in the Livingston district.

<table>
<tr><th colspan="5">Formations and thicknesses.</th><th rowspan="2">General characteristics.</th></tr>
<tr><th colspan="2">Previous interpretation.</th><th colspan="3">Present interpretation.</th></tr>
<tr><td rowspan="2">Post-Laramie.</td><td></td><td colspan="2">Eocene.</td><td></td><td></td></tr>
<tr><td>Livingston, 7,000 feet.
Unconformity.</td><td rowspan="3">Upper Cretaceous.</td><td rowspan="2">Montana.</td><td>Livingston formation, 5,000+feet.
Conformable.</td><td>Brown tuffaceous shale and sandstone, with intercalated agglomerate. Largely andesitic throughout.</td></tr>
<tr><td rowspan="3">Upper Cretaceous.</td><td>Laramie, 1,000± feet.</td><td>Undifferentiated Montana, 750+ feet.</td><td>White quartzose sandstone and sandy shale with coal beds.</td></tr>
<tr><td>Montana, 1,800 feet.
Colorado, 1,800 feet.</td><td></td><td>Colorado shale, 3,700 feet.</td><td>Dark shale and thin beds of sandstone.</td></tr>
<tr><td>Dakota, 500 feet.</td><td colspan="2">Lower Cretaceous.</td><td>Kootenai formation, 500 feet.</td><td>Coarse to conglomeratic sandstone, red shale, and quartzite at top.</td></tr>
</table>

In addition to the sedimentary rocks described, alluvium and terrace gravel occupy the surface in portions of the area mapped. The extent and distribution of these surficial deposits are shown on the map, Plate XXIX.

STRUCTURE.

Folding has been pronounced in the area mapped, and in the western part both folds and faults are numerous. Along the southern border of the area as far west as Yellowstone River the structure is dominated by a mountain uplift along whose base the rocks are upturned more or less sharply, accompanied by minor folds approximately paralleling the mountain front. In the extreme southeast corner of the area a fault of considerable throw branches to the north from a major structural break just outside the district mapped. By this fault the agglomerate member of the Livingston formation is brought into contact consecutively with older rocks down to and including the upper half of the Colorado, and these conditions were formerly interpreted as indications of unconformity. West of this faulted district the rocks in general dip at a moderate angle toward the north, although interrupted by many minor folds. A dome in T. 2 S., R. 13 E., is cut across by Boulder River and Colorado shale is exposed. From the southeast corner of T. 2 S., R. 11 E., an anticline extends almost to the Yellowstone, resulting in an exposure of coal measures several miles wide with rather steep and opposing dips on either side. South of this anticline is a sharply folded syncline inclosing Livingston rocks. The south limb of this syncline was not mapped.

South of Livingston a sharp anticlinal ridge is cut by Yellowstone River, forming the "lower canyon." West of the river this ridge extends about 8 miles along the south border of the area mapped and adjacent to the fold the rocks dip steeply northward. Still farther to the southwest two anticlines bring up Paleozoic rocks and between them a narrow band of Cretaceous strata is inclosed, in which occurs the coal of the Trail Creek field and the syncline is broken by a fault block, as shown on the map (Pl. XXIX). The fault bounding the block on the east is very evident, as the dark shale of the Colorado, dipping 45° E., is in contact with nearly vertical beds of the upper part of the Kootenai. The western limit of the fault block was not ascertained anywhere with definiteness and its location on the map is merely approximate. That a fault is present, however, is clear. From the crest of the anticline west of Meadow Creek the rocks dip eastward consistently, although at various angles. The Kootenai formation gives place to Colorado shale and this in turn to the soft sandstone and sandy shale constituting the coal measures. Farther east Colorado shale, with its characteristic fossils and lithologic appearance, is again met, still dipping to the east. Between the coal measures and the Colorado, therefore, is the fault marking the west limb of the fault block to which reference has been made. In the lack of adequate exposures differentiation between the coal measures and the Colorado is not always possible unless fossils can be found, for although the lithology may be quite different in general the details are often similar. Because of this fact there is, as has been said, uncertainty regarding the location of the western fault.

In the southern part of the Trail Creek field the structure varies to a marked degree from that previously described, but on account of poor exposures knowledge regarding the details of structural relations is uncertain. Mines or prospects in secs. 28 and 34, T. 3 S., R. 8 E., and in sec. 4 of the township to the south give fairly definite evidence that between Trail Creek and the high ridge of volcanic material to the southwest the coal is in a synclinal trough or basin the eastern and southern edges of which are well defined but concerning whose western limit there is considerable doubt. How much of secs. 28 and 33 is underlain by coal is a question which only drilling or underground development can determine. That it is this part of the field which will supply the greater amount of coal in the future there can, however, be little doubt.

The northwestern part of the area mapped has a considerable variety of structural forms, and though the major features are indicated or suggested on the map there are many details which the scale is inadequate to show. One peculiarity in structure which has direct relation to the coal is in the southern part of T. 2 S., R. 7 E. In this locality there appear to be four coal beds which have been prospected or worked in varying degrees. The uppermost and probably the next lower swing around a syncline from their normal strike of nearly south in sec. 26 and outcrop near the top of the bluff east of Meadow Creek. The next lower bed is influenced to a lesser degree by the syncline and extends farther in a southerly direction, almost reaching the south border of sec. 35, where it also swings to the west. It is believed, however, that this bed is terminated by a fault, which presumably trends along Meadow Creek valley. The lowest bed continues still farther south and passes into a fault block, where it is opened at the Harrison mine. Here it is cut by a fault and the dip reversed to the east. From this point it continues south into the Trail Creek field and apparently is the bed worked at the Hoffman and Kountz mines. The point of greatest geologic interest, however, is that the Trail Creek and Livingston fields are thus not distinct units, as has hitherto been supposed.

In the south-central part of T. 2 S., R. 7 E., the coal measures and associated formations are cut by two faults of several hundred feet throw, one of which offsets the coal beds about one-half mile. From this locality the coal-bearing sandstones strike to the northwest, turning southward again near the east border of T. 2 S., R. 6 E. Here they pass beneath the Bozeman "lake beds" which form the floor of Gallatin Valley, just to the west of the area mapped. To the north they reappear at Bridger Canyon and extend along the base of the Bridger Range. This latter locality was examined in 1908, but as no coal of commercial value was found it is not given further consideration in this report.

THE COAL.

OCCURRENCE.

In the Livingston and Trail Creek fields coal occurs as one or more layers in a sequence of sandy beds overlying Colorado shale and overlain in turn by tuffaceous rocks constituting the Livingston formation. As has been stated, there is some question regarding the geologic age of the coal, for on stratigraphic evidence the coal measures are lower Montana, whereas the fossil plants apparently show that they are younger. The coal measures are not productive throughout the area mapped, and it appears that coal in commercial quantity is absent east of R. 8 E., for so far as known the only attempt to mine coal east of Livingston is on Boulder River in the southwest part of T. 2 S., R. 13 E. The quantity of coal formerly produced in the western areas was much greater than it has been in recent years, for the large mines which operated at Cokedale, Timberline, and Storrs have been idle and only a relatively small amount of fuel is mined at Chestnut. Recently there have been indications of a revival of activity, although it is not probable that the Livingston field will ever again be the factor in the fuel production of Montana that it has been in the past. Variability in character and thickness of the coal beds, together with uncertainties resulting from meager knowledge of geologic conditions, have been the chief factors which have caused the decline in production after the more accessible coal was removed.

The productive areas of the Livingston field form well-defined districts, and in the description of the coal each area will be discussed separately. They will be termed the Cokedale, Timberline, Meadow Creek, and Chestnut districts; the Trail Creek area will be treated as a coal field, although it might properly be considered as a district.[1]

COKEDALE DISTRICT.

Formerly a large amount of coal was mined in the vicinity of Cokedale, but at the time of examination in 1908 all the workings had been abandoned for several years and very little information regarding operations was available. The largest mine of the district was in a gulch a short distance northwest of Cokedale. The greater part of the coal came from one bed said to be about 4½ feet thick. This was opened by a slope about 1,500 feet long with a dip of about 60°. The plant was equipped with hoist, washer, and 100 coke ovens. A spur from the Northern Pacific Railway formerly extended to the mine, but this has been torn up and abandoned.

West along the strike of the coal measures from Cokedale the bed was opened and mined, but here also work was abandoned prior to 1908. Apparently this locality is near the west limit of the Cokedale district, for prospects to the west and southwest indicate that the coal is thin and dirty.

A mile east of the Cokedale mine the coal was opened by a slope 500 feet long with a dip of 55° and considerable fuel removed. During a period of labor trouble in the field the portal of the shaft was destroyed and the mine has since been idle. At the time of examination an attempt was being made by the Livingston Coal & Coke Co. to renew production by opening the bed 500 feet farther west on the strike and extending the entry to connect with the old slope. The bed in the new opening is irregular owing to rolls in the floor and roof, but the coal averages about 31 inches thick. A sample of the coal has been tested and it was claimed to coke excellently. It was the intention to rebuild the spur from the Northern Pacific Railway and to make the mine a producer.

A few feet above this bed occurs another, which averages 2 feet thick, and 30 feet higher stratigraphically is a third, which is variable in character and thickness. The lower of these is said to have been

[1] According to Survey practice, the following classes of coal areas are recognized: 1, Coal province; 2, coal region; 3, coal field; 4, coal district. The first corresponds to a geologic or physiographic province; the others are progressively smaller subdivisions.

worked at Cokedale. East of the Livingston Coal & Coke Co.'s mine the beds are thin and impure, as evidenced in numerous prospects between the mine and Yellowstone River. It appears therefore that the Cokedale district is limited along the outcrop to a zone about 3 miles long, and on account of the excessive dip—55° to 60°—the coal passes beyond practical workable depth a short distance from the outcrop.

TIMBERLINE DISTRICT.

The Timberline district has produced a large amount of coal, but for a number of years all the workings have been abandoned. Various rumors are in circulation regarding the abandonment. According to some the district was exhausted and mining rendered unprofitable, but according to other statements considerable accessible coal still remains. Mr. Robert McKee, of Chestnut, who was in general charge of early development, states that the mines were opened in 1883, and that for the two years following shipments amounted to 100 tons a day and for the succeeding 10 years the production of one mine averaged 300 tons daily. The district was connected by a spur with the Northern Pacific and that railway used the greater part of the fuel mined. Mr. McKee and others qualified to know state that four coal beds are present in the Timberline district which were worked in varying degree. One bed is 20 feet thick but is said to have been almost worthless on account of many shale partings.

MEADOW CREEK DISTRICT.

The Meadow Creek district comprises a zone along the outcrop of the coal measures on the east side of Meadow Creek, ending in the vicinity of Storrs on the north and extending southeast to the divide between Meadow and Trail creeks. Throughout its length Meadow Creek flows on the east limb of an anticline and its valley is excavated in the easily eroded Colorado shale. In consequence the coal measures do not extend west of the creek. The structure near the south line of T. 2 S., R. 7 E., seems best explained by hypothesizing a fault trending along the valley, which affects certain of the coal beds as suggested on the map (Pl. XXIX).

As in other parts of the Livingston field, there is little production at present in the Meadow Creek district. In the vicinity of Storrs a large amount of coal was formerly mined, the Washoe Coal & Copper Co. being the principal producer. The greater part of the coal came from two openings, both on the top bed, the larger workings being known as mine No. 3, located in the NW. ¼ NW. ¼ sec. 35. The bed was opened on the strike and workings extended north toward the Timberline district. The upper coal bed outcrops along the crest of the ridge northeast of mine No. 3, and the strata dip at a high angle—60° or more—to the west. The outcrop swings down the ridge to the southwest, then turns to the northwest around the end of a synclinal trough. This is the bed opened at mine No. 1. (See Pl. XXIX.) Between the two openings the bed has not been prospected and it is effectually concealed by talus material. Coal from mine No. 3 was taken in cars down an incline, and thence to the washer and coke ovens.

At the level of the stream one-fourth mile southwest of mine No. 3 a coal bed was developed by two openings. Here the coal dips slightly to the north and is believed by the local miners to be the same bed as that in mine No. 3, for they thought that the strike of the bed at mine No. 3 would carry it directly across the valley to reappear at the lower mines. In accordance with this belief, a tunnel was extended southwest, beginning at the foot of the incline from mine No. 3, in order to open the bed at a new locality. Failure naturally attended this enterprise, as even at the tunnel mouth the bed is well up on the hillside, and its strike is turning to the northwest. In other words, the tunnel remains below the coal of mine No. 3 for its entire length, said to be 2,000 feet.

The Washoe mine No. 1 was also formerly a large producer. The coal bed outcrops near the top of the bluff above the former tipple and was first opened by a slope, which later was superseded by a rock tunnel on the hillside, driven across the strike to tap the bed. Development was confined to the northwest of the entry, as a fault cuts the coal on the opposite side. The entry from the slope extended 900 feet on the strike, and rooms were opened on the rise, here 33°. In 1908 the property was under lease to Mr. J. D. Evans, and at the time of examination the mine had been put in condition for operating and shipping was contemplated. At this mine the first opportunity to study the coal west of Cokedale is presented. A section of the bed taken on the pillar between rooms 1 and 2 is as follows:

Section of coal bed in Washoe mine No. 1.

	Ft.	in.
Main roof, sandstone.		
Bone		1- 5
Coal	2	3
Sandy clay		2
"Blackjack"		0-10
Coal		9-10
Total coal	3 to 3	1

The coal is crushed to such an extent that its original structure is destroyed, and it is so soft that much of it can be removed with a shovel. This feature of crushing seems to be confined principally to the upper bed of the coal measures and is most pronounced in this portion of the Meadow Creek district, where folds, faults, and other results of dynamic action are most evident. In 1910 the writer revisited the Trail Creek field and noted that in the vicinity of Storrs mining operations had been abandoned.

Northwest of mine No. 1 the coal has not been worked to any extent. About a quarter of a mile from the mine a fault cuts the coal measures and offsets the beds to the northeast nearly half a mile. The beds then strike northwest back to Meadow Creek and are again cut by a fault. These faults outline a block which has been raised relatively and are two of the more evident faults in the district. In fact, faults have been a serious obstacle in the district, and are said to have interfered to a great degree in the development of mine No. 3.

The Washoe Co. made an attempt to develop the two lower beds in the coal measures. Both were opened in the gulch southwest of mine No. 3. The upper is said to have been thin and dirty, and the lower, although thicker, also failed to "clean up," though the entry was extended 1,200 feet in the hope that the bed would yield commercial coal. It is claimed that several thin bands in this bed made coke of a superior quality.

The upper of the two beds mentioned strikes across the gulch and extends into sec. 2 of the township to the south, where it swings to the west and is opened at the Monroe mine. (See Pl. XXIX.)

A section of the bed in the Monroe mine is as follows:

Section of coal bed in Monroe mine.

	Ft.	in.
Shale.		
Coal		7½
Clay		1½
Coal		4
Sandstone		1
Coal		7
Shale.		
Total coal	1	6½

A small amount of coal has been mined here for local use.

Study of field conditions seems to justify the belief that the coal bed of the Monroe mine is terminated by a fault in Meadow Creek valley, and that the same bed should reappear to the north on the bluff east of Storrs, but there the coal is either absent or has not been discovered.

The lowest bed formerly mined by the Washoe Co. in the gulch southwest of mine No. 3 continues to outcrop to the south and is not influenced by the syncline which swings the upper beds back to the northwest, for it extends into sec. 2, T. 3 S., R. 7 E., and is opened at the Harrison mine. (See map, Pl. XXIX.) This mine opens the bed on the strike by an entry 700 feet long. The strata inclosing the coal bed are in a tilted fault block with a dip of 75° W. A section of the coal bed is as follows:

Section of coal bed in Harrison mine.

	Ft.	in.
Sandstone.		
Shale		4
Coal	1	8
"Blackjack"		9
Coal	1	2
"Blackjack"		1½
Sandstone.		
Total coal	2	10

The coal is fairly clean and hard and is slickensided to a considerable extent. There is a tendency in both walls to roll, and the bed is therefore not constant in thickness. Up to the time of examination production was confined to a small amount used locally and mined chiefly during the winter months.

Across the stream from the Harrison mine the same coal bed is shown in abandoned workings. Here the bed dips to the east at a low angle, so that the fault block at the Harrison mine must be terminated by a turn to the west of the fault bounding the block on the east. About 500 feet east of the abandoned workings another coal bed has been prospected. This dips to the west at an angle of 45° and is entirely dissimilar to the bed of the Harrison mine. That the structure is not normal is therefore evident, but its nature is unknown.

South of the Harrison mine the coal outcrop can be traced with difficulty, but its probable location is as represented on the map. A carbonaceous zone, believed to be the equivalent of the Harrison bed, is exposed in a ravine in the SE. ¼ SE. ¼ sec. 2, but at this point the rocks stand vertically. This abrupt change in the attitude of the rocks seems best explained by a fault, as suggested on the map. For nearly 2 miles southeast of the ravine mentioned the strata continue to dip at a high angle, and it is not till they approach the Hoffman mine, which will be described later, that they become less inclined. The coal bed has been prospected in several places in sec. 12, but nowhere does development seem to be warranted.

CHESTNUT DISTRICT.

The Chestnut district was formerly one of the principal producing areas of the Livingston field, but in 1908 its production was only a small fraction of the amount mined when development was at a maximum. Two mines, known as the Chestnut and Mountainside, were operated formerly and were controlled by the Northwestern Improvement Co., presumably subsidiary to the Northern Pacific Railway.

The Chestnut mine has been abandoned several years. The coal bed was opened near water level on the north side of the railway, and it is claimed that the entry was extended northwest to sec. 18. In this mine the coal is said to have been variable in character and thickness and much disturbed by faults. It is asserted that all the coal was removed to water level.

The Mountainside mine, south of the railway, was shipping no coal at the time of examination in 1908. Practically all the coal has been removed from the old workings, and development was confined to a lower level. In this mine also the coal is extremely variable, for according to the superintendent, Mr. George Forsyth, the bed ranges from 4 to 20 feet in thickness and is considerably disturbed by faults. The coal is peculiar in appearance. In bulk it is dull and granular, but in detail it is banded with lamellæ of shiny vitreous coal. It is noncoking in character but is an excellent steam fuel.

About 3 miles northwest of Chestnut the coal bed has been opened by Bailey & Beedle in the SW. ¼ sec. 13, T. 2 S., R. 6 E. In September, 1908, the entry was about 175 feet long and a small amount of coal was being mined for local use. At the entry face the bed dips 38° N., but this dip increases to 80° within one-half mile to the east. The coal bed is cut by numerous small faults, and there are many minor irregularities in the roof and floor. As a result the coal is badly crushed and is variable in thickness but averages about 30 inches. The coal is nearly semibituminous in character and has a higher fuel value than any other in the Livingston field. The attitude and variability of the bed render mining expensive, however, and according to recent information Bailey & Beedle have temporarily abandoned the mine.

About 40 feet stratigraphically above the bed mined is a carbonaceous zone 6 feet thick, as shown in a prospect near the present mine. From appearances at the surface, however, this zone contains too great a proportion of impurities to warrant development.

TRAIL CREEK FIELD.

In 1908 coal was being mined and shipped from three localities in the Trail Creek field. The northernmost of these is the Hoffman mine, operated under lease by J. D. Evans and located near the center of sec. 18, T. 3 S., R. 8 E. This is said to have been opened in 1897 by a slope oblique to the dip, which is here 45°. The slope was extended down about 200 feet and coal removed from entries to the right. In February, 1905, a new slope was started directly down the dip, and in September, 1908, it was down 325 feet. The right entry was then 1,000 feet long, and that to the left extended 1,355 feet from the slope. About 125 tons of coal was being mined daily, which was loaded directly into cars at the tipple, three sizes being produced—lump, nut, and run-of-mine.

Two beds are worked in the Hoffman mine, and their character is as follows:

Sections of coal beds in Hoffman mine.

Bed No. 2.

	Ft.	in.
Bone.		
Coal		3½
Bone		6–9
Coal	3–4	
Dirt		6
Coal, bony	1	8
Total coal	4 to 5	11½ 11½

Bed No. 1.

	Ft.	in.
Sandstone	4	
Bone		6
Coal	2	6
Bone		4
Coal	1	8
Dirt		6
Total coal	4	2

Some water is present in the Hoffman mine, which is removed by pumping about 1½ hours each day. In the workings to the right gas seems to be absent, but to the left it is present, though troublesome only in driving new rooms. Ventilation is effected by a fan.

About a mile southeast of the Hoffman mine is the Kountz mine, operated by the Trail Creek Coal & Land Co. Mining conditions are very similar to those in the Hoffman workings, as the bed is opened by a slope with a dip of 42° and entries to right and left. One difference, however, is that there are four levels in the Kountz mine. The bed worked has two benches, each 2 feet thick, separated by a 2-inch sandstone parting. The upper bench is overlain by 1 foot of sandstone, which is left as a roof, and this is overlain in turn by two more benches of coal, not mined in 1908. At the time of the writer's visit to the field in September, 1910, this mine was shut down on account of fire.

In sec. 28, 2 miles southeast of the Kountz mine, the Maxey Bros. own and operate the largest producing mine in the Trail Creek field. The original workings were in the SE. ¼ NE. ¼ sec. 28, at the locality marked No. 1 on the map. In the slope the dip is 34° SW., but toward the northwest it increases to 90° or is even overturned, so that development in that direction was abandoned. A fault just south of the slope stopped work in that direction also and production ceased. In 1903 Maxey Bros. reopened the mine, drove through the fault to the south, and mined a considerable amount of coal. Finding that the dip of the coal bed lessened southward, they made a new entry (No. 2 on the map) and all the coal mined in 1908 came from these workings. In 1910 a third entry (No. 3 on the map) was the main haulage way, being connected with the workings of No. 2.

South of entry No. 2 the outcrop of the coal bed has not been traced. It is probable, however, that a prospect a short distance northeast of the west quarter corner of sec. 34 is on a bed about 100 feet higher stratigraphically than that in the Maxey mine, hence the latter bed is near by and to the east. The dip and strike are such also that the outcrop normally should be expected to continue into sec. 3, T. 4 S., R. 8 E., to connect with a coal bed opened near the southeast corner of the NE. ¼ NW. ¼ sec. 4. At this locality the bed dips 13° NE. and strikes N. 35° W. A section of the bed at this point is as follows:

Section of coal bed in NE. ¼ NW. ¼ sec. 4, T. 4 S., R. 8 E.

	Ft.	in.
Shale.		
Shale and coal	1	
Coal	1	1
Shale		4–8
Coal	3	8
Total coal	4	9

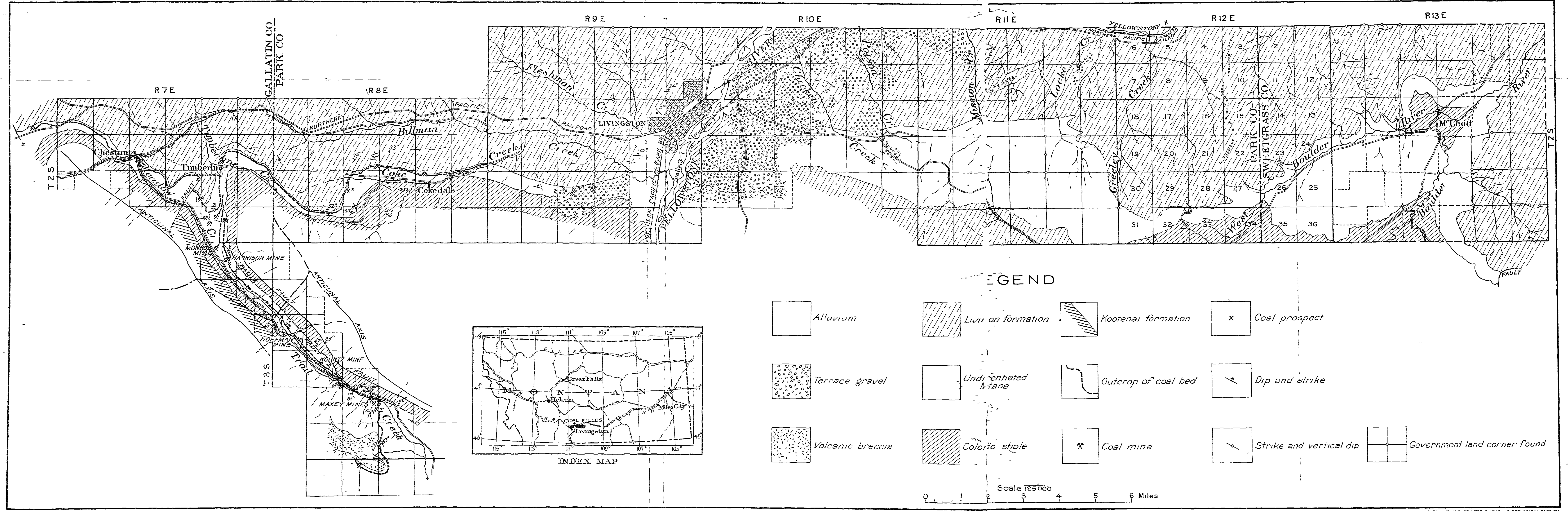
In the Maxey mines the coal bed is very uniform in thickness and character. The bed is 9 feet thick, with sandstone roof and floor and with a 2-inch sandstone parting 66 inches from the bottom. This is left as a roof at present, but when pillars are pulled the coal above the parting will be removed. The dip in No. 2 workings is about 10°.

In 1906 the production was about 150 tons, but in later years it has been increased to 200 tons or more. From the mine the coal first passes over bars with 3½-inch spaces, separating out the lump coal, and the remainder is sorted by a revolving screen into nut, egg, and smaller sizes.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

The coal of the Livingston and Trail Creek fields presents a wide variation in physical appearance and character, ranging from a blocky compact variety at the Maxey mine to soft, crushed, and coking coal in part of the Meadow Creek district. In most of the Livingston field this crushed condition is predominant and the coal is usually a high-grade fuel of the bituminous class, being coked locally and elsewhere furnishing an excellent steam coal. In the Trail Creek field the coal is not crushed and can be sized without



ENGRAVED AND PRINTED BY THE U S GEOLOGICAL SURVEY

GEOLOGIC MAP OF LIVINGSTON AND TRAIL CREEK COAL FIELDS, PARK, GALLATIN, AND SWEETGASS COUNTIES, MONTANA

By W R Calvert

difficulty. It also is a bituminous coal, but of lower grade than the typical coal of the Livingston field.

CHEMICAL PROPERTIES.

As may be inferred from the variability in the physical character of the coal of the Livingston and Trail Creek fields, the chemical character varies in similar manner. Samples were taken from the operating mines and sent to the Survey laboratory at Pittsburgh, and their analyses are presented in the following table:

9817°—Bull. 471—12——26

Analyses of coal samples from the Livingston and Trail Creek coal fields, Montana.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Location.				Thickness.		Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
	Quarter.	Sec.	T. S.	R. E.	Coal bed.	Part sampled			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
					Inches.	*Inches.*													
6596	NE. ¼ NW........	25	2	8	31	31	4.6	A.....	6.2	30.6	36.9	26.26	0.68	4.77	53.79	0.86	13.64	5,440	9,790
								B.....	1.7	32.1	38.7	27.53	.71	4.47	56.38	.90	10.01	5,700	10,260
								C.....	....	32.6	39.4	28.01	.73	4.34	57.38	.92	8.62	5,805	10,450
								D.....	....	45.3	54.7	....	1.01	6.03	79.71	1.28	11.97	8,060	14,510
6597	NW..........	26	2	7	42	37	3.8	A.....	5.8	33.1	50.5	10.57	.50	5.38	69.23	1.01	13.31	6,825	12,280
								B.....	2.0	34.5	52.5	10.99	.52	5.16	71.96	1.05	10.32	7,090	12,770
								C.....	....	35.2	53.6	11.22	.53	5.03	73.47	1.07	8.68	7,240	13,030
								D.....	....	39.6	60.4	....	.60	5.67	82.75	1.21	9.77	8,155	14,680
166-D	....	26	2	7	71	60	3.0	A.....	4.8	30.0	36.5	28.7	.51	....	....	....	....	....	....
								B.....	1.9	30.9	37.6	29.6	.53	....	....	....	....	....	....
								C.....	....	31.5	38.3	30.2	.54	....	....	....	....	....	....
								D.....	....	45.2	54.8	....	.80	....	....	....	....	....	....
3667	SW................	9	2	7	....	....	2.8	A.....	5.4	27.0	37.0	30.63	.33	4.24	50.58	.81	13.41	5,020	9,030
								B.....	2.7	27.7	38.1	31.51	.34	4.04	52.04	.83	11.24	5,165	9,300
								C.....	....	28.5	39.1	32.37	.35	3.85	53.46	.86	9.11	5,305	9,550
								D.....	....	42.1	57.9	....	.52	5.69	79.04	1.27	13.48	7,845	14,120
6621	SE ¼ SW..........	13	2	6	38	38	1.5	A.....	2.1	16.4	73.2	8.31	.86	4.08	81.03	1.28	4.44	7,830	14,090
								B.....	.6	16.7	74.3	8.44	.87	3.97	82.26	1.30	3.16	7,950	14,310
								C.....	....	16.7	74.8	8.48	.88	3.93	82.72	1.31	2.68	7,995	14,390
								D.....	....	18.3	81.7	....	.96	4.29	90.39	1.43	2.93	8,735	15,720
3813	....	18	3	8	98	94	3.4	A.....	12.5	31.0	39.6	16.9	.50	....	....	....	....	....	....
								B.....	9.4	32.1	41.0	17.5	.52	....	....	....	....	....	....
								C.....	....	35.5	45.2	19.3	.57	....	....	....	....	....	....
								D.....	....	44.0	56.0	....	.70	....	....	....	....	....	....
3818	....	18	3	8	62	54	2.9	A.....	12.4	36.8	42.3	8.51	.61	5.64	62.53	.93	21.78	6,085	10,950
								B.....	9.8	37.9	43.5	8.77	.63	5.48	64.40	.95	19.77	6,265	11,280
								C.....	....	42.1	48.2	9.72	.70	4.86	71.38	1.06	12.28	6,945	12,500
								D.....	....	46.6	53.4	....	.77	5.39	79.06	1.18	13.60	7,690	13,840
3725	....	20	3	8	....	....	3.7	A.....	11.7	36.4	41.4	10.52	.39	5.40	61.17	.87	21.65	5,975	10,760
								B.....	8.4	37.8	42.9	10.92	.41	5.18	63.52	.90	19.07	6,205	11,170
								C.....	....	41.2	46.9	11.92	.44	4.63	69.31	.99	12.71	6,770	12,190
								D.....	....	46.8	53.2	....	.50	5.26	78.70	1.12	14.42	7,690	13,840

6607	NW	27	3	8	108	104	9.4	A	16.3	30.1	40.1	13.50	.41	5.15	53.48	.82	26.64	5,135	9,250
								B	7.6	33.3	44.2	14.90	.45	4.54	59.03	.90	20.18	5,670	10,210
								C		36.0	47.9	16.13	.49	3.99	63.92	.98	14.49	6,140	11,050
								D		42.9	57.1		.58	4.76	76.21	1.17	17.28	7,320	13,180

No. 6596. Livingston Coal & Coke Co.'s mine. Sampled by W. R. Calvert from working face.

No. 6597. Washoe Copper Co.'s mine No. 1 (Hodson). Sampled by W. R. Calvert from face of pillar between rooms 1 and 2.

No. 166-D. Washoe Copper Co.'s mine No. 3. Sampled by John W. Groves, 4,600 feet north of portal.

No. 3667. Mountainside mine. Sampled by J. P. Rowe, location in mine not known.

No. 6621. Bailey & Beedle mine. Mine run, sampled from tipple by W. R. Calvert.

No. 3813. Hoffman mine. Sampled by J. P. Rowe from third entry, 800 feet west of foot of slope.

No. 3818. Hoffman mine. Sampled by J. P. Rowe at head of west entry, 1,200 feet in mine.

No. 3725. Kountz mine. Sampled by J. P. Rowe, location in mine not known.

No. 6607. Maxey south mine. Sampled by W. R. Calvert from head of entry, 825 feet from portal.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form is not well suited for comparison, because the amount of moisture in the sample as it comes from the mine is largely a matter of accident, and consequently analyses of the same coal expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted to general comparisons. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated. Analysis D represents the coal after all moisture and ash has been theoretically removed. This is supposed to represent the true coal substance, free from the most significant impurities. Forms C and D are obtained from the others by recalculation. They should not be used in comparison, for they represent theoretical conditions that never exist.

In the analytical work chemists generally recognize that it is not possible to determine the proximate constituents of coal or lignite with the same degree of accuracy as the ultimate constituents. Therefore, the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place only; whereas the ash (in an ultimate analysis), sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. It is also understood that calorific determinations to individual units are not reliable; therefore, in the column headed "Calories," the heat values are given to the nearest five units, and in the column headed "British thermal units" they are given to the nearest tens (the value of a British thermal unit being about one-half that of a calorie).

FUTURE DEVELOPMENTS.

As stated previously, it is probable that development in the Livingston field attained its maximum a number of years ago and that the greater part of the readily accessible coal has been removed. The field is not entirely exhausted, however, and it is likely that coal will be mined in several localities for a considerable period. The coal in the eastern part of the Cokedale district, although thin, is of excellent quality and a considerable quantity remains readily available. Under present conditions it is improbable that there will be a renewal of activity in the Timberline district, and in the Meadow Creek district a relatively large tonnage remains only in mine No. 1. At the Chestnut mine, north of the railroad, the coal is said to be nearly exhausted, but in the Mountainside mine, south of the railroad much is still within reach. Between the old workings of the Chestnut mine and the Bailey & Beedle mine the coal remains untouched, but the high dip causes the amount available to be relatively small. It is in the Trail Creek field, therefore, that the greatest proportion of future development may be expected, although even there the area underlain by coal is not extensive. A sufficient tonnage is undoubtedly present, however, to allow the current operations to be continued in the northern part of the field for a decade or more, and in the southern part, although the available tonnage is a matter of conjecture, it is no doubt ample to provide the present annual production for many years. With all factors taken into consideration it seems probable that, although a considerable amount of steam and domestic fuel will yet be mined in the Livingston and Trail Creek fields, the former area will scarcely again enter largely into the total coal production of the State. Even with increased development in the Trail Creek field and in certain districts of the Livingston field it is improbable that the total annual production will equal the maximum amount in past years.

THE ELECTRIC COAL FIELD, PARK COUNTY, MONTANA.

By W. R. Calvert.

INTRODUCTION.

In 1908 the writer was detailed to examine several coal-producing areas in Montana, and among these was a small district lying to the west of Yellowstone River and north of Yellowstone National Park. This district has been referred to as the Cinnabar coal field, but at the present time it is better known locally as the Electric field, as it is from the railroad station of that name that the fuel is shipped. In this report, therefore, the latter name is applied.

Subsequent to the return of the writer to the office time has not been available until recently to prepare for publication the data obtained in the field, and as the district has not been revisited the discussion of its economic development is in consequence incomplete. Development of a coal field is only one feature of interest, however, and it is the object of this paper not only to set forth such data bearing on the actual mining of coal as were available in 1908, but also to discuss the geology which is directly connected with the coal.

The purpose of the examination in 1908 was not only to study the geology of the area, but also to ascertain the relation of the coal beds to land subdivisions in order that such public lands as might be underlain by coal-bearing rocks could be classified. The Electric field had previously been mapped topographically, but the 200-foot contour interval then employed was not adapted to the later examination and, moreover, there had been no attempt to show the relation of surface features to land lines. Accordingly, in pursuance of the work in 1908, the area was mapped topographically on a 100-foot interval, and the relation of surface features to land subdivisions was ascertained. In this mapping planetable and open-sight alidade were employed and horizontal control was obtained either by foot pacing or by triangulation. Elevations were based entirely on aneroid-barometer readings, so that no special accuracy is claimed for the vertical control. The topography was mapped by E. F. Schramm, and he also assisted the writer in mapping the geology of the field.

The Electric field has been studied and described in more or less detail by previous workers, the earliest report probably being that of J. E. Wolff,[1] who examined the district for the Northern Transcontinental Survey. Later W. H. Weed[2] made a study of the field in connection with the survey of the Yellowstne Park.

GEOGRAPHY.

LOCATION AND EXTENT.

The areas of coal-bearing rocks constituting the Electric field lie in the northeastern part of T. 9 S., R. 7 E., and in the northwestern part of T. 9 S., R. 8 E. Topographic mapping also included portions of the townships adjoining on the north. The field as mapped covers less than 20 square miles, and although this area embraces all producing mines in the field, coal-bearing rocks extend in outcrop beyond the limits of the area represented by the map, on the east side of the Yellowstone and on the south into the park. On the key map (Pl. XXX) is shown the location of the Electric field in the State of Montana.

TOPOGRAPHY.

Topographically the field comprises a mountainous ridge several miles wide lying between the deeply carved valley of the Yellowstone on the east and an area of less rugged country to the west of Mulherin Creek. Cinnabar Mountain, near the northern end of the field, rises 6,900 feet above sea level and 1,700 feet above Yellowstone Valley. South of this mountain the surface slopes downward for about a mile, then rises gradually and culminates in Electric Peak, on the northern boundary of the park, where the altitude is 11,155 feet. It will be seen from the map (Pl. XXX) that the coal-bearing rocks occupy the surface over the greater part of the high country south of Cinnabar Mountain. The occurrence of coal at this high altitude in comparison with Yellowstone Valley necessitates special methods of transportation from the mines to the railway, which will be discussed later in this paper.

POPULATION.

Two small towns are located in the field. Electric is on the Park branch of the Northern Pacific Railway and is the shipping point of the field. Aldridge is situated near the mines south of Cinnabar Mountain and is essentially a coal-mining camp. Aside from these centers of population the field is sparsely settled except in Yellowstone Valley, where conditions are favorable to agriculture.

[1] Tenth Census U. S., vol. 15, Mining industries, 1880, p. 756.

[2] Iddings, J. P., and Weed, W. H., Livingston folio (No. 1), Geol. Atlas U. S., U. S. Geol. Survey, 1894. Also Weed, W. H., Cinnabar and Bozeman coal fields of Montana: Bull. Geol. Soc. America, vol. 2, 1891, pp. 349-364.

GEOLOGY.

STRATIGRAPHY.

OLDER ROCKS.

A wide range in age and variety in lithology is represented by the rocks of the Electric field. The oldest rocks are the pre-Cambrian crystallines, which, according to Weed, are shown in outcrop on the north slope of Cinnabar Mountain. These are overlain by Cambrian strata having a total thickness slightly in excess of 700 feet. Next above the Cambrian are the Jefferson limestone and the Threeforks shale, both of Devonian age and about 400 feet thick in all. Still higher stratigraphically is the Madison limestone, of Mississippian age about 1,800 feet thick. None of these formations were studied in 1908, as they have no direct relationship to the coal-bearing rocks, and the foregoing statements are based on the Livingston folio.

SEDIMENTARY ROCKS MAPPED.

The oldest sedimentary rocks mapped in the field constitute a formation correlated with the Quadrant, which derives its name from the type locality at Quadrant Mountain, in Yellowstone Park. Where exposed in the Electric field this formation consists of variegated gypsiferous shale and thin platy sandstone, overlain by a massive sandstone which is quartzitic at the top, probably from the metamorphic action of an intrusive that occurs just above. The upper surface of this sandstone is beautifully ripple-marked. The Quadrant and associated formations are well exposed in Cinnabar Mountain, where the rocks are vertical in attitude and where erosion has caused the harder members to stand out like walls with the softer shales forming "sags" between. Cinnabar Mountain owes its name to the brilliant red color up the steep slope known as the Devils Slide, which was supposed to be produced by cinnabar, an ore of mercury, but now it is generally recognized that cinnabar is not present and that the red color is due to the gypsiferous shale of the Quadrant formation. No fossils were found in the Quadrant in the Electric field, so that its age is not definitely fixed. In the central part of the State, notably in the vicinity of the Little Belt and Big Snowy mountains, strata of similar lithology and apparent stratigraphic position contain a Mississippian fauna, although in the uppermost beds Pennsylvanian types occur. It is believed, however, that in the Electric field all the strata assigned to the Quadrant are older than Pennsylvanian, and if upper Carboniferous rocks were ever present at this locality they were removed by erosion prior to the deposition of the strata now overlying the Quadrant formation. In the Cinnabar Mountain section the Quadrant is 200 feet thick, although it is possible that certain limestone beds at the base considered to be Madison should be included, thus increasing somewhat the thickness at present assigned to the Quadrant.

Overlying the quartzitic member of the Quadrant are alternating drab to dark shale, gray platy limestone, and thin sandstone, which are correlated with the Ellis formation of the Upper Jurassic on the basis of lithology, stratigraphic position, and fossil evidence. The limestone and shale members contain the following fossils, as identified by T. W. Stanton:

Gryphæa planoconvexa Whitfield.
Astarte meeki Stanton.
Cyprina? iddingsi Stanton.
Pleuromya subcompressa Meek.
Gryphæa calceola var. nebrascensis Meek and Hayden.

The sandstone members of the Ellis appear to carry only *Ostrea strigilecula* White.

As Upper Jurassic fossils were obtained a short distance stratigraphically above the Quadrant formation, it is believed that Pennsylvanian, Triassic, and earlier Jurassic formations are not represented in the Cinnabar Mountain section, but that as in various localities in central Montana the Ellis lies unconformably on strata of lower Carboniferous (Mississippian) age. The total thickness of rocks here assigned to the Ellis is 277 feet.

Above the Ellis is a sequence of sandstones and variegated shales 185 feet thick, which is believed to represent the fresh-water Morrison formation, of Jurassic or Lower Cretaceous age. This determination is based entirely on lithology and stratigraphic position, as no fossils were found.

Overlying the Morrison (?) formation are sandstone and maroon shale, 577 feet thick in all. In the Livingston folio these beds are considered as Dakota, but the evidence now seems sufficient to correlate the formation with the Kootenai, or Lower Cretaceous, which is the coal-bearing formation in the central part of the State. The most striking feature is a coarse to pebbly sandstone 30 feet thick, about 90 feet above what is considered the base of the formation. Beneath this sandstone is a carbonaceous zone in which at one place coal a foot thick was found. Above the sandstone is maroon shale, so that in every respect the formation is strikingly similar to the Kootenai as known elsewhere in the State and fossils alone are lacking to make the correlation absolute.

Above the Kootenai formation is a mass about 2,800 feet thick, consisting mainly of dark shale and intercalated thin beds of sandstone. This mass is entirely of Colorado age, as distinctive fossils have been found throughout the formation. Near the top the following fossils were obtained, as identified by Stanton:

Ostrea sp.
Modiola sp.
Inoceramus acutiplicatus Stanton.
Baculites asper Morton?
Scaphites ventricosus Meek and Hayden.
Exogyra sp.
Inoceramus sp.
Pinna sp.
Crassatellites sp.
Turritella sp.
Cyrodes sp.
Fasciolaria? sp.
Actæon sp.

The assignment of this entire mass to the Colorado is at variance with previous writers, as the upper half was believed to be the equivalent of the Pierre shale and Fox Hills sandstone, both of Montana age. The presence of Colorado fossils at the top is, however, sufficient evidence to refute this former interpretation.

Overlying the Colorado shale is a mass of sandstone and sandy shale which constitutes the most important division of the entire geologic column, as in it occurs the coal of the field. In previous reports these coal-bearing rocks have been assigned to the Laramie, but the evidence now at hand suggests that they are considerably older. They rest conformably on beds formerly considered to be Fox Hills but now known to be Colorado, so that stratigraphically the coal measures are the equivalent of the lower Montana. Fossil evidence, although rather meager, strengthens this view. One collection from the Newton mine contained the following:

Modiola sp., fragments of a striated species.
Cardium sp., probably new.
Corbula perundata Meek and Hayden.
Fusus? sp.

From strata in the Foster mine a single small specimen was taken resembling the young of *Corbicula occidentalis* Meek and Hayden. Stanton, who made the identification, refers to the collection as follows:

> These fossils include both brackish-water and marine species. The brackish-water forms are the Modiola and the Corbula, both of which have been found in the Judith River and Claggett formations of other parts of Montana and in the Mesaverde of Wyoming and Colorado. The Corbicula belongs to the same fauna and has about the same range, although similar species occur in the Laramie also. The Cardium and Fusus, although not specifically determined, are especially important because they are marine forms and are therefore strong presumptive evidence that the rocks from which they came are older than Laramie. Taken together, therefore, the fossils tend strongly to confirm the opinion previously reached on the basis of stratigraphic evidence that the coal-bearing rocks at Electric belong in the Montana group and are older than Laramie.

Another collection was received from Mr. R. M. Magraw, superintendent of the Montana Coal & Coke Co., in 1908 and included the following:

Ostrea subtrigonalis Meek and Hayden.
Corbula sp.
Melania insculpta Meek.
Melania sp.

Stanton writes in a letter to Mr. Magraw:

> These species are in part different from those which you sent last spring from a neighboring locality, but they belong to the same general fauna and tend to confirm the conclusion then reached—that your coal-bearing rocks are older than Laramie.

The stratigraphic and paleontologic evidence presented above points fairly conclusively to the fact that the coal-bearing strata of the Electric field are not Laramie, as previously considered, but constitute a part of the Montana group. In thickness and in character of material they resemble the Mesaverde as developed to the south in Wyoming and Colorado, but the use of that formation name is not entirely applicable in view of the fact that the lowest beds rest on strata containing a Colorado fauna, thus demonstrating that at least the lowest beds are older than Mesaverde. The stratigraphic position of the coal-bearing rocks is similar to that of the Eagle sandstone, the lowest formation of the Montana group, but the lithology and thickness are adverse to such a correlation, inasmuch as the Eagle as known throughout its wide extent in the State is probably nowhere more than 400 feet thick and is a well-defined sandstone unit. In the Electric field, on the contrary, the coal-bearing rocks under discussion are nearly 1,000 feet thick and contain a large proportion of shale. It seems best, therefore, to designate the strata as undifferentiated Montana and not to attempt the assignment of a definite formation name.

The coal-bearing rocks, or undifferentiated Montana, are probably the youngest sedimentary rocks of Cretaceous age that are present in the Electric field. In secs. 17 and 18, T. 9 S., R. 8 E., there is an area where rocks probably younger than Cretaceous are exposed. These consist of water-laid material, mainly of volcanic origin. The lower portion consists of coarse to pebbly bedded sandstone, the sand grains and pebbles being reworked volcanic material. Above are light-colored, nearly structureless beds composed largely of volcanic ash and andesitic pebbles. Still higher stratigraphically are sandy beds, coarsely cross-bedded, overlain in turn by about 100 feet of poorly exposed strata, and at the top of the section the rocks are coarsely conglomeratic, the pebbles and bowlders consisting of greenish volcanic material apparently andesitic. These rocks are overlain with high angular unconformity by igneous flows. In the Livingston folio the stratified rocks are mapped as acidic andesitic breccia and flows, but in the written description reference is made to certain unspecified localities where water has been a factor in the deposition of such material. In the area under consideration, however, there can be little doubt regarding the sedimentary character of the beds, although their volcanic appearance and original source are evident. The thickness of these beds is about 600 feet.

Data are not available to determine the age of these strata. That they are considerably older than the volcanic material that overlies them is evidenced by the angular discordance between them. Moreover, their age antedates the major dynamic disturbance of the district, as is indicated by the fact that they are involved in the large fault that passes up the valley across sec. 18, for not only are the rocks brought into contact with strata well down in the Colorado shale, but they have also been tilted at high angles adjacent to the fault plane.

The lower contact of the strata was nowhere observed, but in all probability the rocks lie unconformably on Colorado shale. In regard to their geologic age, therefore, all that can be said is that they are considerably younger than the coal-bearing rocks and much older than the overlying igneous flow, which in the Yellowstone Park folio is considered of Neocene age. They may, therefore, be assigned with considerable confidence to the Eocene, but their position in that series can not be fixed.

In view of the sedimentary character of the beds described and the fact that they constitute a well-defined geologic unit, it seems desirable to designate them by a specific formation name, and as Reese Creek flows along the fault limiting these rocks on the west, the name Reese formation is proposed.

In the vicinity of Cinnabar Mountain an excellent opportunity presented itself to measure and examine the various geologic formations previously described, with the exception of the Reese. Practically every foot of the geologic section is there exposed, and careful measurement was made with a tape, beginning at what was considered the base of the Quadrant formation and continuing up to the base of the undifferentiated Montana. The latter was measured either by Locke level or by pacing across inclined strata, so that the results are not so reliable as those obtained by tape. The detailed section is as follows:

Section of Paleozoic and Mesozoic beds measured at Electric, Mont.

	Feet.
Undifferentiated Montana, Upper Cretaceous:	
Shale, sandy, and sandstone, alternating	60
Sandstone, soft, massive, lower 18 feet alternating with dark shale	42
Shale, dark, alternating with sandstone	28
Sandstone	6
Sandstone, thin, alternating with dark shale	65
Clay shale, dark, and in places thin sandstone	32
Sandstone, firm, massive	6
Shale, dark, alternating with thin earthy green sandstone	41
Sandstone, soft, massive, at bottom becoming argillaceous and toward top thin-bedded	18
Clay shale, dark, and thin sandstone, with three carbonaceous zones but no coal	28
Shale, carbonaceous	7
Sandstone, soft and massive to unconsolidated; a 2-foot coal zone 2 feet from the top	54
Limestone, argillaceous	4
Sandstone, soft, unconsolidated	31
Sandstone, soft, massive	25
Shale, arenaceous	12
Coal zone	4

Undifferentiated Montana, Upper Cretaceous—Continued.	Feet.
Shale, dark	16
Sandstone, soft, cross-bedded	14
Shale, dark	15
Sandstone, dark green, firm at top, grading down into soft sand	10
Shale, dark	12
Sandstone, greenish, weathering brown, firm, massive	16
Shale, dark	36
Coal and carbonaceous shale	6
Shale, soft, sandy, and in places thin sandstone beds	78
Sandstone, soft, massive	30
Sandstone, soft, generally massive; in places dark shaly layers	217
Sandstone, grading into dark sandy shale at base	42
	955
Colorado shale, Upper Cretaceous:	
Shale, dark, sandy, and thin sandstones	88
Shale, dark, and plates of sandstone, sandy at top; fossils collected 75 feet from base	395
Shale, dark, and thin plates of sandstone	793
Shale, dark, and platy sandstone; limy concretions 37 feet from base containing fossils	154
Sandstone, greenish, fine grained	3
Shale and thin sandstone, alternating	31
Sandstone, lower 40 feet dark and thin bedded, upper 54 feet gray and more massively bedded, all hard and dense; upper member quartzitic at top	94
Shale, dark, and thin plates of sandstone	69
Sandstone, thin bedded	23
Sandstone, dark and shaly at base, merging into shale with sandstones in places	270
Sandstone, brownish, firm, shaly at base, becoming purer upward	31
Shale, dark, with sandstone beds a few inches thick in places; the upper part is sandy, with thin sandstones in places	358
Shale, dark at base, intercalated with thin sandstones; pure sandstone at top	92
Sandstone, thin bedded at base, soft and massive near top	17
Shale, sandy, alternating with thin sandstone layers	49
Shale, dark, fissile, interlaced with plates of thin sandstone	221
Sandstone, shaly, becoming more sandy upward, and merging into dark shale; the sandstone weathers rusty	65
Shale, dark	22
	2,775
Kootenai formation, Lower Cretaceous:	
Quartzite, thin, intercalated shale near top	13
Shale, sandy	14
Quartzite	16
Shale and thin sandstones	17
Sandstone, quartzitic	32
Shale, sandy	7
Quartzite	9
Shale, calcareous, and thin limestones	19

Kootenai formation, Lower Cretaceous—Continued.	Feet.
Limestone, lower 12 feet weathers light buff; upper 3 feet orange-yellow	15
Soft beds, concealed	69
Sandstone, coarse grained, thin and cross-bedded	19
Shale, dark, and thin plates of sandstone	10
Limestone, thinly bedded, with shale partings	14
Shale, maroon and greenish, and thin lenticular limestones	32
Limestone, purple, concretionary	8
Shale, maroon, with lenses of purple concretionary limestone	22
Limestone, purple	3
Shale, maroon	9
Sandstone at top, metamorphosed at base	25
Intrusive	4
Sandstone, coarse grained, massive, conglomeratic at base	30
Sandstone, thin, platy, dark shale, and a thin coal bed	12
Sandstone, soft, massive, shaly at top	9
Partly concealed; upper part sandy shale or soft sandstone	88
Shale, alternating with sandstone, latter predominating	85
Total (sedimentary rocks)	577
Morrison (?) formation, Upper Jurassic or Lower Cretaceous:	
Sandstone, brownish, soft, capped by 1 foot of intrusive	23
Shale, variegated, and sandstone, alternating, the latter reddish brown	65
Intrusive	8
Shale, purplish and maroon, alternating with thin reddish-brown sandstone	79
Sandstones, thin, and sandy shale, with 2 feet of brown sandstone at top	18
Total (sedimentary rocks)	185
Ellis formation, Upper Jurassic:	
Sandstone, greenish gray, massive, with several oyster-bearing layers	41
Shale, dark, calcareous, at base, with shaly fossiliferous limestone, passing into shaly sandstone 30 feet from base, above a soft thin sandstone and sandy shale	86
Limestone, dark gray	2
Shale, dark	3
Limestone, drab-colored, compact, fine grained	4
Shale, greenish, compact	5
Intrusive	30
Limestone at base, calcareous shale and thin limestone above; lower limestone contains abundant Ostrea	28
Shale, dark, merging upward into shaly limestone	19
Limestone, drab	4
Shale, dark	11
Limestone, drab, platy, fossiliferous	6
Partly concealed; where exposed is dark shale and thin platy limestone; drab color	68
Intrusive	86
Total (sedimentary rocks)	277

	Feet.
Quadrant formation, Mississippian(?):	
Sandstone, gray, massive, moderately firm at base, passing into quartzite	81
Variable beds, soft red platy sandstone, maroon and red shales, and yellow sand; all gypsiferous	72
Shale, green, highly gypsiferous	48
Madison limestone, Mississippian.	
	201

IGNEOUS ROCKS.

On the map (Pl. XXX) no attempt is made to show igneous rocks except where they occur as surface flows of considerable size. As noted in the Cinnabar Mountain section, however, intrusives are not uncommon, and farther south this type of rock was noted even more frequently. Electric Peak was an active volcano in Tertiary time and from that center radiates a system of dikes and sills. Few of these had been encountered in the various mine workings up to 1908, but as development is extended southward they must be taken into consideration and they are certain to detract materially from the commercial value of that part of the field, if in fact they do not render mine operations impracticable.

STRUCTURE.

Much variety in the way of structure is presented in the Electric field. In general, the area may be said to represent a fault block narrowing to an apex north of Cinnabar Mountain and depressed relatively many thousand feet. As indicated on the geologic map, the fault that delimits the block throws the coal measures into contact with ancient crystalline rocks east of Yellowstone River, and on the west side of the block the fault is probably of nearly equal magnitude. The block is highly folded and faulted within itself, the faults being of both normal and thrust types with great variability in angle of slippage planes. Near the apex of the fault block the rocks are practically vertical in attitude, causing the various formations to be exposed as bands, each corresponding closely in width to the actual thickness of the formation itself. Near the saddle south of Cinnabar Mountain the dips gradually decrease and for a short distance the sandy beds of the undifferentiated Montana are practically horizontal. Complexity in structure prevails, however, in passing southward to Electric Peak and the strata inclosing the coal are disturbed by many minor folds and faults. One fault trending westward in the central part of sec. 1, T. 9 S., R. 8 E., is of sufficient magnitude to cause a repetition of the coal measures and to separate entirely the two producing districts of the field. A fault of even greater throw is located in the valley of Reese Creek. On the map (Pl. XXX) only the more important structural breaks are shown.

This complexity of structure is the chief difficulty attending coal mining in the field, as in all the underground workings faults have been encountered and their variety in type causes doubt as to the best method of finding the coal on the unexposed side of the fault plane. On the other hand, it is almost certain that the high grade of fuel occurring in the field is due largely to the metamorphism resulting from dynamic movement. This feature is well attested in certain of the mines, notably in the Aldridge workings, where noticeable anthracitization of the coal is attendant upon sharp folds or occurs in the vicinity of faults.

THE COAL.

OCCURRENCE.

As shown on the geologic map (Pl. XXX) the coal of the Electric field is associated with rocks designated as undifferentiated Montana. These rocks occupy two distinct areas in the field. The smaller of these is found in secs. 6 and 7, T. 9 S., R. 8 E., and the other lies in the northeastern part of the township adjoining on the west. To the former the term "Electric district" is applied, as the town of that name is located at the margin of the area, and the other, for a similar reason, is designated the "Aldridge district." The approximate extent of each district is suggested on the map by the outcrop of coal bed No. 1. This coal is, however, the highest stratigraphically of the three main beds present in the field, and because of this fact the actual area underlain by coal may be slightly larger than indicated, although either steep dips along the outcrop or topographic conditions are such that in general all three beds outcrop in a narrow zone. The coal outcrops can be followed with a fair degree of certainty along the margin of the Electric district, although relations are somewhat obscured by faults in the central part of sec. 1. The location of the outcrops on the east side of the Aldridge district is likewise fairly evident on the ground, but between the Aldridge and Foster mines (see map) exposures are entirely lacking. That the coal of the Aldridge district occurs in a synclinal trough is, however, evident, but this trough may be less regular than suggested on the map. On the basis of the data obtained in 1908 no statement can be made relative to the extent southward of the Aldridge coal district. The moderate dip of the rocks in the southeastern part of sec. 11, T. 9 S., R. 7 E., suggests that the structural trough flattens and that in consequence the coal may continue southward to the limit of the area mapped. On the other hand, structure elsewhere in the field is complex and the possible conditions outlined above may not exist.

The coal beds present in the field are known locally as Nos. 1, 2, and 3, named in descending stratigraphic order. Shafting and drilling in the vicinity of Aldridge has disclosed the interrelation of these three beds as shown by the following section furnished by Superintendent Magraw:

Partial section of coal measures in the vicinity of Aldridge.

	Ft.	In.
Slate	5	
Soapstone	4	
Alternating slate and sandstone	43	
Sandstone	41	
Coal bed No. 1	3	4
Slate and sandstone	40	
Hard slate	3	
Sandstone	60	
Slate	5	
Indurated sandstone	74	
Slate	18	
Coal		6
Blackjack	1	
Slate	11	
Coal bed No. 2	4	2
Interval	50-60	
Coal bed No. 3	3	10

Of these coal beds only No. 1 is worked to any extent, as it alone is prevailingly coking in character. It was reported that the lower two beds are of coking quality in the vicinity of Electric, but in the main part of the field near Aldridge that characteristic appears to be lacking.

All the coal mined in 1908 was produced by the Montana Coal & Coke Co., which was operating three mines near Electric and three in the Aldridge district and was developing several other prospects.

DEVELOPMENT.

ELECTRIC DISTRICT.

Of the eastern group of mines that are included in what is considered as the Electric coal district, the Newton and Intermediate were the chief producers. In 1908 the Newton mine had been open 12 years and was developed by a slope driven 1,000 feet down a dip of approximately 40°. The bed is variable in thickness but in general is comparable to that in the Intermediate mine. The latter mine was opened in 1908, and at the time of examination the slope had been driven 275 feet. At the portal the dip is 24°, but at the end the dip increased to vertical and the coal pinched out. An entry was then turned to the right, but a fault was encountered within a short distance. A section of the coal bed in the Intermediate mine is as follows:

Section of coal bed in Intermediate mine.

	Inches.
Hard "soapstone" roof.	
Dirt and coal	6
Coal	6–7
Clay	2
Coal	4
Thin clay parting.	
Coal	9–12
Fine-grained sandstone	2
Coal	6
Clay	½
Coal	4
Gritty clay floor.	
	39½–43½

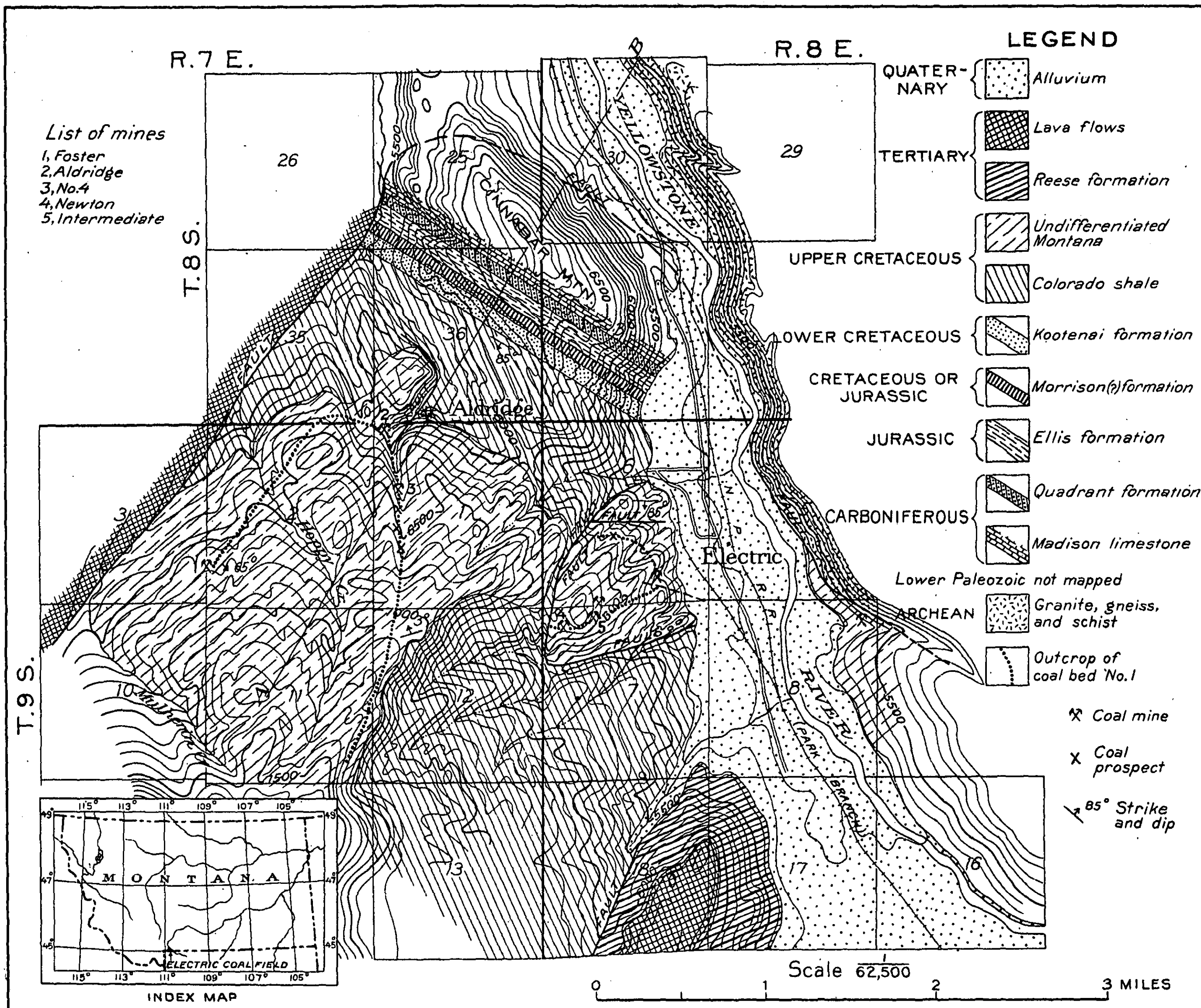
At the time of examination in 1908 development was being started on bed No. 1 at a locality about half a mile northeast of the Intermediate mine.

ALDRIDGE DISTRICT.

In 1908 three mines were in operation in the Aldridge district, namely, the Aldridge, Foster, and No. 4—all presumably on bed No. 1, although the identity of the bed worked in the Foster mine had not been definitely established. Of these the first named was much the largest, as removal of coal had been in progress since 1894. About 150 tons constituted the daily production in 1908, but development was not in progress and coal was obtained by retreat and removal of pillars. The coal in this mine ranges from low-grade bituminous to semianthracite, the latter occurring where the bed has been subjected to intense folding. It was found that the coal is of poor quality in the east entry under Hoppy Creek, and work in that locality was abandoned. Much of the coal in the mine is crushed and could be shoveled direct from the face without undercutting.

Mine No. 4 is located about half a mile south of the Aldridge opening and in 1908 was producing 50 or 60 tons daily. This mine has since been abandoned.

The Foster mine is located about a mile and a quarter southwest of Aldridge. In 1908 it was producing about 75 tons a day. The coal was formerly prospected at this place, and in May, 1907, the prospect was reopened and development began. The main entry was driven oblique to a 65° dip, and two entries had been turned to the right. Little of the coal came out as lump, but in general it was harder than that of the Aldridge mine. As a rule the coal was structureless and the foliation so noticeable in the Aldridge workings was not observed here.



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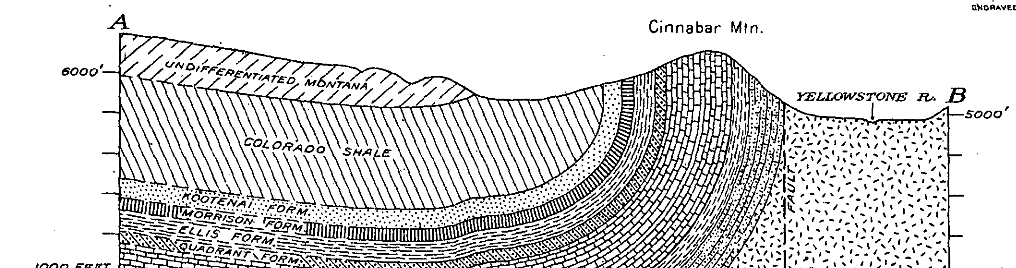

GEOLOGIC MAP AND SECTION OF THE ELECTRIC COAL FIELD, PARK COUNTY, MONTANA

By W. R. Calvert

TRANSPORTATION AND UTILIZATION OF THE COAL.

As suggested by the map of the Electric field, coal occurs mainly at a much higher altitude than Yellowstone Valley, and in consequence ordinary methods of transportation from the mines to the railroad are not practicable. Accordingly, aerial-tram systems were installed. One was operated between the Newton and Intermediate mines and the south tipple. This was a gravity system with 20 buckets of 1,450 pounds capacity. A 38-bucket system had been installed between Aldridge and the north tipple and one of 28 buckets conveyed coal from the Foster mine to Aldridge. In 1908 the tram between Aldridge and Electric was not in use, as a more economical method of conveyance was employed. This consisted of a flume between Aldridge and the settling house at the north tipple. The coal from the Aldridge, Foster, and No. 4 mines was conveyed in this flume from the washer at Aldridge into the tanks at the settling house. Here the finely crushed coal passed first into tanks of about 23 tons capacity and the overflow passed in turn into tanks of lesser dimensions. The final overflow, still containing a considerable amount of carbonaceous material, ran into a settling pond, and it was hoped that some method for its utilization could be discovered. The large percentage of ash present, however, practically precluded its use. After the settling tanks were filled the contents were dumped into bunkers below and allowed to drain from 24 to 72 hours, dependent on the demand from the coke ovens. From the bunkers the coal was hauled in 12-ton cars to the ovens, of which there were 125, each of 6 tons capacity and of ordinary type. Coal from all the mines was mixed together before charging, in order to assure uniformity in the final product, as it was found that coke from the washed coal of the Aldridge district was noticeably different from that obtained from the unwashed coal of the mines operated near Electric.

Practically all the coal produced in the entire field was coked, the market being chiefly the smelters at Butte and Anaconda. The smelters asked for coke of not more than 18 per cent ash content, but it was found difficult to approach that standard, the usual amount of ash being above 20 per cent.

CHEMICAL CHARACTER OF THE COAL.

Samples of the coal were obtained in several mines of the Electric field and were sent to the Geological Survey laboratory at Pittsburgh for analysis. These analyses are presented in the following table. They are given in four forms, designated A, B, C, and D. Form A represents the coal as received at the laboratory and presumably as it is taken from the mine. Form B shows the chemical composition of the coal after excess moisture has been removed by a current of warm air and the weight of the sample remains constant. Form C represents the theoretical composition after elimination of all moisture, and form D is given to show the coal substance itself free from both moisture and ash. The last two forms are not obtained by direct analysis but by recalculation from A and B.

In analytical work chemists generally recognize that it is not possible to determine the proximate constituents of coal or lignite with the same degree of accuracy as the ultimate constituents. Therefore the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place only, whereas the ash (in an ultimate analysis), sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. It is also understood that calorific determinations to individual units are not reliable; therefore in the column headed "Calories" the heat values are given to the nearest five units, and in the column headed "British thermal units" they are given to the nearest tens (the value of a British thermal unit being about one-half that of a calorie).

Analyses of coal samples from the Electric coal field, Montana.

[F. M. Stanton, chemist in charge.]

Laboratory No.	Name of mine.	Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heat value.	
		Quarter.	Sec.	T. S.	R. E.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
6599	Aldridge	NW	1	9	7	0.9	A	1.9	19.8	54.7	23.60	.44	4.35	64.40	.86	6.35	6,290	11,320
							B	1.0	20.0	55.2	23.81	.44	4.29	64.98	.87	5.61	6,345	11,420
							C		20.2	55.8	24.05	.45	4.22	65.63	.88	4.77	6,410	11,540
							D		26.6	73.4		.59	5.56	86.42	1.16	6.27	8,440	15,190
6601	Foster	SE	3	9	7	2.4	A	3.0	29.5	56.4	11.08	.85	5.12	73.60	1.14	8.21	7,380	13,290
							B	.6	30.3	57.7	11.35	.87	4.97	75.41	1.17	6.23	7,560	13,610
							C		30.5	58.1	11.42	.88	4.93	75.89	1.18	5.70	7,610	13,700
							D		34.4	65.6		.99	5.57	85.67	1.33	6.44	8,590	15,470
6610	Newton	NW	7	9	8	3.2	A	4.3	27.3	48.9	19.49	1.33	4.81	64.07	.97	9.33	6,340	11,410
							B	1.1	28.2	50.6	20.13	1.37	4.60	66.20	1.00	6.70	6,550	11,790
							C		28.5	51.1	20.36	1.39	4.53	66.91	1.01	5.80	6,625	11,920
							D		35.8	64.2		1.75	5.69	84.02	1.27	7.27	8,315	14,970
6639	"Store opening" (bed No. 3)	NW	1	9	7	2.7	A	5.2	35.3	40.1	19.4	.62					5,935	10,690
							B	2.6	36.3	41.2	19.9	.64					6,100	10,980
							C		37.3	42.2	20.5	.65					6,265	11,270
							D		46.9	53.1		.82					7,875	14,170
6600	Washed coal for coking from Foster and Aldridge mines.					16.6	A	17.5	19.4	45.2	17.91	.52	5.36	55.05	.88	20.28	5,485	9,880
							B	1.1	23.2	54.2	21.48	.62	4.22	66.01	1.05	6.62	6,580	11,840
							C		23.5	54.8	21.71	.63	4.15	66.73	1.07	5.71	6,650	11,970
							D		30.0	70.0		.80	5.30	85.24	1.37	7.29	8,495	15,290

Of the foregoing samples, that from the Aldridge workings was obtained by the mine foreman about 8,000 feet from the entrance. The coal in this mine, as in others in the field, is variable in character, and representative samples were taken daily by the foreman and analyzed at the company's laboratory in order to control the coke mixture. The sample (laboratory No. 6599) represents, therefore, the coal mined at the time of examination in 1908. The sample from the Foster mine (laboratory No. 6601) was likewise obtained by the foreman of those workings as best representing the average character of the coal. This sample was taken about 800 feet from the portal. The sample from the Newton mine (laboratory No. 6610) was obtained by the writer about 1,200 feet from the entrance. A sample (laboratory No. 6639) was also obtained by the writer from what was known as the "store opening," a prospect on bed No. 3 near the company's store at Aldridge, to ascertain if that bed were of coking quality.

In addition to the samples referred to, a representative sample of coke from washed coal from the Foster and No. 4 mines was taken by the company's chemist, for constant chemical check was kept on the coke as well as on the coal. This sample was analyzed at the Survey laboratory at Pittsburgh and as received contained 0.82 per cent moisture, 2.49 per cent volatile matter, 76.19 per cent fixed carbon, 20.50 per cent ash, and 0.66 per cent sulphur and had a heat value of 11,196 British thermal units.

The analyses given above show that the coal of the Electric field is a high-grade fuel. The large amount of waste, however, and the unusual mining conditions render the field a difficult one in which to operate economically. Only the facts that coke is in great demand by the smelting industry of the State and that coal of coking quality is not abundant in this region make it possible to operate in the Electric field at a profit.