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MARIUS R. CAMPBELL
GEOLOGIST IN CHARGE

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THE CENTRAL PART OF THE BULL MOUNTAIN COAL FIELD, MONTANA.[a]

By R. W. Richards.

INTRODUCTION.

Field work.—The survey of the Bull Mountain coal field, Montana, which was begun during the summer of 1907 by L. H. Woolsey,[b] was continued during the month of May and up to the middle of June, 1908, by M. A. Pishel and the writer, and from that time until the 1st of November by Henry Hinds, Frank R. Clark, James H. Bridges, and the writer. The present paper is a preliminary statement of the results obtained in the area bordering the north and east sides of that portion of the Bull Mountain field examined and discussed by Woolsey. The residents of the region rendered valuable assistance and the Republic Coal Company materially aided the progress of the work by the contribution of information gathered by its prospecting parties.

The primary purpose of the survey, as in the previous season, was the collecting of data for the classification and valuation of public lands supposed to be coal bearing. The only investigation in the Bull Mountain coal field previous to that of 1907 was that of the geologists of the Transcontinental Survey in 1881.[c] This was largely confined to the Mammoth coal bed, the discussion of which has been reviewed by Woolsey. The results of this earlier work, so far as identification is possible, agree closely with those obtained by the Geological Survey, but the work itself was carried on with much less detail.

Location and extent.—The Bull Mountain coal field is located in the southeast-central part of Montana, as may be seen by referring to the index maps of Plates IV and V. The field lies, roughly speaking, about 30 miles north of Billings, and is mainly bounded on the

[a] A full report on this coal field is in preparation and will be published as a separate bulletin.

[b] Woolsey, L. H., The Bull Mountain coal field, Montana: Bull. U. S. Geol. Survey No. 341, 1908, pp. 62-77.

[c] Eldridge, G. H., Montana coal fields: Tenth Census, vol. 15, 1886, pp. 753-755.

north by Musselshell River. Two parts of the field, however, cross the river, one in the vicinity of Musselshell and the other near Roundup. The east boundary of the field is still more irregular and crosses the heads of Wild Horse and Alkali creeks about 12 miles east of Musselshell post-office, in R. 31 E. The south boundary is within T. 5 N.

The field as a whole is about 36 miles from north to south and 30 miles from east to west. The part treated in this report is L-shaped and comprises about 612 square miles. It includes Ts. 5 and 6 N., Rs. 28 and 29 E.; T. 7 N., Rs. 25, 26, 27, 28, and 29 E.; T. 8 N., Rs. 25, 26, 27, 28, 29, and 30 E.; and portions of T. 9 N., Rs. 27 and 28 E. Roundup, the only mining town of the field, and the center of population, is situated on Musselshell River in T. 8 N., R. 25 E., about 2 miles northeast of a small trading point, formerly known as Roundup post-office. It presents to-day a remarkable instance of the rapid growth of a coal-mining camp.

Commercial relations.—The Bull Mountain coal field has been brought into prominence by the building of the Pacific coast extension of the Chicago, Milwaukee and St. Paul Railway, now known as the Chicago, Milwaukee and Puget Sound Railway. This field is the most promising source of coal supply for this new transcontinental road, a fact which has led to its rapid development.

Butte, a mining and smelting center, and one of the largest consumers of coal in Montana, is entered by the line of railway passing through Bull Mountain, and Roundup coal is being brought into this market on favorable competitive terms with coal from the other fields that up to the present year have supplied the industries of that city.

Billings, a large center of population, about 20 miles south of the southern edge of the Bull Mountain coal field and about 50 miles south of Roundup, derives its fuel supply mainly from the Red Lodge and Bear Creek districts, but direct railway connection between Roundup and Billings is a possibility of the future.

Drainage.—The Bull Mountain coal field occupies the higher portion of the main divide between Yellowstone and Musselshell rivers in Rs. 25 to 31 E. The streams draining the north side of the field and entering Musselshell River, named in order from west to east, are as follows: Goulding Creek, Naderman Coulée, Halfbreed Creek, Berrigan Coulée, Parrot Creek, Schnall Coulée, Fattig Creek, and Hawk Creek. The principal creeks which enter Yellowstone River from the southeast portion of the field examined are Buffalo, Hibbard, Cow Gulch, and Railroad creeks. The streams on both sides of the divide are for the most part intermittent, but all of them have deep-cut valleys that are often flooded after heavy showers.

TOPOGRAPHY.

The portion of the Bull Mountain field examined during the season of 1908 has an extreme relief of about 1,300 feet and exhibits a type of topography that is the result of rather mature erosion upon nearly horizontal beds of alternating hard and soft rocks. The traveler passing along the northern boundary of the field on the Chicago, Milwaukee and Puget Sound Railway sees to the south, in the background, high buttes, such as Three Buttes and the main northern Bull Mountain Mesa. Radiating from them in the mid-ground he sees rugged divides which are dissected into mere skeletons by innumerable coulées. In some places heavy horizontal sandstone strata produce extensive flats, which as a rule are utilized for grazing purposes. In the foreground stretches the flood plain of Musselshell River, which where irrigated produces excellent crops of alfalfa and grain. Badland topography is uncommon and is limited to a band of sandy clay shale which outcrops near the base of the coal-bearing rocks.

GEOLOGY.

STRATIGRAPHY.

The upper rocks of the Bull Mountain coal field belong to the Fort Union formation of the Tertiary system. The lower rocks, which rest in apparent conformity upon the Bearpaw shale of the Cretaceous, have by previous writers been either referred to the Laramie or designated "transition beds," between the Cretaceous and Tertiary systems. They are regarded as equivalent to the somber beds of the Miles City field. The upper 1,650 feet of the section contains an abundant fauna and flora, which have been identified as of Fort Union age by F. H. Knowlton and T. W. Stanton. The underlying 200 to 300 feet of somber-colored shale and coarse yellow sandstones, with beds of carbonaceous sandstone and shale, have yielded a few fossils of possible Fort Union age. The bottom portion of the section, comprising the doubtful Laramie or transition beds, is apparently barren of fossils and consists of alternating gray sandstones and clay shales with thin beds of coal.

Stratigraphy of the central part of the Bull Mountain coal field, Montana.

System.	Formation.	Thickness.	Description.
		Feet.	
Tertiary	Fort Union formation	1,650	Yellowish sandstones and shales interstratified with lignite beds.
(?)		200–300	Somber-colored shale and coarse yellow sandstones, with beds of carbonaceous sandstone and shale.
Cretaceous	Laramie (?) formation	1,480	Alternating gray sandstones and clay shales, with thin coal beds.
	Bearpaw shale		Gray to brown shales and clay.

A section of the lower beds is given below to show the proportions of the different rocks and the relative positions of the coal beds.

Section of lower rocks (Laramie?) of the Bull Mountain coal field, near Musselshell, Mont.

	Ft.	In.
Sandstone, gray (base (?) of Fort Union).		
Sandstone, yellow, coarse, soft	212	4
BIG DIRTY COAL BED.		
Carbonaceous sandstone and shale, with ½-inch to 1-inch streaks of coal	10	5
Sandstone, yellow, soft	6	6
Carbonaceous sandstone and shale, with streaks of coal as above	7	9
Sandstone, yellow, coarse, with iron concretions	15	4
Limestone	1	
Sandstone	14	
Coal		8
Shale, yellowish	30	
Sandstone	15	
Coal		4
Shale, gray		4
Coal		8
Shale, gray	34	
Sandstone, with iron concretions	55	
Limestone	3	
Shale, gray	3	4
Coal		3
Bone		3
Coal		7
Shale		4
Coal		3
Sandstone, yellow, weathering into rounded forms	16	
Shale	11	2
Coal		10
Limestone concretions	10	
Shale	30	
Sandstone	15	
Shale	2	
HOMESTEAD COAL BED.		
Coal		11
Shale, carbonaceous		9
Coal	1	1
Shale		1
Coal		11
Shale		1
Coal		6
Shale	18	6
Coal	1	8
Shale	6	
Coal		2
Shale	4	7
Sandstone	2	

	Ft.	In.
Shale	4	
Coal, bone		2
Coal	1	
Shale	10	9
Coal		3
Shale	5	
Sandstone	10	
Shale	1	6
Coal	1	6
Shale	10	
Sandstone	16	
Shale	10	
Coal		10
Shale	2	
Sandstone, with limestone cap	13	
Shale	41	
Sandstone, yellow, coarse, with limestone cap	40	
Shale	179	6
Sandstone	40	
Shale	92	6
Sandstone, yellow and gray	5	
Shale	74	
Sandstone, yellow to gray, weathering to rounded pebbles	30	
Shale, caky, with thin limestone bands	389	
Sandstone, calcareous	3	
Shale	80	
Sandstone	15	
Sandstone, yellow, porous	11	6
Concealed	131	2
Sandstone, brown, thin-bedded	26	5
Shales, clay, gray to brown (Bearpaw shale).		
	1,777	8

The character of the rocks which were identified as Fort Union and which constitute the upper portion of the Bull Mountain section is illustrated graphically in the columnar sections on Plates IV and V. This section, which is a generalization of several sections measured on the north and southeast sides of the mountains, differs from that published by Woolsey[a] for the southwest portion of the field chiefly in the intervals between certain coal beds. The most noticeable difference is the thickening of the beds near the base of the section by about 450 feet.

STRUCTURE.

The central part of the Bull Mountain field has a comparatively simple structure. It consists of a large, shallow synclinal basin, having a general northwestward axial trend, and a rather accentuated lip at its northwestern extremity. The syncline merges on its

[a] Op. cit.

northern border into a mild anticline whose flanks dip about 5°. The anticline is parallel on the north by a smaller but sharper syncline, the greater portion of which lies to the north of the area shown on the accompanying maps.

COAL.

GENERAL STATEMENT.

The coal of the Bull Mountain field is for the most part high-grade subbituminous ("black lignite") or low-grade bituminous. Mining has not been carried on for a sufficiently long period to observe the coal under all conditions of exposure, and thus to determine accurately its "stocking" qualities. If the coal proves to stock well it should probably be classed as bituminous coal. Twenty coal beds that in places attain a thickness of more than 2 feet were studied. The general habit of the beds is lenticular, though several beds are notable exceptions to this rule, and it has been possible to trace their outcrop completely around the mountains. An attempt was made to locate and define the workable portion of the beds by a study of the outcrop, supplemented by drill sections in the northwestern part of the field. The ravines, coulées, and ridges were carefully searched for outcrops of coal. All coals thus discovered were traced and those having a thickness of 2 feet or more were mapped. The traverses of the coal outcrop were made either by compass and pacing or by triangulation, according to the character of the topography. All traverses were tied to land corners. The position of these corners was assumed in general to be correctly given on the maps of the land surveys except along the right of way of the Chicago, Milwaukee and Puget Sound Railway, where the railway survey, being later than the land survey and doubtless more accurate, was accepted. Certain gross inconsistencies in the position of land corners were evident even by the method of work pursued, and these are shown on the maps. These maps indicate the number and character of the corners found, an effort being made to distinguish between government corners, doubtful government corners, corners reported by the railway survey but not visited by members of the party, and corners established by private individuals. The outcrops of the principal coals are platted in solid, broken, and dotted lines, which represent within certain rough limits the thickness of the coal beds and the position of the outcrops with reference to section corners.

DETAILED DESCRIPTIONS.

In this discussion the coals will be taken in order, beginning with the lowest bed and continuing upward to the highest bed in the Bull

Mountains proper. Named in this order, the principal coal beds are the Homestead, Big Dirty, Carpenter, Spendiff, Snyder, Snelling, Roundup, Wildhorse, "C. A.," Buckey, Chandler, Dougherty, Ostrander, Pompey, Saddler, Mammoth, Rehder, Rock Mesa, Carter, Matt, Bull Mountain, Wescott, Strait, Red Butte, Fattig, and Summit.

The thickest and probably best coal of the doubtful Laramie rocks has been called the Homestead bed. The following section, measured in a prospect, illustrates the character of the bed:

Section of Homestead coal bed, in T. 9 N., R. 27 E.

	Ft.	In.
Shale with coal streaks	2	
Coal	1	3
Bone		4
Coal		4
Bone		2
Coal		3
Shale	1	
Coal	1	1
Total coal	2	11

The sample of coal which was taken at this point from the 1-foot 3-inch bench at the top of the bed gave a calorific value of 12,116 British thermal units in the air-dried state, and on this basis alone the coal may be considered a high-grade subbituminous or possibly a low-grade bituminous. The coal, although almost freshly mined, showed marked indications of weather checking. The Homestead bed and its companion thinner beds were deemed unworthy of mapping in the field, and may be dismissed without further discussion.

The Big Dirty coal bed, called by Woolsey[a] the Glendive bed, is not workable in the Bull Mountain field, but in places it produces conspicuous outcrops (P coal, Pls. IV and V) and makes a useful marker by which to limit the area of coal-bearing rocks. In order that this bed may not be confused with any of the valuable coals, its distribution and character will be fully treated.

In the southeastern portion of the field the Big Dirty coal bed does not outcrop continuously, but its blossom was found in the southeast corner of T. 5 N., R. 28 E., and near the southeast corner of supposed sec. 23, T. 5 N., R. 29 E. (unsurveyed), the bed consists of 3 feet of carbonaceous shale and sandstone. It outcrops conspicuously along Cow Gulch, in the southeastern part of the township, where it consists of about 4 feet of carbonaceous shale. Outside of the area mapped during the present year this coal was seen in the

[a] Woolsey, L. H., op. cit., p. 66.

southeastern portion of T. 5 N., R. 32 E., on Buffalo Creek, and at this point consists of 20 feet of carbonaceous shale and sandstone, with thin streaks of coal. The Big Dirty coal bed has not yet been examined between this point and the center of T. 9 N., R. 30 E., where it is exposed as 11 feet of carbonaceous shale and sandstone, with the characteristic thin, irregular streaks of coal. In sec. 18, directly north of D. Chandler's prospect on the Carpenter coal, the Big Dirty thins to about 5 feet. The outcrop continues westward along the northern rim of the Fort Union basin, and was measured in the northwestern portion of T. 9 N., R. 28 E., where it shows two benches of carbonaceous shale and sandstone 4 and 3 feet thick, containing thin seams of coal and separated by a parting of sandstone 2 feet 6 inches thick. The outcrop continues nearly due west from this point to the northwest corner of the township, where it rounds the end of the syncline and takes a nearly southwest course. The bed as measured in sec. 20, T. 9 N., R. 27 E., consists of 5 feet of carbonaceous sandstone and shale, with thin seams of coal and 1 foot of dirty coal at the base. The outcrop crosses Musselshell River in the northeastern part of T. 8 N., R. 27 E., and thence runs approximately west, aside from the irregularities due to the topography. A prominent outcrop may be seen in the railway cut in sec. 3, one-half mile east of the Arkwright Sheep Company's ranch, where a thickness of about 6 feet of coaly shale is exposed. To the west, in secs. 5 and 6, the outcrop is very conspicuous, as it covers a dip slope for a considerable distance. Although it was not possible to obtain an actual measurement of the bed in this part of the township, it appears to be at least 20 feet thick and is composed of alternating carbonaceous shales and sandstones, with thin layers of coal. Fragments of the eroded coal collect in the coulees and appear to be of a fairly good quality. The outcrop continues across the next township to the west in the same general westerly direction and is well exposed at some places, especially in sec. 2, north of the river road, in an isolated butte. At this point it shows at least 2 feet of dirty coal. There is a more prominent outcrop in sec. 9, where the bed, 6 feet thick, is exposed in a railway cut. The amount of coal, however, is small and carbonaceous shale and sandstone predominate. In sec. 18 the bed is 10 feet thick, but consists mainly of dirty coal and carbonaceous shale. In T. 8 N., R. 25 E., the outcrop of the Big Dirty bed swings toward the northwest from a point in sec. 14 about 1 mile west of Roundup. The thickness in this township, as shown by several measurements, is about 10 feet, but the interbedded carbonaceous shale and sandstone predominate over the coal. The bed was next observed in the township to the south, where it out-

crops near the Elso schoolhouse. The following section was measured at this point:

Section of Big Dirty coal bed, near Elso schoolhouse, in sec. 7, T. 7 N., R. 25 E.

	Feet.
Carbonaceous shale, sandstone, and coal	6
Shale	2
Carbonaceous shale, sandstone, and coal	4

In the township to the west (T. 7 N., R. 24 E.), the Big Dirty coal bed outcrops on Kern Creek at two points. At the upper locality, which is about 4 miles from the last-mentioned section, it has the following composition:

Section of Big Dirty coal bed, in T. 7 N., R. 24 E.

	Ft.	In.
Shale, bituminous, with streaks of coal	2	11
Coal		10
Dirt		8
Bone		½
Coal		6
Shale, bituminous		5
Coal		3
Shale, bituminous	1	5
Coal		5
Shale, bituminous		10
Coal		½
Bone		2
Clay, sandy		6
Coal		3
Total coal	2	3½

The lower outcrop on Kern Creek about 2 miles from its mouth shows 2 feet of coal near the bottom of the bed. Coal taken from the bed at this point has been used by several ranchers with fairly good results, but it contains a large amount of ash and slacks in a short time. The probability of a bed of this character improving with depth or distance back from the outcrop is too remote to be considered, and capital expended in its development would undoubtedly be wasted.

The Carpenter coal is named from the creek on which it is mined in T. 9 N., R. 30 E. This bed is 450 feet stratigraphically above the Big Dirty coal bed. The main outcrop extends along the northern and eastern edges of the Bull Mountain field, and although it was not examined in detail, certain general statements concerning it can be made.

The Carpenter coal bed has the following section at W. C. Grant's opening in sec. 26, T. 9 N., R. 30 E., which may be considered typical of the thicker portion of the bed.

Section of Carpenter coal on Carpenter Creek.

	Ft.	In.
Coal, and some mineral charcoal	5	
Bone		2
Coal	1	1
Shale		1½
Coal, with six ½-inch partings	2	11
Total coal	9	

It thins gradually to the west; in T. 9 N., R. 29 E., it averages about 4 feet in thickness and in T. 9 N., R. 28 E., so far as could be observed, it is less than 2 feet thick. A closed outcrop of coal about 2 feet 8 inches thick which may belong to this bed is exposed on Fishel Creek in T. 8 N., R. 29 E., about three-fourths of a mile above August Schrader's ranch.

Bore-hole information in the vicinity of Musselshell post-office shows that the bed thins toward the south. The thickness of the bed and its position in the section indicate that the coal of the Fishel Creek locality may be safely correlated with the Carpenter coals. An exposure of coal which is probably an outcrop of the Carpenter bed was seen in the northwestern part of T. 7 N., R. 31 E. At this point, as the following section shows, the coal is separated into four benches by partings.

Section of Carpenter coal bed in T. 7 N., R. 31 E.

	Ft.	In.
Coal		6
Sandstone, bituminous		½
Coal	1	2
Shale	2±	
Sandstone	26	
Shale	2±	
Sand	1	2
Coal	1	2
Shale	1	11
Coal	1	7

The partings appear to thicken toward the southwest, but no measurements were taken showing more than 2 feet of coal. The better portion of the Carpenter coal bed therefore appears to lie in Tps. 8 and 9 N., Rs. 29 and 30 E. Further work is necessary, however, to determine the exact conditions under which these beds occur in the northeastern portion of the field. An analysis of a sample of the Carpenter coal given in the table on page 79 shows a calorific value somewhat lower than that of the Roundup coal.

Between the Carpenter and Roundup coal beds on Fattig Creek a number of thin coal beds, the Snelling, Snyder, and Spendiff (Ob, Oc, Od coals, Pl. V), locally show sections having from 1 to 3 feet of

coal. These beds are, however, relatively unimportant and do not merit further discussion.

The Roundup coal bed is about 600 feet stratigraphically above the Big Dirty coal bed, and at present is commercially the most important coal in the field, as all the active mines, namely, shafts Nos. 1 and 2 of the Republic Coal Mining Company and the Commercial mine of the Roundup Coal Mining Company, are located upon this bed. The coal is at present mined only in T. 8 N., R. 25 E. (Oa coal, Pl. V), but an abandoned prospect formerly operated by W. C. Grant in T. 8 N., R. 29 E. is apparently located on the same bed.

The westernmost outcrop of the Roundup coal near the north boundary of T. 7 N., R. 25 E., presents a scarcely workable section, but in sec. 33, T. 8 N., R. 25 E., it is thicker, as shown below:

Section of Roundup coal bed in sec. 33, T. 8 N., R. 25 E.

	Ft.	In.
Coal		2
Sandstone	1	
Coal	1	
Shale	1	8
Coal	1	6
Total coal	2	8

From this point the outcrop runs nearly due north to Musselshell River, north of which for about a mile it swings to the west, and thence extends roughly northward (except for irregularities due to the topography) to the nose of the main Bull Mountain syncline in sec. 8, T. 8 N., R. 25 E. A typical section along a portion of the bed is given below:

Section of Roundup coal bed in sec. 16, T. 8 N., R. 25 E.

	Ft.	In.
Bone		3
Coal	6	
	6	3

From this locality it runs nearly southeast to the Commercial mine of the Roundup Coal Mining Company, where the bed is reported to attain a maximum thickness of 6 feet. About half a mile to the southeast, however, in a slope in the NW. ¼ NE. ¼ sec. 23, it contains only 4 feet of coal, but the thickness increases toward the southeast so that in the Republic mine No. 1 it ranges from 5 feet 9 inches to 6 feet 1 inch and has a rather constant roof of about 4 to 6 inches of bituminous shale, overlain by heavy sandstone.

The next opportunity to examine the bed is in sec. 18, T. 8 N., R. 26 E., about one-eighth of a mile west of J. W. Newton's ranch, and here, owing to the burning, it is impossible to make a careful measurement of the coal. It is at least 5 feet thick. From this point

the outcrop is projected across the flood plain of the river to an exposure in sec. 17, where the bed shows the following section:

Section of Roundup coal bed in sec. 17, T. 8 N., R. 26 E.

	Ft.	In.
Coal		3½
Bone		½
Coal	3	7
Total coal	3	10½

Near Berrigan Coulee the character of the section begins to change, a portion of the coal being replaced by carbonaceous shale. The amount of shale seems to increase gradually toward the east to a certain point and then to decrease to the east fork of Parrott Creek, where the following section was measured:

Section of Roundup coal bed in sec. 19, T. 8 N., R. 27 E.

	Ft.	In.
Coal		3
Shale		3
Shale, carbonaceous		4
Coal	3	3
Total	3	6

The coal bed at this point seems to have recovered its characteristic features and the coal maintains the same quality and thickness to Fattig Creek. On the west side of this stream the following section is exposed:

Section of Roundup coal bed in sec. 32, T. 8 N., R. 28 E.

	Ft.	In.
Shale, carbonaceous		8
Coal		5
Shale		1
Coal	1	
Shale		½
Coal		7½
Total coal	2	½

From this point eastward the coal undergoes a rapid deterioration into shale and decreases in thickness until it measures only 1 foot 6 inches in sec. 28, T. 8 N., R. 28 E.

The Roundup coal ranges in quality from a high-grade subbituminous to a low-grade bituminous, and has a calorific value of more than 10,000 British thermal units in the air-dried sample. It is a good coal for steam purposes and appears to withstand shipment well if mined under sufficient cover.

The Wildhorse coal is relatively unimportant in the area examined, although its eastern continuation from the point where the bed crosses the east boundary of T. 5 N., R. 27 E. (O coal, Pl. IV), was

mapped and numerous measurements were obtained, of which the following is representative of the thicker portion of the bed:

Section of Wildhorse coal bed in sec. 18, T. 5 N., R. 28 E. (unsurveyed).

	Ft.	in.
Coal		2
Coal, with ⅛-inch to ¼-inch streaks of shale		4
Coal	2	9
Total coal	2	11

On the north side of the Bull Mountains the Wildhorse bed where present is represented by less than 2 feet of coal. It is possible that in the development of the field the Wildhorse and Roundup coal beds will be found to be identical, although the evidence in hand does not warrant that interpretation.

The "C. A." coal is 95 feet above the Wildhorse coal bed and persistent in the southeast portion of the field. It reaches its greatest thickness in sec. 36, T. 6 N., R. 28 E. (Na coal, Pl. IV), thinning both to the west and to the east. It is of poor quality, appearing on the outcrop to be nearer lignite than subbituminous, and is characterized by a very persistent parting, as shown in the following typical section:

Section of "C. A." coal in sec. 9, T. 5 N., R. 28 E.

	Ft.	in.
Coal		6
Shale		5
Coal	1	6½
Total coal	2	½

The Buckey coal occurs 60 feet above the "C. A." bed, and though prominent in the area examined in the previous year by Woolsey is of slight importance in that portion of the field mapped during 1908. The bed shows a workable thickness for a short distance along the western border of T. 5 N., R. 28 E. (N coal, Pl. IV), but nowhere exceeds 2 feet 6 inches in thickness.

Between the Buckey and the Dougherty coal the rocks are generally barren of coal beds. The Chandler coal, 40 feet below the Dougherty, was found near Railroad Creek, Cow Gulch, and Fattig Creek. It is usually thin and of poor quality.

The Dougherty coal is persistent throughout the area examined and is workable except in T. 8 N., R. 26 E. (M coal, Pls. IV and V), and portions of T. 7 N., Rs. 26 and 27 E. It is 510 feet stratigraphically above the Roundup coal, as determined by a leveled section near Fattig post-office and a bore-hole section in T. 7 N., R. 26 E., on the west fork of Parrott Creek. A typical section of the workable portion of the bed in sec. 17, T. 7 N., R. 26 E., in the northwestern part of the field shows 3 feet 8 inches of coal.

According to information gathered from the bore holes the bed appears to thin in the eastern part of the same township, but to the north the measurements on the outcrop range from 1 foot 6 inches to 2 feet 1 inch. In a section in T. 7 N., R. 27 E., on one of the forks of Parrott Creek, it again increases in thickness.

Section of Dougherty coal in sec. 22, T. 7 N., R. 27 E.

	Ft.	in.
Coal	2	6
Shale		4
Coal		2
Total coal	2	8

The shale parting of the above section is persistent and thickens eastward to a maximum of 9 inches. The following section is representative of the coal bed near the head of the dry fork of Hawk Creek:

Section of Dougherty coal in sec. 5, T. 6 N., R. 29 E. (unsurveyed).

	Ft.	in.
Coal	1	5½
Shale		2
Shale, bituminous		5
Coal	2	1½
Total coal	3	7

The sections to the west of this point show a gradual increase in the thickness of this coal until the maximum is apparently reached in Cow Gulch, where the following measurement was made:

Section of Dougherty coal bed in sec. 10, T. 6 N., R. 28 E.

	Ft.	in.
Coal		1½
Shale		1
Coal	4	9
Total coal	4	10½

From this point the outcrop takes a general southwesterly course and the bed is extremely variable in thickness, thinning to 1 foot 6 inches in sec. 20, T. 6 N., R. 28 E., but in sec. 21 reaching 2 feet 11 inches. At a point where the south fork of Railroad Creek enters the township it shows the following section:

Section of Dougherty coal bed in sec. 31, T. 6 N., R. 28 E.

	Ft.	in.
Coal, poor		1
Coal	2	½
Shale		1
Coal		6½
Shale		4
Coal		1
Total coal	2	9

The coal of the Dougherty bed is undoubtedly high-grade subbituminous and appears to be one of the cleanest and most uniformly thick coals of the field. A sample taken from the outcrop at Cow Gulch showed, after being air dried, a calorific value of 10,771 British thermal units. The Dougherty coal generally has an excellent sandstone roof and a shale floor, two valuable factors which, together with its quality, should lead to early development of this bed.

About 60 feet above the Dougherty coal in Rs. 28 and 29 E., the Ostrander coal (La coal, Pls. IV and V) is persistent and, though commonly thin, it locally assumes a workable thickness, as shown in the following representative section:

Section of Ostrander coal bed in sec. 16, T. 6 N., R. 28 E.

	Ft.	In.
Coal		6
Bone		2
Coal	3	
Total coal	3	6

The same coal in the northern part of the field, in T. 8 N., R. 26 E., where measurements have been obtained, ranges from 1 foot 4 inches to 3 feet.

The Pompey coal, one of the most promising in the southwestern part of the Bull Mountain field, is apparently absent in the area covered by this report.

In the northeastern part of T. 7 N., R. 27 E., on Parrott Creek, the Saddler coal bed (Ka coal, Pl. V) occurs about 40 feet below the Mammoth bed and ranges in thickness from about 1 foot 6 inches of coal to a maximum of 2 feet 2 inches. In the remainder of the field this bed is thin except at a point almost directly north of the easternmost of the Three Buttes, where it shows the following section:

Section of Saddler coal bed in sec. 32, T. 7 N., R. 28 E.

	Ft.	In.
Coal	1	6
Shale		½
Coal	2	5
Total coal	3	11

The Mammoth coal bed (N coal, Pls. IV and V) is the thickest bed occurring in any part of the field so far examined. The portion mapped during the present year, combined with that given by Woolsey,[a] closes the outcrop around the Bull Mountains.

The Mammoth coal bed was examined by Eldridge,[b] and while, in general, results similar to his were obtained by the Geological

[a] Woolsey, L. H., op. cit., pp. 60–75.

[b] Eldridge, G. H., Montana coal fields: Tenth Census, vol. 15, 1886, pp. 753–755.

Survey party, yet different interpretations have been given to some of the facts. For example, the outcrop is shown on the accompanying maps (K coal, Pls. IV and V) as extending not so far east as on the earlier map of Eldridge, and in the northwestern part of the field the coal bed now called the Rehder is undoubtedly what Eldridge designated as the upper bench of the Mammoth. It is clearly possible that Eldridge's interpretation may be correct and final determination must await the development of mining. The Mammoth coal bed is undoubtedly workable throughout the part of its area mapped in 1908, although a number of small partings are invariably present and here and there reach such a thickness that it is difficult to decide from the section whether portions of the same bed or distinct beds are represented. For example, in the excellent exposure at Schlaberg camp, on Fattig Creek, a parting enters and thickens at the rate of 3 feet in 100, and yet the same parting measures only 10 feet 6 inches 6 miles distant at Douglas camp, on Cow Gulch, where the section given below was measured:

Section of Mammoth coal bed in sec. 10, T. 6 N., R. 28 E.

	Ft.	in.
Coal	8	6
Shale		3
Sandstone	2	
Shale		6
Sandstone, gray	10	
Shale		6
Coal	2	
Shale	1	
Coal	3	
Total coal	13	6

This section was sampled for analysis and the upper bench gave a fuel value of 11,610 British thermal units and the lower bench 10,771 British thermal units in air-dried samples.

The extensive burning of the coal along the outcrop of the Mammoth bed, especially on both sides of the divide between Parrott and Halfbreed creeks, makes it difficult to obtain sufficient measurements to estimate the content of the coal bed in the northwestern part of the field. The effect of the burning itself, however, may be taken as a rough indication of the thickness of the coal bed, and it may be safely assumed that the bed is at least 3 feet thick inside of the burnt zone, which is probably not over 200 feet wide.

The Rehder coal bed (J coal, Pl. V) occurs about 35 feet higher in the geologic section than the Mammoth bed, and is practically limited in distribution to T. 7 N., R. 26 E., and the southwest quarter of T. 7 N., R. 27 E. The outcrop is extensively burned, a fact

which renders it difficult to obtain satisfactory measurements. However, the following is believed to be a representative section:

Section of Rehder coal bed in sec. 12, T. 7 N., R. 26 E.

	Ft.	in.
Coal	3	
Bone		1
Coal		11
Total coal	3	11

About 45 feet above the Rehder coal, or 80 feet above the Mammoth coal, there is a persistent but erratic coal bed called the "Rock Mesa" coal (I coal, Pl. IV). This bed is everywhere present in the southwestern portion of the field, as it is in the area examined in 1908, and in both localities it contains persistent partings which within short distances are likely to attain proportions deleterious to the commercial value of the coal. This bed is usually covered by a shale roof. The following section is typical for T. 7 N., R. 26 E.:

Section of Rock Mesa coal bed in sec. 27, T. 7 N., R. 26 E.

	Ft.	in.
Coal	1	7
Shale		2
Coal		10
Total coal	2	5

In T. 7 N., R. 27 E., the maximum observed thickness of the coal is 3 feet 7 inches, which occurs in sec. 20, but there are many places in this township where the bed contains only small amounts of coal or the outcrop is obscured by grassed and forested slopes. In the eastern part of the field the Rock Mesa coal ranges from less than 1 foot 6 inches to a maximum of 3 feet 4 inches, but in most places it is less than 3 feet thick.

On the east side of the Three Buttes, about 50 feet above the Rock Mesa bed, is a coal bed which has been named the Carter coal (Ha coal, Pls. IV and V). This bed shows a thickness of 2 feet 8 inches in sec. 9, T. 6 N., R. 28 E., at the head of Cow Gulch, but thins in both directions, and so far as known is unimportant elsewhere.

Between the Carter coal and the Bull Mountain coals is the Matt coal, which attains some importance in the southwestern part of the field, but the measurements obtained in the area treated in this report were less than 1 foot, so that the bed need not be considered here.

The Bull Mountain coals (F and G coals, Pls. IV and V) in general outline the high mesas and buttes in the south-central portion of the field, and occur at a distance of about 130 feet above the Rock Mesa coal. This interval is 85 feet less than that observed by Woolsey in the southwestern portion of the Bull Mountains.

The two Bull Mountain beds are separated by only 12 to 20 feet of sandstone and shale. The upper bed is usually underlain and overlain by conspicuous dark-gray clay shale 20 to 30 feet thick. The upper bed is in most places the thicker of the two and the following may be taken as an average section of both coal beds:

Section of Bull Mountain coals in sec. 15, T. 6 N., R. 28 E.

	Ft.	in.
Coal (F)	4	5
Shale	12	
Coal (G)	2	11

In many places one of the beds, usually the lower one, falls below 2 feet in thickness, and here and there both beds are thin and of doubtful value.

The coal-bearing area lying above the Bull Mountain coals is small, but comprises a number of beds (A, B, C, D coals, Pl. V) spaced at intervals of 15 to 60 feet. Many of these beds have probably lost a large part of their coal from burning, which baked and reddened the tops of the high buttes and mesas, so that thorough prospecting is necessary to locate the undestroyed portions. These higher coal beds are relatively inaccessible and therefore unimportant at the present time. The names, intervals, and known relative importance of these coals is shown on the maps and in the columnar section, except a small outlier in the Three Buttes section of the field, which was not mapped because of its insignificant area.

CHARACTER.

PHYSICAL PROPERTIES.

The coals of the Bull Mountain field are pitch black to brown black in color and when rubbed on unglazed porcelain leave a darkish-brown to black streak. They commonly show lustrous bands which vary in character, ranging from dull waxy or bright submetallic on a fresh fracture to a dull satiny luster in the parts of the coal bearing mineral charcoal, or "mother coal." The waxy and bright bands range from less than one-eighth inch to over 1 inch in thickness.

Joints have been observed in all the coal beds where they are well exposed. The joint planes are parallel to joints in the roof, many of which are continuations of those in the coal. The joint planes are in general nearly at right angles to each other and in places constitute well-defined face and butt cleats, so that the coal when shot down in the mine falls in roughly cubical blocks. The lumps of coal show a tendency to break up into smaller cubes on exposure to the atmosphere. Some of the banded coal on continued exposure disintegrates into platy flakes, while that which lacks the banded structure resists the process of disintegration for a longer period, but in nearly all cases

finally breaks up by checking off in small chips with conchoidal surfaces. A net of pyrite or marcasite, together with their alteration products, and fine powdery gypsum is occasionally found along the joint planes. When the coal is broken by a blow from a hammer conchoidal to smooth fracture surfaces are likely to predominate over cleavage surfaces parallel to the joint planes. The coherence ranges from brittle to tough, and the impact is dull rather than metallic. The texture of the coal is dense to laminated and only in a few places shows slight indications of a woody character. The coal is of low specific gravity. The accessory substances fall into several groups—sulphides, sulphates, and hydrocarbons. The sulphides, marcasite and pyrite, have already been noted. In addition to gypsum, the sulphate mentioned above, epsomite has been found in fairly large quantities in connection with some of the higher coals, especially the lower Bull Mountain (G) coal. With this particular coal the epsomite forms a surficial deposit attaining a maximum thickness of about a foot directly underlying the coal bed in sec. 8, T. 6 N., R. 28 E. Resin and sulphur are locally present in small rounded masses irregularly and sparsely scattered through the coal. The coal burns with a yellowish flame of moderate length and occasionally gives off a strong, pungent sulphurous odor. In burning the coal decrepitates rapidly, and when used in locomotives the fragments blow out of the stack or fall between the grate bars. These difficulties have been overcome to a considerable extent, however, by modifying the character of the forced draft and by using specially constructed grates. It is advisable to admit a rather large amount of air above the grate and also to distribute the coal unevenly upon the grate to prevent choking the process of combustion. The ash is fine, ranges from gray to reddish-yellow in color, and is not clinkery unless the coal is dirty.

CHEMICAL PROPERTIES.

As the examination of the Bull Mountain field was practically limited to a study of the coal outcrops it was not possible to collect more than a few unweathered samples for analysis, owing to the lack of mining developments. The samples were collected in conformity, as nearly as possible, with the regulations of the United States Geological Survey, and the analyses were made under the direction of F. M. Stanton at the Pittsburg laboratory. An examination of the coals as received from the mine shows that the moisture content ranges from 12.69 to 22.77 per cent, the amount of ash from 4.15 to 7.70 per cent (exclusive of Roundup No. 6235, a bore-hole sample whose high ash is due to the inclusion of rock dust), and the British thermal units from 8,863 to 11,034. The only strictly fresh sample (Roundup No.

5900) heads the list and the Carpenter sample (No. 7197) foots it. The last sample was taken under very thin cover, and probably represents a weathered condition of the coal, not apparent on visual examination. The loss of moisture on air drying ranges from 2.70 to 16.30 per cent, the minimum representing an unweathered facies and the maximum a sample taken on the outcrop of the Dougherty coal.

Analysis of coal samples from the Bull Mountain field, Montana.

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

Name of coal bed	Homestead.	Carpenter.	Roundup.			Dougherty.	Mammoth.	
Laboratory No.	6829	7197	5800	6235	7195	6830	6828	6831
Sample as received:								
Prox. Moisture	18.14	22.77	12.69	18.35	16.66	21.56	18.65	17.43
Prox. Volatile matter	27.22	27.00	28.71	23.34	27.85	30.46	29.62	31.16
Prox. Fixed carbon	50.49	45.58	50.90	39.06	48.07	43.02	46.61	48.09
Prox. Ash	4.15	4.65	7.70	19.25	7.42	4.96	5.12	3.32
Ult. Sulphur	.88	.32	.54	.31	1.00	.72	.78	.35
Ult. Hydrogen	5.46	5.47	5.44	.....	5.61	.....	.....	.....
Ult. Carbon	60.48	53.49	64.26	.....	59.22	.....	.....	.....
Ult. Nitrogen	.77	.93	.88	.....	.97	.....	.....	.....
Ult. Oxygen	28.26	35.14	21.18	.....	25.78	.....	.....	.....
Calories	5,789	4,924	6,130	4,799	5,681	5,009	5,495	5,711
British thermal units	10,420	8,863	11,034	8,638	10,226	9,016	9,892	10,280
Loss of moisture on air drying	14.00	13.50	2.70	13.70	7.20	16.30	14.80	12.90
Air-dried sample:								
Prox. Moisture	4.81	10.72	10.27	5.39	10.19	6.28	4.52	5.20
Prox. Volatile matter	31.65	31.21	29.51	27.04	30.01	36.39	34.76	35.78
Prox. Fixed carbon	58.72	52.69	52.31	45.26	51.81	51.41	54.71	55.21
Prox. Ash	4.82	5.38	7.91	22.31	7.99	5.92	6.01	3.81
Ult. Sulphur	1.02	.37	.56	.35	1.08	.82	.92	.40
Ult. Hydrogen	4.54	4.59	5.28	.....	5.18	.....	.....	.....
Ult. Carbon	70.32	61.84	66.04	.....	63.82	.....	.....	.....
Ult. Nitrogen	.90	1.08	.91	.....	1.04	.....	.....	.....
Ult. Oxygen	18.40	26.74	19.30	.....	20.89	.....	.....	.....
Calories	6,731	5,693	6,300	.....	6,122	5,984	6,450	6,558
British thermal units	12,116	10,247	11,340	10,000	11,020	10,771	11,610	11,804
	Ft. in.	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*	*Ft. in.*
Thickness of bed (total coal)	2 11	5 3	4	5	2 6	4 10½	5	8 6
Thickness of part sampled	1 3	4 6	4	5?	2 6	4 10½	5	6

6829. Upper 1 foot 3 inches of Homestead coal bed, about 12 miles northwest of Musselshell post-office.
7197. All except upper 9 inches of Carpenter coal bed about 6 miles east of Musselshell post-office.
5800. Full thickness of Roundup coal bed, SW. ¼ NE. ¼ sec. 23, T. 8 W., R. 25 E.
6235. Full thickness (?) of Roundup coal bed, bore-hole sample, T. 6 N., R. 26 E.
7195. Full thickness of Roundup (?) coal bed, about 6 miles south of Musselshell post-office.
6830. Full thickness of Dougherty coal, NW. ¼ SE. ¼ sec. 10, T. 6 N., R. 28 E.
6828. Full thickness of lower bench of Mammoth coal bed, SW. ¼ NW. ¼ sec. 10, T. 6 N., R. 28 E.
6831. Lower 6 feet of upper bench of Mammoth coal bed, SW. ¼ NW. ¼ sec. 10, T. 6 N., R. 28 E.

A better comparison of the coals can be made from the analyses on the air-dried basis and in these the moisture ranges from 4.52 to 10.70 per cent and the British thermal units from 10,000 to 12,116. As there is good reason for believing that the other coals will approximate the Roundup coal when sampled under mine conditions, the Roundup may be taken as a type of the Bull Mountain coals. If compared with several coals from adjacent fields, on the basis of the data in the following table, the Roundup coal ranks well, especially in total carbon when considered apart from its ash and moisture.

Comparison of various Montana and Wyoming coals.

	Laboratory No.	Air dried.				Ash free.		
		Moisture.	Ash.	Fixed carbon.	British thermal units.	Moisture.	Total carbon.	British thermal units.
Roundup	5800	10.27	7.91	52.31	11,340	11.15	71.71	12,314
Red Lodge	3590	7.34	12.57	42.17	10,270	8.39	66.56	11,746
Bear Creek	5822	6.26	13.65	44.69	11,444	7.25	67.64	12,789
Lewistown	5872	2.79	9.04	52.37	11,563	8.56	73.23	12,712
Lewistown	5473	6.59	8.45	62.79	10,570	7.19	68.58	11.545
Sheridan (Carneyville)	5388	17.30	3.68	42.38	10,096	17.96	61.02	10,548

	Laboratory No.	Ash and moisture free.			Ratios, air dried.		
		Total carbon.	Total hydrogen.	British thermal units.	Fuel.	C/H.	C/O.
Roundup	5800	80.71	0.04508	13,860	1.77	12.5	3.42
Red Lodge	3590	72.66	.05187	12,714	1.11	11.7	2.78
Bear Creek	5822	72.91	.05237	14,288	1.26	11.9	3.64
Lewistown	5872	80.09	.03657	13.902	1.70	13.6	4.85
Lewistown	5473	74.90	.04411	12,441	1.84	14.0	2.92
Sheridan (Carneyville)	5388	74.37	.04746	12,777	1.16	10.4	1.93

DEVELOPMENT.

Coal mining in the Bull Mountains is restricted to the Roundup bed in the northwestern part of the field, on Musselshell River and a fork of Halfbreed Creek. The thriving town of Roundup is an indication of the rapid development of the coal-mining industry. Early in the eighties coal of workable thickness was known here and a carload was taken out by William Crane and shipped to Marcus Daly at Anaconda, but not until 1907 was commercial mining begun. In the fall of that year the Republic Coal Company attempted to work the Roundup bed by a slope extending under the Musselshell River, but the cover, consisting mainly of alluvium, permitted the entrance of great quantities of water, which rendered this plan unfeasible. A shaft on the south side of the river, in sec. 24, T. 8 N., R. 25 E., which had been originally intended for an air shaft, was enlarged and used as the main shaft for mine No. 1. The coal was penetrated at a distance of 137 feet from the surface and is mined by the room and pillar method. Mule haulage is used underground. The mine is equipped with a complete pumping, hoisting, and loading plant. The coal as it comes from the mine is clean and is used mine run, or stored in pockets that feed directly into coal cars. The joints in the overlying rocks are charged with water, which flows into the new workings until exhausted. The water that thus drains into the mine has, however, been successfully handled by the pumps. This

water is of excellent quality and will probably be utilized by the town of Roundup. The production of mine No. 1 for 1908 is reported to have been 39,348 tons.

During 1908 the Republic Coal Company acquired coal rights in sec. 36 of the same township and started operation on mine No. 2 near the center of the section. The coal is reported to have been encountered in the main shaft at a depth of 347 feet from the surface on March 11, 1909, and is said to be 5 feet thick at this point. An extensive pumping, hoisting, and loading plant is under construction. Mine No. 2 has been connected with the main line of the Chicago, Milwaukee and Puget Sound Railway by a spur up Half-breed Creek to the mine.

In October, 1908, the Roundup Coal Mining Company opened in sec. 23, T. 8 N., R. 25 E., a commercial mine consisting of a slope, with adequate equipment for mining, hoisting, and loading. This mine is connected with the main line of the Chicago, Milwaukee and Puget Sound Railway by a spur and is designed to supply coal for consumption of towns along the railway, the entire production of the Republic Coal Company being utilized by the railway company.

Local demands for coal in Roundup and other settlements along the Chicago, Milwaukee and Puget Sound Railway will increase as a result of the growth of manufacturing industries and gain in population.

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