# THE SENTINEL BUTTE LIGNITE FIELD, NORTH DAKOTA AND MONTANA.

By A. G. LEONARD and CARL D. SMITH.

## INTRODUCTION.

As shown by the key map (fig. 1), the Sentinel Butte field is a small area near the center of the Fort Union region of coal and lignite bearing rocks of Tertiary age, which cover a considerable area in the northern part of Wyoming, the eastern quarter of Montana, the western

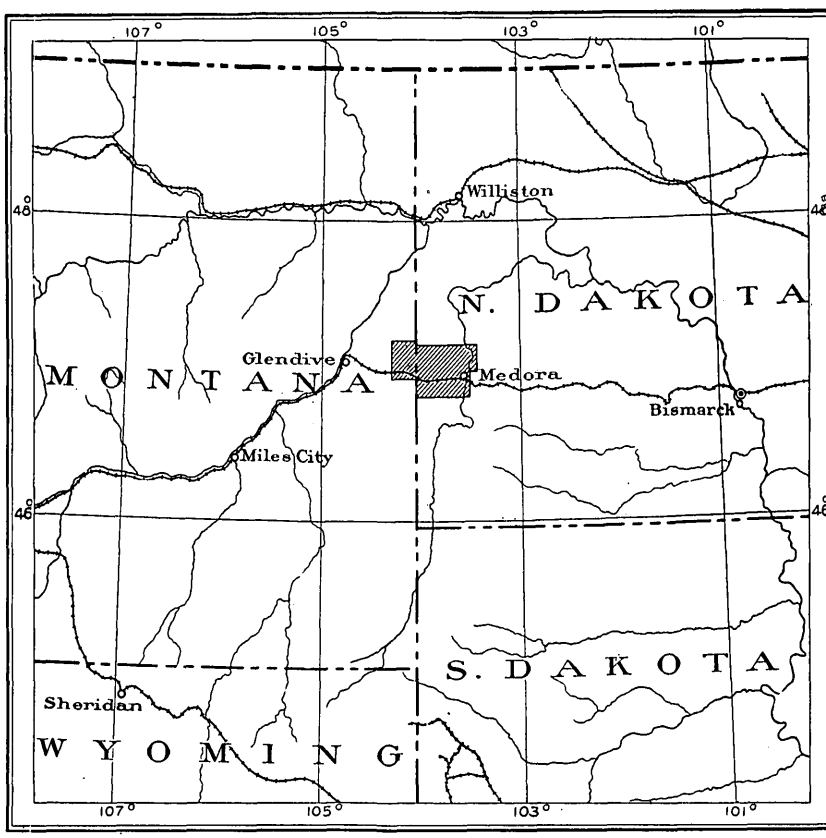



FIG. 1.—Index map showing location of the Sentinel Butte lignite field, North Dakota and Montana.

half of North Dakota, and the northwest corner of South Dakota. The field examined in 1907 comprises approximately 25 townships—19 in Billings County, N. Dak., and 6 in Dawson County, Mont., on either side of the Northern Pacific Railway.

The geologic investigations were undertaken primarily for the purpose of classifying the public lands with special regard to lignite. In order to do this, the character, depth, and horizontal distribution of the beds of lignite were studied in detail, and outcrops and exposures were located with reference to established land corners.

This region has been investigated in a general way by a number of geologists, notably by Wood, Wilder, and Leonard, of the North Dakota Geological Survey, and by Storrs, of the Federal Survey. In the field work the writers were ably assisted by Fred H. Kay and W. H. Clark, and in the office Mr. Kay compiled the accompanying map from the original township plats used in the field.

## ACCESSIBILITY.

Much of the lignite of this field is accessible without great difficulty. The area is traversed from east to west by the Northern Pacific Railway, which is not more than 15 or 18 miles from any part of it. Many of the lignite beds that outcrop along Little Missouri River could be readily reached by a branch line along the valley of that stream, and the same is true of the lignite on Beaver Creek. Other parts of the field would be accessible to railways built across the upland plains.

## DRAINAGE AND WATER RESOURCES.

With the exception of an area drained by a few streams heading in the westernmost tier of townships and flowing northwestward into Yellowstone River, the field lies in the drainage basin of Little Missouri River, which flows northward across the eastern part and contains running water throughout the year. Beaver Creek, also a perennial stream, runs northeastward across the western part of the field and joins Little Missouri River some distance north of the area mapped. All the other streams are intermittent, but some of them contain water in pools during dry seasons.

## TOPOGRAPHY.

Broadly characterized, the region is a rolling plain which is minutely dissected near the larger streams, the result being so-called badlands. Three important eastward-flowing streams—Andrews, Knutson, and Wannigan creeks—empty into Little Missouri River. All these streams have cut deep valleys in the plain and exposed to view the strata which underlie its surface. The badlands are confined chiefly to a strip of country bordering Little Missouri River and extending about an equal distance on either side. This very rough area, with its bare clay slopes, sharp divides, and rain-carved buttes, occupies a belt 15 to 20 miles wide. The entire width of the badlands, however, is not included in the district studied, as they extend from

north to south along its eastern border only. On the west they pass into the rolling plain which stretches to the badlands of Yellowstone River.

Conspicuous features of the valley of the Little Missouri are the broad flats which occur at intervals on both sides at an elevation of 240 feet above the river. They have a width of 1 or 2 miles and overlooking them are bluffs rising rather abruptly 160 to 200 feet higher, or about 420 feet above the river. These flats were probably formed when the land was considerably lower than at present, and the river, having reached base-level, meandered back and forth over a flood plain 4 or 5 miles wide. The surface was then elevated, and the river gained a new erosive power and has since cut its inner gorge to a depth of about 240 feet below its old valley bottom, represented by the flats. The valley as a whole has a depth of 420 to 440 feet below the upland plain in which it has been eroded. The altitude of this upland plain ranges from 2,700 to 2,800 feet, and rising above it are three prominent buttes—Sentinel, Square, and Camels Hump—with great numbers of lesser buttes. Sentinel Butte has a height of 3,350 feet above sea level, and its flat summit forms a landmark visible for 20 to 30 miles in all directions.

The gently rolling plain is itself the product of long-continued erosion, which has doubtless been going on ever since Oligocene time, resulting in the removal of 800 to 1,000 feet of strata from this region. Remnants of these eroded beds are found in the buttes just mentioned, Sentinel Butte rising 650 feet above the plain at its base and containing on its summit the evidence of a still more recent formation that has almost entirely disappeared. Sentinel and Square buttes are capped with heavy ledges of sandstone, about 100 feet thick, which have protected them from erosion and given them their flat summits. In the vicinity of Sentinel Butte there are a large number of small buttes that rise from 150 to 175 feet above the surrounding surface to a fairly uniform height and are capped by a thick layer of baked and fused clay. This red clay, which has protected the buttes from erosion, was formed by the burning of the 21-foot bed of lignite that is present in the base of Sentinel Butte.

In places the change is abrupt from the upland plain to the badland belt along the river. To one looking out over the badlands from some commanding point the scene presents an indescribable waste of steep-sided ridges, bluffs, buttes, domes, and pinnacles carved out of the soft clays and sands of the Fort Union formation. The bare slopes which are so conspicuous a feature of the region everywhere show the marks of the last shower, being grooved with countless tiny channels formed by the rivulets of water which poured down their sides. At one or more horizons bands of red, burnt clay may be readily traced with the eye for many miles in the bluffs and ridges. These beds of clay,

rendered hard and resistant by the heat of the burning lignite, have been an important factor in the formation of the picturesque badlands.

## GEOLOGY.

### STRATIGRAPHY.

#### FORT UNION FORMATION.

Practically all of the strata in the area under discussion belong to the Fort Union formation (early Eocene). In common with the rocks of the adjoining regions they have in the past been generally referred to the Laramie, but according to F. H. Knowlton, who spent some time in this field in the summer of 1907 making collections of plant remains, their Fort Union age is unmistakable.

There is a very noticeable difference between the lower Fort Union beds, which outcrop in the bluffs bordering Little Missouri River, and the upper beds, occurring in the tops of the higher ridges, divides, and buttes, usually back some distance from the river. The lower member is composed of buff and light ash-gray clays and sands in alternate layers. The upper member is formed of strata considerably darker in appearance, mostly dark gray, with many brown, ferruginous, sandy nodules and concretions. The contrast between these members is so well marked and their contact so clearly defined that it can be readily distinguished at a distance and traced without difficulty wherever it is exposed. Over most of the eastern half of the field a thick bed of lignite or a layer of red clay formed by the burning of the lignite occurs just at the contact of the upper and lower members. But even where the coal or burnt-clay bed is wanting, the line of separation is readily discernible. The lignite beds appear equally in both divisions, though there are perhaps more in the lower. Of the workable lignite beds shown in the generalized section (Pl. II) the lower five are in the lower member, the next separates the two members, and the other three beds are in the upper division.

The character of the Fort Union formation is well shown by the following sections:

*Section in river bluff about one-fourth mile below the crossing at Short's ranch, in the SE. ¼ sec. 1, T. 142 N., R. 102 W.*

| | Ft. | in. |
|---|---|---|
| Clay and sand, buff and gray, on which rest the somber beds of the upper member | 17 | |
| Lignite | 1 | 6 |
| Sand, fine grained; contains some clay, buff and gray | 77 | |
| Lignite | 1 | |
| Clay, gray and yellow | 16 | |
| Lignite, impure, containing two thin clay seams | 1 | |
| Clay and sand | 17 | |
| Clay, brown | 1 | |
| Clay, gray | 7 | 6 |
| Lignite and some brown clay | | 6 |
| Clay, blue and yellow | 7 | |

| | Ft. | in. |
|---|---|---|
| Clay, brown and carbonaceous | | 8 |
| Sand, with some clay | 6 | |
| Clay | 4 | |
| Lignite | | 8 |
| Clay, gray | 1 | 6 |
| Lignite | 1 | |
| Clay, gray and yellow | 3 | |
| Sand, gray, fine | 8 | |
| Lignite | 2 | 6 |
| Clay, blue | 7 | 6 |
| Lignite | 1 | 8 |
| Clay, blue, plastic | 5 | 6 |
| Lignite, with 6-inch clay parting 3 inches above bottom | 2 | 6 |
| Clay, blue, plastic | 3 | 6 |
| Lignite | | 5 |
| Clay, blue, plastic | 3 | |
| Lignite | | 9 |
| Clay, blue | 3 | |
| Sand, yellow and gray, fine grained and laminated | 4 | |
| Lignite | | 1 |
| Clay, gray | | 6 |
| Lignite, with 1-inch parting | | 9 |
| Clay, bluish gray | 4 | |
| Clay, gray and brown, with a thin streak of lignite | | 4 |
| Sand, yellow and gray | 3 | |
| Clay, light gray, growing sandy above | 1 | 4 |
| Clay, brown | | 4 |
| Lignite | 1 | 6 |
| Clay, light gray, with thin streak of lignite | 1 | 1 |
| Sand, gray | 3 | |
| Clay, blue and yellow | | 8 |
| Sand, yellow and gray | 4 | |
| Clay, sandy and finely laminated | 1 | 4 |
| Clay, blue | | 3 |
| Lignite | | 3 |
| Clay | | 7 |
| Lignite | | 6 |
| Sand, growing clayey above | 2 | |
| Clay, bluish gray, with thin streak of lignite | 6 | |
| Sand, gray | 5 | |
| Lignite | 1 | 2 |
| Clay, sandy, yellow | 6 | |
| Lignite, with some brown clay | | 4 |
| Clay, sandy and laminated toward top | 14 | |
| Lignite | | 2 |
| Clay, gray | 3 | 6 |
| Lignite and brown clay | | 1 |
| Sand, gray, fine | 1 | 6 |
| Clay, gray | 2 | |
| Clay, brown, with 2 to 4 inches of lignite at base | | 8 |
| Clay, light gray | 2 | 8 |
| Sand, gray, fine grained, with hard ledge of rock near top; exposed above river | 14 | |
| | 288 | 3 |

It will be noted that although there are twenty beds of lignite in the foregoing section, none of them is workable, the thickest being 30 inches. But the thick lignite bed which outcrops less than 2 miles above and below the point where the section was measured can not here be far below river level.

The following section was measured in the NE. ¼ sec. 4, T. 142 N., R. 101 W., 3 miles east of the one just given, and lies wholly in the upper division of the Fort Union, its base resting on top of the lower member:

*Section 3½ miles east of Short's ranch, in the NE. ¼ sec. 4, T. 142 N., R. 101 W.*

| | Ft. | in. |
|---|---|---|
| Sand and clay in alternating layers, more argillaceous at the base. | 80 | |
| Lignite band, thin. | | |
| Clay, sandy | 10 | |
| Clay, bituminous | 2 | |
| Clay, sandy | 10 | |
| Powdery material, probably weathered, shaly lignite. | | |
| Clay, gray, forming when wet a sticky mud, sandy near middle | 25 | |
| Lignite in two beds, the upper 1 foot and the lower 1½ feet, separated by 4 inches of brown shale | 2 | 10 |
| Clay, gray, with hard, concretion-like masses of same color | 55 | |
| Lignite | 2 | |
| Clay, gray, sandy | 10 | |
| Lignite | 1 | |
| Clay, gray, sandy, more clayey above and below | 50 | |
| Lignite | 3 | 6 |
| Sand and sandy clay, gray, rather coarse sand near center, fine grained at top and bottom, with yellow bands | 55 | |
| Lignite | 1 | |
| Sand, clayey, bluish gray, contains irregular ironstone bands, rather coarse sand at base, but grows gradually finer till at top it is a clay | 40 | |
| Lignite, poor<br>Clay, gray<br>Lignite, poor } Bed F, Sentinel Butte group | 1<br>7<br>3 | 3 |
| | 358 | 7 |

The beds of the upper division of the Fort Union are found in Sentinel Butte, and the following section was measured there:

*Section at Sentinel Butte.*

| | Ft. | in. |
|---|---|---|
| Clay, calcareous | 10 | |
| Limestone, alternating with calcareous clay; the limestone is very compact and fine grained, brittle, siliceous, and gray and white in color, weathering into very thin laminæ; contains fish remains | 5 | |
| Clay, gray, very calcareous, weathering to greenish | 25 | |
| Sandstone, gray, hard | 80 | |
| Clay, gray and yellow, sandy | 30 | |
| Clay, brown, with thin seam of lignite | 1 | 6 |

| | Ft. | in. |
|---|---|---|
| Clay, gray and yellow, sandy | 53 | |
| Lignite | | 6 |
| Sand, fine grained, clayey | 12 | |
| Clay, brown and gray, containing many selenite crystals | 4 | |
| Sandstone, soft, fine-grained | 1 | |
| Lignite | 1 | 6 |
| Clay, brown and carbonaceous | 1 | |
| Clay, bluish gray | 10 | |
| Sand, gray, cemented in places into a soft sandstone | 12 | |
| Clay and sand, not well exposed | 55 | |
| Lignite | | 6 |
| Clay, gray, sandy | 37 | |
| Clay, gray, with no sand | 2 | |
| Lignite | 6 | |
| Clay, brown at the top, sandy | 5 | |
| Sand, gray, fine | 4 | |
| Clay, gray, sandy, containing nodules | 15 | |
| Sand, finely laminated | 4 | |
| Clay, gray, sandy, with ferruginous bands | 8 | |
| Clay, brown, sandy | 1 | |
| Clay, gray | 5 | |
| Clay, gray, sandy, containing abundant siliceous and ferruginous nodules, arranged mostly in bands at certain horizons; these hard nodules project from surface of softer clays, and cap small clay columns | 25 | |
| Sand and clay not well exposed | 25 | |
| Lignite | 21 | 2 |
| Unexposed to level of railroad at Sentinel Butte station | 190 | |
| | 650 | 2 |

The Fort Union formation has a thickness in this region, as measured on its outcrop, of 900 feet. If to this be added 820 feet of lignite-bearing rocks, which are probably to be referred to the Fort Union, penetrated by the Medora well below the lowest lignite outcropping in the field, the total thickness is 1,720 feet.

### OLIGOCENE ROCKS.

Overlying the heavy sandstone which forms the summit of Sentinel Butte and constitutes the topmost member of the Fort Union formation, there are about 40 feet of calcareous clay and limestone, as shown in the Sentinel Butte section. These beds are merely the remains of a formation which doubtless at one time covered a large area in this region. Strata which have yielded Oligocene vertebrates, and which occupy a similar horizon immediately over the massive sandstones at the top of the Fort Union, occur in Chalk Butte, 70 miles farther southeast. Other similar buttes in northwestern South Dakota and southeastern Montana have likewise been referred to the Oligocene.

## STRUCTURE.

Little can be said of the structure of the small area here discussed except that the strata have a low dip—20 feet to the mile—toward the northeast. However, work in adjoining territory has proved that the structure of the field is the result of an upward fold of the rocks, or anticline, whose axis trends northwest and southeast and is located 25 miles to the southwest. This anticline is well exposed at the mouth of Cedar Creek, Montana, where it is crossed by Yellowstone River. Here 300 feet of Pierre shale, of Cretaceous age, is brought to the surface, and the overlying rocks, including the Fort Union, dip away from it, steeply toward the southwest and gently toward the northeast. The gentle dip continues, however, to the northeast corner of the field represented on the accompanying map, where the rocks are horizontal. What is probably an extension of this disturbance is marked by an exposure of Pierre shale on Little Beaver Creek, in Bowman County, N. Dak.[a]

Throughout the field the dip is so slight that it can be detected only by tracing certain well-marked horizons and by noting their change of altitude from point to point. For example, the elevation of the contact of the buff and somber-colored members in the base of Sentinel Butte is 2,850 feet above sea level, but in the northeast corner of the area the same contact is at 2,430 feet. Further evidence that the rocks are tilted is the fact that artesian water has been obtained at Medora. A well was sunk here by the Northern Pacific Railway Company to a depth of 940 feet, where a water-bearing sandstone was reached. To judge from the thickness of the Fort Union section at Glendive, Mont., it is believed that this sandstone lies near the base of the formation and that it is exposed at a higher level far to the southwest along the flank of the anticline mentioned above.

## THE LIGNITE.

### GENERAL STATEMENT.

By referring to the columnar section on the map accompanying this report (Pl. II), it will be noted that workable beds of lignite occur at nine different horizons in the 900 feet of strata exposed in the field. A great many other beds 1 foot or less in thickness can be seen in almost any well-exposed rock section, but no attempt has been made to note them. The workable lignite beds, with one exception, are for convenience of description divided into groups, the lower being termed the Medora and the upper the Sentinel Butte group. The lowest lignite exposed in the field is called the Harmon bed; it outcrops in the east bank of Little Missouri River a short

[a] Leonard, A. G., Bull. U. S. Geol. Survey No. 316, 1907, p. 196.

distance above the Harmon ranch, at the southern boundary of the field. The two uppermost members of the Sentinel Butte group are so meager in distribution that their outcrops have not been mapped. The record of a drill hole sunk at Medora shows that at least 800 feet of lignite-bearing rocks lie below the Harmon bed.

## VARIABILITY.

Heretofore the lignite beds of this general region have been described as lenticular in form and impossible of correlation for distances exceeding 2 or 3 miles. It is true that the lignite is variable in thickness and horizontal extent, but some of the more important beds have been traced continuously for 24 miles and have been correlated with much certainty for greater distances. So far as this area is concerned, there is a more or less definite law controlling the disappearance of the beds. It has been observed that the two lower members of the Sentinel Butte group become thin and pinch out toward the northwest. Some of the members of the Medora group follow the same rule, but whether this law has a general application can be ascertained only by further detailed work in the surrounding territory. The clinker zone left by the burning of the two lower members of the Sentinel Butte group bears conclusive evidence that they formerly occupied the entire southeast corner of the field and that they extended still farther to the east and southeast, covering a large territory beyond the limits of last season's investigations.

## CLINKER.

A noticeable feature which has had a great influence on the topography of the field is the clinker or baked and partially fused sands and clays, due to the burning of the coal beds. The prevailing color of this material is red, but various shades of yellow and green were also observed. The more completely fused portions are usually dark red to black. At places these clinker zones are 100 feet thick, but it is not likely that so great a thickness has resulted from the burning of a single bed. The distance back from the outcrop of a bed to which burning may take place depends on the amount of cover. Wherever the cover is great enough combustion is soon smothered by the weight of the overlying material. It is impossible to give exact figures in this connection, as no prospecting or mining has ever been done where a lignite bed is rimmed by clinker. In prospecting for lignite along an outcrop which has been burned it will be noted that the base of the clinker, which is usually well marked, is on a level with the base of the bed of lignite.

It may be well to say here that, as a general rule, the lignite beds that have been burned most extensively are the thicker and purer

beds, although here and there dirty beds burn, making considerable clinker. Moreover, the burning of thicker beds causes more complete fusion of the overlying material than the burning of thin or impure beds.

Little is known as to the manner in which the lignite may have been ignited, except in a few places where it is known to have been set on fire by human agencies and is still burning. Other explanations as to the origin of the fire are more or less theoretical and attribute it to lightning, to prairie fires, and to spontaneous ignition. All of these causes have doubtless been instrumental, each becoming active under favorable conditions.

## EXPLANATION OF MAP.

The outcrops of seven different beds of lignite have been mapped in various parts of the field, and in order to distinguish these beds, a columnar section showing their relative positions has been placed on the map, with a letter opposite each, corresponding to the same letter written along its line of exposure on the map (Pl. II).

## DETAILED DESCRIPTION OF LIGNITE BEDS.

A few representative detailed sections, beginning with the lowest lignite exposed in the area covered by this report, are given in the following pages, in the order of their occurrence.

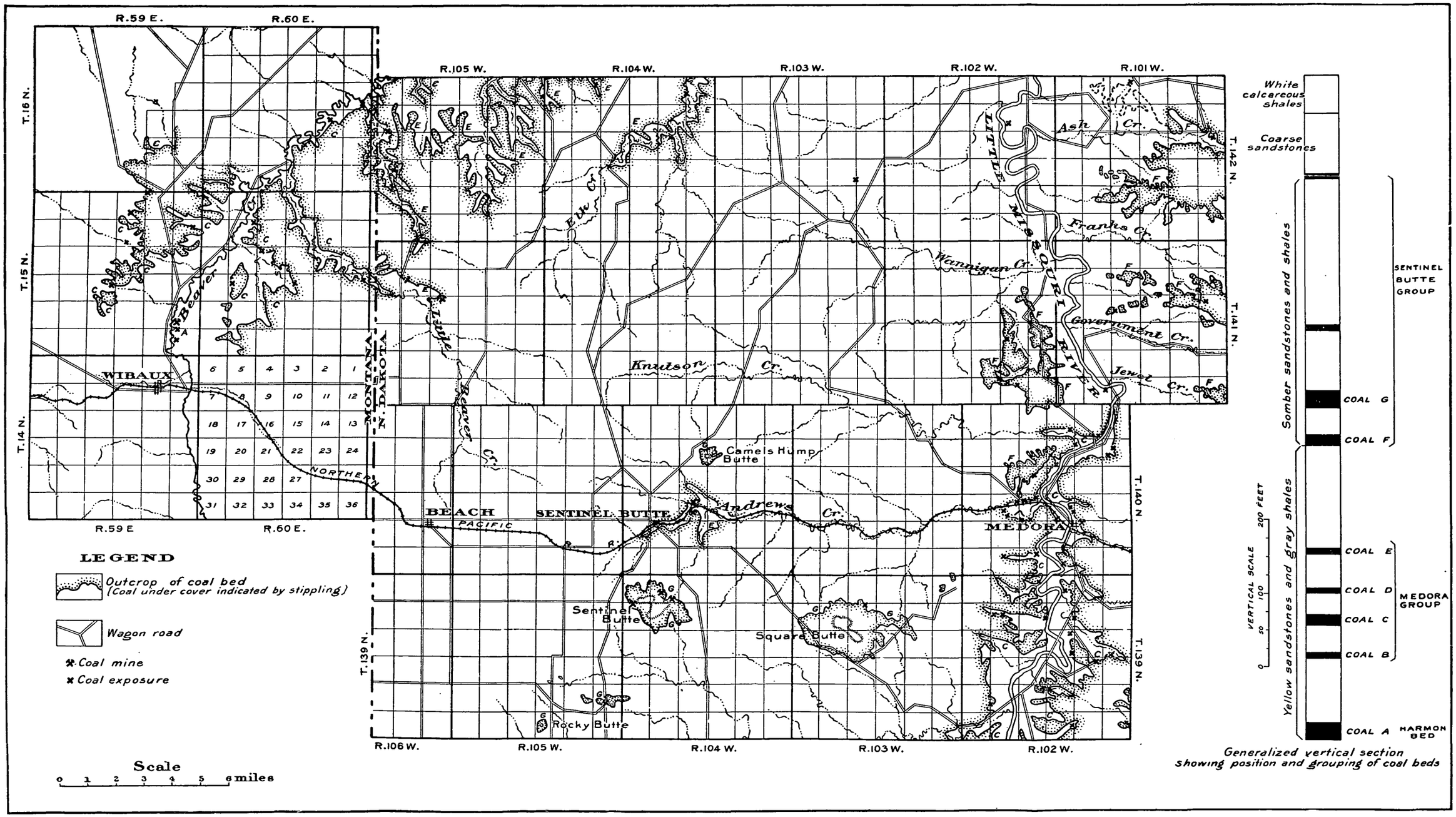
### HARMON LIGNITE BED.

The Harmon lignite, A in the columnar section, is the lowest bed of consequence within the limits of the area investigated. It is partially exposed in the east bank of Little Missouri River, one-half mile south of the south boundary of the Sentinel Butte field. Here the section is as follows:

*Section of Harmon lignite one-half mile south of south boundary of Sentinel Butte field, on Little Missouri River.*

| | Ft. | in. |
|---|---|---|
| Clay, sandy. | | |
| Lignite | | 4 |
| Clay, sandy | | 5 |
| Lignite (with four thin shale partings) | 4 | 2 |
| Lignite | 7 | 6 |
| Lignite (with three thin shale partings) | 1 | |
| Lignite (base concealed by water) | 2 | 6 |
| Total lignite | 15 | 6 |

North of this exposure the bed dips beneath the level of the river and does not appear again in the eastern part of the field. Lignite, which is without doubt the Harmon bed, was penetrated in a well sunk by the Northern Pacific Railway Company at Medora. The




Generalized vertical section
Showing position and grouping of coal beds

MAP OF THE SENTINEL BUTTE LIGNITE FIELD, NORTH DAKOTA AND MONTANA.

By A. G. Leonard, C. D. Smith, and F. H. Kay.

well record shows it to be 23 feet thick and about 120 feet below the surface.

A lignite occupying the same position in the section as the Harmon bed outcrops in the east bank of Beaver Creek, 2 miles north of Wibaux, Mont. It ranges from 8 feet 6 inches to 9 feet 3 inches in thickness and is mined to supply local trade. Northward from this point the lignite dips below the level of the creek, but to the south it rises slightly above the creek level as far as observed. In T. 15 N., R. 59 E., in Montana, the Harmon lignite outcrops near the head of Box Elder Creek, a tributary of Yellowstone River, but its outcrop has not been mapped. In T. 16 N., R. 59 E., this bed outcrops near the head of Cottonwood Creek, but owing to the fact that it has been burned extensively no complete section of the bed could be measured. A partial exposure, where only the top portion could be seen, measures 8 to 10 feet. The upper part of this bed, or a bed occupying a similar position in the section, was noted in the south bank of Beaver Creek, a short distance north of the field.

### MEDORA GROUP OF LIGNITE BEDS.

The Medora group of lignite beds, so named because of the occurrence and exposure of its members in the bluffs of Little Missouri River at and near Medora, N. Dak., occupies a position from 150 to 290 feet above the Harmon bed. The group comprises four beds, designated in the vertical section on the map by the letters B, C, D, and E. Along Little Missouri River the outcrop of only one member of the group, bed C, has been mapped. This bed, the second above the base of the group, is more persistent and thicker than the others, and has been mined for local use at a number of places, notably near Medora. But as the three lower members lie within a vertical range of 60 to 80 feet, the mapped outcrop of the second above the base, bed C, marks approximately in steep slopes and bluffs the outcrop of the other two. The outcrop of the uppermost member of the group has been mapped wherever it shows workable thickness.

At the southern boundary of T. 139 N., R. 102 W., the lowest member of the Medora group, bed B, has an elevation of 100 feet above the level of Little Missouri River, and in conformity with the general dip of the inclosing rocks the various members of the group dip toward the northeast and disappear below the level of the river near the north line of T. 140 N., R. 102 W.

All the members of the group are exposed in the northern and western parts of the field, notably on Elk, Beaver, Little Beaver, and Dry creeks.

Some detailed sections of members of this group follow:

*Section of bluff on west bank of Little Missouri River 500 feet south of south line of T. 139 N., R. 102 W.*

| | | Ft. | in. |
|---|---|---|---|
| Sandstone, yellowish white, soft, and gray sandy clay | | 145 | |
| Bed C[a] | Lignite | 6 | 6 |
| | Shale, brown | 1 | 7 |
| | Lignite | | 6 |
| | Shale, brown and gray | 1 | 7 |
| | Lignite, upper 10 inches dirty | 3 | |
| Clay and sandstone | | 40 | |
| Bed B | Lignite, soft and powdery | 1 | 2 |
| | Clay, gray | 2 | 3 |
| | Lignite, weathered | 2 | 10 |
| Clay, buff | | 17 | 6 |
| Shale, carbonaceous | | 4 | 2 |
| Clay, yellow, sandy | | 27 | 6 |
| Lignite | | 1 | |
| Clay, light colored | | 17 | |
| Shale, carbonaceous | | 1 | 1 |
| Clay | | 9 | |
| Clinker and concealed to river level | | 20 | |
| Total lignite | | 15 | |

*Section of two lower members of Medora group near Custer Trail ranch, in the SE. ¼ sec. 15, T. 139 N., R. 102 W.*

| Shale, carbonaceous. | | Ft. | in. |
|---|---|---|---|
| Bed C | Lignite | 1 | 6 |
| | Shale | | 6–11 |
| | Lignite | 6 | 6 |
| | Clay, brown | 1 | |
| | Lignite | 5 | 10 |
| Clay, sandy | | 40 | |
| Bed B: Lignite | | 6 | 6 |
| Clay, sandy | | 66 | 6 |
| Clay, carbonaceous | | 3 | 6 |
| Clay, sandy, to level of river | | 10 | |
| Total lignite | | 20 | 4 |

*Section at Medora, in the NW. ¼ sec. 26, T. 140 N., R. 102 W.*

| Shale, brown. | | Ft. | in. |
|---|---|---|---|
| Bed D: Lignite | | 4 | 6 |
| Shale, clay, and sandstone | | 30 | |
| Bed C | Lignite | 8 | 2 |
| | Clay, white | | 3 |
| | Lignite | | 11 |
| Clay, sandy, to river level | | 40 | |
| Total lignite | | 13 | 7 |

[a] 125 feet above river level.

*Section near mouth of Knutson Creek, in the NW. ¼ sec. 11, T. 140 N., R. 102 W.*

| | Ft. | in. |
|---|---|---|
| Bed D: Lignite | 5 | 6 |
| Clay, sandy | 25 | |
| Bed C: Lignite | 9 | |
| Concealed to river level | 20 | |
| Total lignite | 14 | 6 |

A bed of lignite 5 feet thick exposed in the south bank of Little Missouri River, in the NE. ¼ sec. 32, T. 141 N., R. 101 W., probably represents the second member below the top of the Medora group, the other members being present below the level of the river.

Bed E shows workable thickness, and its outcrop has been mapped along the banks of Andrews Creek, in T. 140 N., R. 104 W., near the town of Sentinel Butte. Two sections follow:

*Section of bed E in the NE. ¼ SW. ¼ sec. 21, T. 140 N., R. 104 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, soft, yellowish | 20 | |
| Lignite | 5 | 2 |
| Clay | 5 | 6 |
| Lignite | 1 | |
| Clay | 5 | 6 |
| Lignite | 1 | 6 |
| Total lignite | 7 | 8 |

*Section of bed E in the SE. ¼ sec. 22, T. 140 N., R. 104 W.*

| | Ft. | in. |
|---|---|---|
| Clay, blue, sandy | 6 | |
| Lignite | 1 | 6 |
| Clay, bituminous | | 4 |
| Lignite | 5 | |
| Total lignite | 6 | 6 |

An exposure of bed C in sec. 11, T. 142 N., R. 102 W., on the east side of Little Missouri River, shows the following section:

*Section of bed C in east bank of Little Missouri River, in sec. 11, T. 142 N., R. 102 W.*

| | Ft. | in. |
|---|---|---|
| Clay, sandy. | | |
| Lignite | 1 | |
| Clay | 5 | 6 |
| Lignite | 3 | |
| Clay, sandy | 6 | |
| Lignite | 6 | |
| Clay, sandy | 3 | 6 |
| Lignite | 6 | |
| Clay. | | |
| Total lignite | 16 | |

Farther north, on the west side of the river, the following section is exposed:

*Section of bed C on west bank of Little Missouri River near Bryan's ranch, about 1 mile north of north line of T. 142 N., R. 102 W.*

| | | Ft. | in. |
|---|---|---|---|
| Bed C | Lignite | 2 | 10 |
| | Clay | | 10 |
| | Lignite | 3 | 4 |
| | Clay | | 10 |
| | Lignite | 7 | 7 |
| Clay, sandy, to river level. | | | |
| | Total lignite | 13 | 9 |

An exposure of this bed near the mouth of Roosevelt Creek, a short distance north of the foregoing section, shows the same number of benches of lignite, all slightly thinner.

In sec. 34, T. 142 N., R. 103 W., on Wannigan Creek, near Bird's ranch, an exposure of lignite is 3 feet 9 inches thick. This is probably bed E.

In T. 142 N., R. 104 W., bed E is exposed in the banks of Elk Creek, near Wilson's ranch. In sec. 16 this bed measures 4 feet 4 inches. Farther down the creek the section is as follows:

*Section of bed E in the SW. ¼ sec. 1, T. 142 N., R. 104 W.*

| | Ft. | in. |
|---|---|---|
| Lignite | | 8 |
| Clay | | 6 |
| Lignite | 2 | 6 |
| Total lignite | 3 | 2 |

In T. 142 N., R. 105 W., bed E is of workable thickness in a number of places and has been mapped entirely across the township. Toward the northwest it becomes thin, but to the east it is thicker, as shown by the section near the northeast corner of the township:

*Section of lignite beds near the northeast corner of T. 142 N., R. 105 W.*

| | Ft. | in. |
|---|---|---|
| Clays, dark gray, with irregular black calcareous bands | 100 | |
| Sandstone, yellowish, and gray clay | 40 | |
| Lignite | 1 | |
| Clay, gray, and yellow sandstone alternating | 30 | |
| Lignite | 3 | 6 |
| Clay, gray, and yellow sandstone alternating | 50 | |
| Lignite | 1 | 4 |
| Sandstone and clay alternating | 20 | |
| Lignite | 1 | 2 |
| Sandstone and clay alternating | 15 | |
| Bed E: Lignite | 6 | |
| Clay, blue-gray | 6 | 6 |
| Lignite | 1 | 3 |

| | Ft. | in. |
|---|---|---|
| Sandstone and clay alternating | 47 | |
| Bed D: Lignite | 5 | 6 |
| Sandstone and clay | 10 | |
| Lignite | | 4 |
| Sandstone and clay alternating | 20 | |
| Bed C: Lignite | 2 | 9 |
| Bed C: Clay, gray | | 11 |
| Bed C: Lignite | 4 | 3 |
| Sand and clay | 35 | |
| Bed B: Lignite | 3 | 8 |
| Clay, sandy | 11 | |
| Level of Beaver Creek. | | |
| Total lignite | 30 | 9 |

On Little Beaver Creek, in T. 141 N., R. 105 W., beds C and E show workable thickness, but only a small portion of the outcrop of bed E has been followed out. Toward the south its outcrop is divided by a number of partings and is lost in the grass-covered prairies.

The outcrop of bed C disappears below the level of Little Beaver Creek about one-half mile east of the State line, where it is about 6 feet thick.

Two mines or strip pits have been opened on bed E, one in the NW. ¼ sec. 8 and the other in the NW. ¼ sec. 16. Sections of the lignite at these mines follow:

*Section of bed E in the NW. ¼ sec. 8, T. 141 N., R. 105 W.*

| | Ft. | in. |
|---|---|---|
| Lignite | 6 | 6 |
| Clay, sandy | 8 | |
| Lignite | 3 | |
| Total lignite | 9 | 6 |

*Section of bed E in the NW. ¼ sec. 16, T. 141 N., R. 105 W.*

| | Ft. | in. |
|---|---|---|
| Lignite | 2 | 2 |
| Clay, white | | 6 |
| Lignite | | 5 |
| Clay, white | | 6 |
| Lignite | 5 | 6 |
| Total lignite | 8 | 1 |

In T. 16 N., R. 60 E., Montana, and in the northwestern part of T. 142 N., R. 105 W., North Dakota, bed C is thin and unworkable. Toward the south its outcrop runs through T. 15 N., R. 60 E., rising gradually above the level of Beaver Creek. Its outcrop is nearly everywhere marked by a fringe of clinkered material, due to the burning of the bed. The outcrop was not mapped farther south than the northern part of T. 14 N., R. 60 E., though the clinker occurs in the prairies to the southern boundary of the field.

A number of lignite beds lower in the section than bed C of the Medora group are exposed along the east bank of Beaver Creek, in the southeastern part of T. 16 N., R. 60 E. In a bluff on the east bank of Beaver Creek, in the NE. ¼ sec. 27, the following section was measured. The three upper beds probably represent bed C, with partings greatly increased.

*Section in the NE. ¼ sec. 27, T. 16 N., R. 60 E., Montana.*

| | Ft. | in. |
|---|---|---|
| Sandstone, soft, yellow-white | 22 | |
| Lignite | 2 | |
| Sandstone, soft, dark | 5 | 6 |
| Lignite | 1 | |
| Sand, clayey, gray | 4 | 9 |
| Lignite | 3 | 6 |
| Sandstone, soft, white | 20 | |
| Lignite | 5 | 6 |
| Sandstone, white, clayey | 10 | 3 |
| Lignite | 4 | |
| Clay, dark gray | 30 | |
| Lignite | | 5 |
| Level of Beaver Creek. | | |
| Total lignite | 16 | 5 |

An exposure of bed C in the NE. ¼ sec. 12, T. 15 N., R. 59 E., measures 12 feet, but the upper part of the bed contains many thin partings of clay. Northward from this point the bed becomes thin, as shown by a measurement in the southwest corner of T. 16 N., R. 60 E., where it is only 5 feet thick. Toward the southwest the bed rises gradually and appears in small isolated areas near the tops of the highest hills.

### SENTINEL BUTTE GROUP OF LIGNITE BEDS.

The Sentinel Butte group of lignite beds is so named on account of its occurrence in Sentinel Butte. Although the distribution of its members is now restricted to small detached areas, hundreds of clinker-capped buttes at the horizon of the two lower members of the group, dotting almost the entire eastern half of the area surveyed, bear evidence of the fact that these members covered at some earlier time a much larger area than at present, and that they have been burned over nearly all of the area.

The lowest member of the group, bed F of the columnar section, has its greatest development in the eastern part of the field, where it is from 10 to 16 feet thick. It is found at the contact of the buff sandstone and gray shale with the somber-colored member above. This contact is well marked on account of the abrupt change in the color and character of the material, and can be readily followed throughout the district where it occurs.

The second member of the group, bed G, from 25 to 50 feet above the lowest member, shows to better advantage in the south-central part of the surveyed area, in the base of the higher buttes, where its outcrop is marked by a fringe of clinker. Both the lower members become thin and disappear toward the northwest. These beds have been so generally burned that few exposures showing their whole thickness can be found. Other members ranging from 100 to 250 feet above the base of the group are so limited in distribution in the region examined that they will not be considered further than to say that they occur in Sentinel, Flat Top, and Camels Hump buttes, and in a small area in the extreme northeastern part of the region. The maximum thickness of the members of this group and their positions in the geologic column are shown in the graphic section on the map (Pl. II). Some detailed sections of the two lower members of the group are given below.

A few exposures of parts of the two lower members of the Sentinel Butte group were noted in the southeast corner of the field, where small patches of somber-colored beds are underlain by them. The coal is about 350 feet above the level of Little Missouri River at the southern boundary of the field. The outcrop of the lignite is so concealed by a fringe of clinker that it is difficult to find the whole of the lower bed exposed, but it is about 17 feet thick, apparently without partings. These beds are unimportant here, as they are detached bodies of small extent.

*Section of bed G in the northeast base of Sentinel Butte, in the SE. ¼ sec. 5, T. 139 N., R. 104 W.*

| | Ft. | in. |
|---|---|---|
| Clay, sandy, somber colored. | | |
| Lignite | 14 | |
| Clay | | 3 |
| Lignite | 6 | 11 |
| Clay. | | |
| Total lignite | 20 | 11 |

This bed has been mined here for local use. The same bed has been mined in the NE. ¼ NW. ¼ sec. 7, 1¼ miles west of this exposure, and is there 20 feet 11 inches thick. It has also been mined in the SW. ¼ sec. 5, but its whole thickness could not be seen.

A number of small areas underlain by the lower members of the Sentinel Butte group remain in the southeast corner of T. 139 N., R. 105 W. Near the center of sec. 25 of this township, lignite is mined for neighborhood use by stripping. A section follows:

*Section near center of sec. 25, T. 139 N., R. 105 W.*

| | Ft. | in. |
|---|---|---|
| Clay, white. | | |
| Lignite, weathered | 8 | |
| Clay | | 10 |
| Lignite (base concealed) | 7 | |
| Total lignite exposed | 15 | |

The lower bench is partially concealed, but is reported to be 10 feet thick and to be underlain by clay. This bed also occurs in the base of Rocky Butte, in sec. 34, but is so concealed by clinker that no measurement of its thickness could be made. To judge from the thickness of clinker produced by its burning along the outcrop, however, it is in all probability workable.

In the base of Square Butte, in T. 139 N., R. 103 W., beds F and G are separated by 25 feet of sandy clay. Their outcrops have been so completely burned that the coal is exposed at only a few points. Bed G, exposed in the NE. ¼ sec. 9, T. 139 N., R. 103 W., is 15 feet thick without partings. Bed F is about 5 feet thick. A few small isolated buttes, underlain by these two members of the group, lie between Square Butte and Little Missouri River, but the presence of clinker prevented any measurements. Bed G occurs in the base of Camels Hump Butte, in secs. 9 and 10, T. 140 N., R. 104 W., as indicated by the fringe of clinker left by its burning, but no actual exposure could be seen.

In the southeastern part of T. 141 N., R. 102 W., bed F outcrops near the top of a plateau, 250 feet above the level of Little Missouri River. It thins out toward the north and is worthless. In the N. ½ sec. 35 only the upper 6½ feet of the bed could be seen.

In the northern part of T. 142 N., R. 101 W., bed F, the lowest member of the group, is divided and replaced by partings so that little of it remains. Here the upper members of the group are thin and dirty.

In the eastern part of T. 142 N., R. 102 W., and in T. 142 N., R. 103 W., bed G outcrops near the top of the higher divides in the badlands. It is 250 feet above the river level, ranges in thickness from 3 to 5 feet, and is scarcely accessible for mining operations.

A few isolated buttes of sufficient height to contain bed F are found in T. 141 N., R. 103 W., and in T. 142 N., R. 104 W., but the rocks are either barren or contain thin, unworkable beds of lignite.

In T. 141 N., R. 101 W., bed F, at the contact of the somber-colored beds and the lighter beds below, occurs in more or less isolated buttes on the divides between Franks Creek and Government Creek, at an elevation of about 250 to 300 feet above Little Missouri River. In the SW. ¼ sec. 5 a small butte is underlain by this bed, which is 11 feet 6 inches thick, with a 3-inch clay parting 6 inches from the bottom. In the NW. ¼ SE. ¼ sec. 12 an exposure of a part of the bed measures 16 feet. It is probably not much thicker. A part of the S. ½ sec. 36 is underlain by this bed, but the presence of clinker prevented any measurements.

In secs. 8, 9, 10, 16, and 17, T. 140 N., R. 102 W., at an elevation of about 275 feet above Little Missouri River, an irregular plateau is underlain by bed F, the lowest member of the group. Its outcrop is usually concealed by clinker, and no satisfactory measurements of its thickness could be made.

Bed F occurs in T. 142 N., R. 101 W., at an elevation of about 250 feet above Little Missouri River. Its outcrop is extremely sinuous and is everywhere fringed by a rim of clinkered material. In the southeastern part of the township the lignite is so concealed that no measurements of its thickness could be made, but it is probably about as thick as it is in the next township south, or about 15 feet. North of Ash Creek partings develop in the bed, replacing and dividing it so that it is rendered unworkable. Some detailed sections of this bed follow:

*Section of bed F in NE. ¼ sec. 4, T. 142 N., R. 101 W.*

| | Ft. | in. |
|---|---|---|
| Lignite | 1 | 3 |
| Clay | 7 | |
| Lignite | 3 | |
| Total lignite | 4 | 3 |

*Section of bed F near center of N. ½ sec. 13, T. 142 N., R. 101 W.*

| | Ft. | in. |
|---|---|---|
| Lignite | 2 | 7 |
| Clay | | 7 |
| Lignite | 1 | 11 |
| Clay | 1 | 1 |
| Lignite | 1 | 5 |
| Total lignite | 5 | 11 |

*Section of bed F near northeast corner sec. 15, T. 142 N., R. 101 W.*

| | Ft. | in. |
|---|---|---|
| Lignite | 2 | 8 |
| Clay | | 8 |
| Lignite | 4 | 2 |
| Total lignite | 6 | 10 |

## CHARACTER AND USES OF THE LIGNITE.

The lignite is brown, tough, and woody in structure. It slacks rapidly on exposure to air and sunlight, especially when much handled or subjected to long hauls by rail. As a rule the grain of the wood and the compressed trunks of trees with branches are plainly visible in the coal, but pockets and layers of shiny, black, textureless, brittle coal are scattered through many beds. These pockets become more apparent on exposure to weathering agencies, as they slack more rapidly than the woody parts.

There is apparently a slight change in the character of the lignite toward the west. Near Wibaux less woody material appears in it than at Medora and Sentinel Butte. At Glendive, still farther west, the lignite is almost entirely of the black, brittle variety. This change may be due to the fact that the coals at Glendive are much lower in the rock section than those farther east, and hence are older and have suffered a greater degree of metamorphism than the higher coals.

The impurities in the lignite consist mainly of sand and clay partings, which are difficult to separate in mining. Intimate mixtures of fine sand or clay and lignite, of irregular shape and extent, are rather common in the beds, and are not easily detected without close examination, as they have the same color as the lignite. Crystals of selenite or gypsum are also found.

The fact that the woody parts of the lignite are freer from impurities than the textureless parts is recognized by ranchmen and farmers, who usually throw aside the less desirable lignite in mining.

Heretofore the lignite has been little used except as a local fuel supply, but the fact that lignites similar in every respect are mined on a commercial scale at Lehigh, N. Dak., 40 miles to the east, and near Glendive, Mont., 25 miles to the west, seems to justify the statement that the field is one of growing importance.

Briquetting tests of North Dakota lignite have been made by the United States Geological Survey fuel-testing plant and by individuals. No binder is used, but the product is firm and gives excellent results, except when subjected to forced draft, which has the effect of disintegrating the briquets and carrying the unburned particles out through the smokestack.

Another consideration that adds materially to the value of the brown lignite is its surprising success in the producer-gas plant. The following statement has been made concerning the value of North Dakota lignite in the gas producer and gas engine:[a]

> The result of the steam test was so unsatisfactory that there is nothing by which a direct comparison can be made of the efficiency of the fuel used in the producer-gas plant as compared with the efficiency developed in the steam plant. Nevertheless a comparison of the results obtained on other coals under the steam boiler is instructive. The table shows that to produce one electrical horsepower hour in the producer-gas plant required 2.29 pounds of dry North Dakota lignite, whereas to produce the same result in the steam plant required 3.39 pounds of the best West Virginia coal. This means that North Dakota lignite, with the moisture eliminated, will do more work when used in a producer-gas plant than the best coal of the country will do in a steam plant.

Many detached terraces or flats along Little Missouri River are too small to justify the construction of expensive canal systems for the purpose of irrigation. In other parts of this general region such terraces, from 10 to 30 feet above water level, are being watered by pumping from adjacent streams, lignite being used as fuel. Lignite in abundance is at hand or within easy reach of most of the probable locations of such plants on the Little Missouri, and it seems likely that with the settlement of the country more use will be made of it for this purpose.

The samples for the following analyses were all taken from open pits where the coal was more or less weathered. It is believed that

[a] Prof. Paper U. S. Geol. Survey No. 48, pt. 1, 1906, p 111.

the analyses would be slightly different, especially with respect to their original moisture content, had the samples been taken from fresh faces of coal, out of reach of atmospheric agencies.

*Proximate analyses of samples of lignite from the Sentinel Butte field, North Dakota-Montana.*

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

| Laboratory No. | 5779 | 5781 | 5782 | 5784 |
|---|---|---|---|---|
| Sample as received: | | | | |
| Moisture | 34.50 | 35.72 | 35.40 | 43.51 |
| Volatile matter | 29.76 | 31.88 | 38.25 | 25.23 |
| Fixed carbon | 28.53 | 23.54 | 20.71 | 24.87 |
| Ash | 7.21 | 8.86 | 5.64 | 6.39 |
| Sulphur | .99 | 1.53 | .84 | 1.04 |
| Calories | 3,730 | 3,538 | 3,781 | 3,230 |
| British thermal units | 6,714 | 6,368 | 6,806 | 5,814 |
| Loss of moisture on air drying | 21.00 | 23.30 | 17.00 | 32.60 |
| Air-dried sample: | | | | |
| Moisture | 17.09 | 16.19 | 22.17 | 16.19 |
| Volatile matter | 37.67 | 41.57 | 46.08 | 37.43 |
| Fixed carbon | 36.11 | 30.69 | 24.95 | 36.90 |
| Ash | 9.13 | 11.55 | 6.80 | 9.48 |
| Sulphur | 1.25 | 1.99 | 1.01 | 1.54 |
| Calories | 4,721 | 4,613 | 4,555 | 4,792 |
| British thermal units | 8,499 | 8,302 | 8,200 | 8,626 |

5779. Sec. 16, T. 141 N., R. 105 W., North Dakota.
5781. Sec. 8, T. 141 N., R. 105 W., North Dakota.
5782. Sec. 25, T. 139 N., R. 105 W., North Dakota.
5784. Sec. 5, T. 139 N., R. 104 W., North Dakota.

## ESTIMATED TONNAGE OF LIGNITE.

It has been estimated that the total amount of lignite in the field within 1,000 feet of the surface and 3 feet or more in thickness is approximately 33,126,269,000 tons, equivalent to one bed 36.94 feet thick covering an area of 792 square miles.

## MINING OPERATIONS.

All mining in the field is done to supply local demands. One-eighth of a mile northeast of Medora a drift has been opened to the southeast for 70 feet on a bed of lignite at the base of the bluff. The same bed was formerly worked on the west side of Little Missouri River about one-fourth mile west of the railway station at Medora, where mining operations were carried on by the Northern Pacific Railway Company as early as 1884. These workings have been abandoned and the entries allowed to cave in, so that the lignite can not now be seen. Other openings from which lignite has been taken during the fall and winter months are found at many points in the field. Throughout most of the area lignite is the only fuel used, and the ranchmen and settlers mine and haul the few tons they need from the nearest available outcrop, which is commonly not many miles distant.

Timber suitable for mining operations is scarce except along the valley of Little Missouri River.

# THE MILES CITY COAL FIELD, MONTANA.

By ARTHUR J. COLLIER and CARL D. SMITH.

## INTRODUCTION.

The Miles City coal field, situated in the northern part of Custer County, Mont., about 90 miles west of the North Dakota line, is a small part of a large area of Tertiary coal-bearing rocks which extends from eastern Montana southward into Wyoming, northward into Canada, and eastward into North and South Dakota. The area as here described comprises about 1,000 square miles. Rocks and coals of the same age in Carbon, Dawson, Rosebud, and Custer counties, Mont., have been examined and described[a] in previous reports of the Geological Survey, and detailed studies during 1907 of coal-bearing rocks of the same age in the Sentinel Butte field of North Dakota and Montana, in the Bull Mountain and Red Lodge fields of Montana, and in the Sheridan and Glenrock fields of Wyoming, are reported in this volume. The coals are generally of low grade and are classed as subbituminous and lignite.

The present report is a preliminary statement intended to give advance information regarding the coal resources of the field, leaving the more purely scientific questions for consideration at a later date, when the investigations in this and other parts of the region shall have been completed. It is based on a season's field work by the writers, who were assisted by Carroll H. Wegemann and Ralph W. Howell. Through July and August the party was in charge of Mr. Collier, who was called away to other work on September 1; at that time Mr. Smith suspended his work in the Sentinel Butte field and took charge of the party at Miles City, continuing in the field until November 1.

The purpose of the investigation was primarily to ascertain the limits of the area underlain by workable coal and to classify the coal lands. With these objects in view, copies of the original township plats were used as a base for geologic mapping. Although

[a] Leonard, A. G., Coal in Dawson, Custer, and Rosebud counties, Montana: Bull. U. S. Geol. Survey No. 316, 1907, pp. 194-211. Darton, N. H., Coals in Carbon County, Montana: Idem, pp. 174-193.

many of the surveys in this region are old, a large percentage of the original monuments are still preserved, and no townships purporting to have been surveyed were found in which classification of the land was utterly impossible for lack of corners.

Owing to the facts that the strata are practically horizontal and that no coal is known below drainage levels, the areal distribution of the coal depends to a remarkable extent on the topography, and data were collected for a topographic map with a contour interval of 50 feet. The flat map (Pl. III) herewith presented is compiled from the various field sheets, with such reduction of scale as has been found necessary for the present publication.

## GEOGRAPHY.

### LOCATION OF FIELD.

The geographic location and outlines of the area examined are shown on the index map (Pl. III). Its relations to the eastern Montana coal fields, together with its more general geographic and commercial relations, are indicated on the coal map of the United States (Pl. I).

### COMMERCIAL RELATIONS.

Miles City, the principal town of the field and the county seat of Custer County, is situated in the western part of the area examined, at the mouth of Tongue River, on the main line of the Northern Pacific Railway, which here follows the south side of Yellowstone River. The western extension of the Chicago, Milwaukee and St. Paul Railway also crosses the Yellowstone from the north a short distance above Miles City, and parallels the Northern Pacific through the town, crossing again to the north side a short distance below the area mapped.

Two stage roads lead from Miles City to the region south and east. The Ekalaka road, which extends eastward to Knowlton and thence southward to Ekalaka, is the only practicable way by which wagons can be taken from Miles City directly across to Powder River, badlands to the north and south rendering travel almost impossible. A road following up Tongue River gives access to the region south of Miles City. About 10 miles above the mouth of Tongue River Pumpkin Creek enters from the east side, and a road along this creek furnishes an easy line of travel across the divide to Powder River and to Powderville, 20 miles south of the area under discussion. There are also passable wagon roads extending approximately north and south along Powder River and Mizpah and Cottonwood creeks, east of Tongue River. West of Tongue River there are many routes by which wagons can be taken over the greater part of the district.

At present no coal is shipped away from this part of Montana. Miles City, with a population of about 5,000, furnishes the best market, but the coal is used for domestic purposes by nearly all the ranchmen and farmers throughout the surrounding country. The largest individual consumers at the present time are the electric light and water companies of Miles City.

A broader field of usefulness for these fuels will probably be found in the production of power for irrigating many small detached tracts of land for which elaborate systems of canals are impracticable. Such tracts are especially numerous along Tongue and Powder rivers, and several pumping plants, some of which use steam and others gasoline engines, are already in operation.

The valley of the Yellowstone is in most places broad, but the meandering of the stream from bluff to bluff has left the flats disconnected. Two such flats, known as Sadie Bottom and Keogh Flat, lie a short distance above Miles City, and a project to irrigate them by pumping water from the Yellowstone, using the lignite near by as fuel, is under consideration by the Reclamation Service. About 9,000 acres along Tongue and Yellowstone rivers are under irrigation by a ditch which takes water out of Tongue River 10 miles above its mouth.

## DRAINAGE.

Yellowstone River, rising in the Rocky Mountains several hundred miles to the southwest, flows diagonally across the northwest corner of the field and carries a large volume of water during all seasons of the year. Tongue and Powder rivers, rising in the Bighorn Mountains of Wyoming, flow northward across the area and join the Yellowstone. Both of these streams are perennial, but during the latter part of the summer water in them is extremely low. Back from the valleys of these master streams the region is drained by an intricate network of intermittent watercourses, usually in narrow canyons or gulches. Moon, Pumpkin, Mizpah, Cottonwood, and Locate creeks, the principal tributaries of the main rivers, usually contain water in pools, but do not flow continuously except in wet seasons.

## TOPOGRAPHY.

The total relief between the highest and lowest points in the field does not exceed 900 feet, but much of the topography is exceedingly complicated in detail. Four rather distinct topographic types—lowlands, plateaus or uplands, badlands, and river terraces—can be recognized and are indicated on the profile accompanying Pl. III. The lowlands are situated in the valleys of the larger streams and include most of the irrigable land.

The upland areas comprise an undulating surface at elevations from 500 to 900 feet above the main drainage levels. Although these plateaus are somewhat uneven and in places are broken by buttes and canyons, they include large tracts level enough for cultivation, but not susceptible to irrigation for lack of available water. The largest upland area southeast of Miles City, known as the Pine Hills country, where dry-land farming has been successfully practiced for several years, is rather thickly settled.

The most distinctive topographic features of this region are its badlands, which almost everywhere surround the upland areas and form a ragged fringe separating them from the lowlands of the valleys. In these areas the topography is broken into intricate detail. Drainage is maturely developed and is affected by a multitude of intermittent watercourses in narrow canyons, which conform to no general system. The interstream areas are eroded into sharp peaks and ridges or narrow mesas at various elevations. In general, the individual hills and spurs or topographic units are comparatively small. The relief from canyon to hilltop in few places exceeds 200 feet, but the multitude of such features makes the badlands exceedingly difficult to traverse and renders them unfit for anything except grazing. The line of demarkation between the lowland and the badland areas is usually distinct and definite, the badland bluffs and buttes rising abruptly at the edges of the valleys.

In many places along Yellowstone and Powder rivers there are broad benches or terraces from 100 to 250 feet above river level. These terraces represent former valleys of the streams where gravel, which now serves as a protecting cap, was deposited. As they occur in the midst of the badlands they are rendered conspicuous by the abrupt change of topography. The terraces are too high above the level of the streams to be irrigated, but they are valuable for their production of wild hay, and may become more valuable for dry-farming purposes.

A noticeable feature of the region—one which adds picturesqueness as well as roughness to the badlands—is the red clinker or partly fused and baked sand and clay due to the burning of coal beds. Owing to the superior resistance of this material it has withstood the processes of erosion longer than surrounding softer rocks, and is thus left capping buttes and ridges and fringing the outcrops of unburned coals.

## GEOLOGY.

### STRATIGRAPHY.

Except for some unimportant alluvial deposits in the valleys all the rocks exposed in this district are of Tertiary age and belong to a formation called the Fort Union, which has been recognized in many

parts of Montana, Wyoming, North Dakota, and South Dakota. It is named after Fort Union, an old military post at the mouth of Yellowstone River. The total thickness of the formation can not be determined in this field, as neither top nor base is represented. The rocks consist of comparatively fine material, mainly clay shale and sandstone, including lignite and thin beds of impure limestone. They are all fresh-water deposits and contain an extensive fossil flora of about 400 species of plants which resemble those of modern times, and a fauna including fishes, fresh-water mollusks, and reptiles. Evidence now in hand indicates that the waters in which these sediments were deposited extended from east-central Wyoming to northern Montana, and from Livingston, Mont., eastward to the center of North Dakota. Within these limits areas not occupied by Fort Union rocks are those in which, owing to deformations of the earth's crust, they have been removed by erosion.

The total thickness of Fort Union rocks exposed in the Miles City field is about 900 feet, which may be increased by data obtained from drill holes at Miles City to a total of 1,400 feet. From a comparison of the section at Miles City with that exposed about 70 miles to the northeast near Glendive it is inferred that the base of the Fort Union formation is not very deeply buried, and it is probable that some of the drill holes at Miles City have penetrated to underlying Cretaceous rocks.

The Fort Union rocks exposed are readily separated into two members by a marked difference in lithologic character. The lower member, about 500 feet thick, consists mainly of alternating beds of clay shale and sandstone, having a general dark-gray or somber hue. In detail the individual layers of this part of the formation, especially the sandstones, show numerous irregularities of deposition. Thin layers of ferruginous limestone occur at short intervals throughout the section, and concretion-like masses of the same material, more or less lenticular in form, are included in the shales and sandstones. The thicker sandstone beds are usually characterized by more or less irregular cross-bedding. Coal is found at numerous horizons, but the beds are extremely variable in thickness and horizontal extent. The many alternations of soft rocks with thin hard layers give rise during erosion to marked badland topography.

Altogether sections of the rocks vary greatly in their detail from place to place, certain general features, such as thicker coal beds at or near certain horizons and prevalent sandstones or abundant concretions at others, can be recognized in a general way throughout the field. The following section, measured in detail near Miles City, is inserted to illustrate the rapid alternation of various materials comprising this part of the Fort Union formation:

*Section of the lower member of the Fort Union formation near Miles City, Mont.*

| | Ft. | in. |
|---|---|---|
| Limestone at base of upper member | 3 | |
| Shale, white | 7 | |
| Coal and shale, dark | | 6 |
| Shale, gray | 20 | |
| Limestone, weathering brown | 1 | |
| Shale, light gray | 10 | |
| Shale, dark gray | 8 | |
| Limestone, weathering reddish brown | | 6 |
| Shale, dark yellow | 6 | |
| Coal | | 6 |
| Shale, gray | 21 | |
| Limestone, weathering light red | 1 | |
| Shale, gray | 25 | |
| Sandstone, white, with limestone concretions | 8 | |
| Shale | 2 | |
| Sandstone | 8 | |
| Shale, white | 2 | |
| Shale, gray | 5 | 6 |
| Sandstone, gray | 20 | |
| Limestone, weathering red | | 3 |
| Sandstone, gray | 4 | |
| Limestone, weathering red | | 6 |
| Sandstone, gray | 4 | |
| Coal and shale | 1 | 10 |
| Sandstone, gray | 3 | 6 |
| Limestone, weathering light red | 1 | 6 |
| Sandstone, gray | 4 | |
| Limestone, weathering light red | | 6 |
| Shale, dark | 3 | |
| Limestone, weathering red | | 3 |
| Sandstone, gray | 2 | |
| Coal | | 8 |
| Shale, yellow | 5 | |
| Limestone, weathering light red | | 8 |
| Shale, gray | 13 | |
| Limestone, weathering red | | 6 |
| Sandstone, fine gray | 3 | |
| Limestone, weathering red | | 2 |
| Sandstone, gray | 2 | |
| Limestone, weathering red | | 2 |
| Sandstone | 5 | |
| Coal (Weaver bed) (D, Pl. III) | 2 | 5 |
| Shale | | 4 |
| Coal | 1 | 3 |
| Shale | | 10 |
| Coal | | 6 |
| Shale | | 6 |
| Coal | | 3 |
| Shale, sandy, dark yellow | 6 | |
| Limestone, brittle | | 6 |
| Shale, dark gray | 5 | |

| | Ft. | in. |
|---|---|---|
| Shale, fissile, dark brown | 4 | 6 |
| Coal | | |
| Shale, gray, with numerous limestone concretions | 17 | |
| Limestone, weathering red | | 6 |
| Shale, dark, with thin layers of red limestone | 10 | |
| Sandstone, brown, containing fragments of carbonaceous material | 7 | |
| Coal | 1 | 6 |
| Shale, light gray | 9 | |
| Limestone, red | | 2 |
| Shale | | 3 |
| Coal | | 3 |
| Shale, blue | 8 | |
| Coal, with three small streaks of bone | 3 | 4 |
| Sandstone | 6 | |
| Shale | 4 | |
| Sandstone | 2 | 6 |
| Shale | 3 | |
| Coal | | 7 |
| Shale | | 6 |
| Coal, dirty, with several white partings, one-half inch to 1 inch thick (Laney bed) (C, Pl. III) | | 5 |
| Shale | 1 | |
| Sandstone | 2 | |
| Shale | 4 | |
| Limestone, weathering red | | 6 |
| Sandstone, gray, with some thin layers of shale | 25 | |
| Limestone, weathering red | | 6 |
| Shale, sandy, yellowish gray | 8 | |
| Coal | | 8 |
| Shale | 3 | |
| Sandstone, friable, gray | 20 | |
| Shale, sandy, many concretions | 5 | |
| Limestone, weathering red | 3 | |
| Sandstone, coarse, gray | 17 | |
| Limestone, weathering light red | | 6 |
| Sandstone | 3 | |
| Shale, brown with blue bands | 10 | |
| Sandstone | 6 | |
| Coal and shale | 2 | |
| Shale, sandy, gray, usually cross-bedded | 50 | |
| Coal | | 6 |
| Shale, sandy | 5 | |
| Coal (Kircher bed) (A, Pl. III) | 5 | |
| | 465 | 3 |

This member is conformably overlain by more homogeneous rocks, mainly sandy shale, which, as exposed by erosion, are generally of a light-yellow color. This member of the Fort Union formation is here designated the upper member. The somber color which prevails in the lower part of the formation is represented in the upper part only by an occasional bed of gray or light-blue shale.

Coal beds in this member are not so numerous near Miles City as in the lower member, but are more constant in thickness and quality. The workable coal is confined to two beds, 160 and 300 feet above the base of the member.

In some places these rocks give rise to badland topography, but in general the features are larger than those produced in the somber-colored beds below; the hills and buttes are higher and the level stretches more extensive. Calcareous layers such as occur in the lower beds are not expressed in the topography, but many of the buttes are capped with the clinkers of burned coal. The characteristic features of these two members of the Fort Union formation indicate conclusively that the conditions which prevailed during the deposition of the lower member were much more changeable than those during the deposition of the upper. When the lower beds were deposited shallow-water conditions evidently prevailed, with shifting currents and changes of elevation too frequent to permit the formation of extensive beds of coal. The carbonaceous materials in many of the coal beds are thoroughly macerated, and no doubt in some places were partially decomposed by exposure to air before the overlying strata were laid down. During the deposition of the upper beds general conditions were more stable, and consequently the different layers of this part of the formation are more uniform both in thickness and distribution. Though there is some false bedding, it is neither so common nor so well marked as in the lower beds. The coals retain more of their original woody texture and are distinctly lignitic in appearance.

## STRUCTURE.

Throughout the area under discussion the strata, except where they are locally displaced by surface influences, lie perfectly flat. No deep-seated faults have broken them, though in some localities displacements of a few feet, attributable to purely local conditions, have been observed. As a result of this simple structure no rocks lying below the level of Yellowstone River are exposed. Individual coal beds may be traced and correlated with certainty throughout the field, and their outcrops coincide with contour lines. The map (Pl. III) showing in detail the outcrops of the more important coal beds has the appearance, therefore, of a contour map with irregular contour interval.

Some facts, however, indicate that either all or a large part of the field lies in a shallow syncline or basin. A number of wells drilled at Miles City yield a fair flow of artesian water which, in order to reach the surface, must have descended along bedding planes from some higher levels. It is thought that the source of this water is to the west of the field, where there is some evidence that underlying Cretaceous rocks outcrop at Howard, on the Yellowstone. The rise of

the rocks in that direction is scarcely greater than the gradient of the river. About 70 miles northeast of Miles City, near Glendive, there is a pronounced anticline, which brings the Pierre shale to the surface. This flexure has a northwest-southeast axis and is believed to mark the northeast limit of the basin in which Miles City is situated. A few miles south of this district the lower member of the Fort Union formation rises to the summit of the divide between Tongue and Powder rivers, and it is thought that here also there may be a broad anticline separating the Miles City field from the Sheridan field of Wyoming.

## THE COAL.

### GENERAL CONDITIONS.

Coal beds are distributed at short intervals through the entire section of rocks exposed, but many of them are too thin to work, or, if thick enough to work, are too impure for commercial use. The drill holes sunk about Miles City in search of artesian water have revealed no coal beds of consequence to a depth of 500 feet below the river level, indicating that the Kircher coal, which lies about 50 feet above river level, is the lowest workable bed and practically the base of the coal-bearing rocks.

A distinct change in the character of the coals, as in that of the other strata, can be noted in passing from the lower to the upper beds. The former vary greatly in thickness and purity from place to place. In many localities they contain numerous thin partings and seem to have been deposited under changeable conditions. On close examination a majority of the lower coals are found to be black in color and to exhibit comparatively little of the woody texture characteristic of the higher coals. The absence of woody texture is attributed to more complete maceration of the carbonaceous material during the time of its deposition.

The character of the lignite in the upper beds indicates that the conditions during its deposition were comparatively stable; the beds are more uniform in thickness and contain fewer sand and clay partings than the lower beds. The coal-forming material suffered little change while accumulating, for its woody texture is clearly visible. In luster and color the coal is more lignitic than that of the lower beds, and it is more liable to spontaneous combustion, as is shown by the prevalence of clinkers along the outcrop of the beds.

The number of coal or lignite beds visible in the badlands has naturally led to the conclusion that great quantities of coal are available in the immediate vicinity of Miles City, but although it is true that the quantity is great the percentage that can be mined economically is relatively small, and before any large area is purchased for mining purposes it should be thoroughly tested by drilling. In the upland

regions comparatively little coal is exposed in natural outcrop, but the beds present are more uniformly valuable and the areas which can be regarded as coal land are larger than in the badlands.

## EVIDENCE OF BURNED COAL.

In many places, especially in the areas underlain by the upper member, the thicker beds of lignite have burned along their outcrop, and the adjacent rocks, together with the clay and sand partings of the lignite beds, have been metamorphosed and hardened. The resulting rock has a general red color, though it ranges from only slightly altered shale and sandstone to black vesicular slag resembling lava, for which it has often been mistaken. The prevailing red color is doubtless due to the presence of iron, which has been partly reduced, so that these rocks interfere slightly with the working of the magnetic needle. Where the cover is great the extent of burning back from the outcrop is limited, and it can probably be safely assumed that the lignite is intact under a cover of 100 feet. There are, however, large areas fringed by outcrops of clinker in which the cover is thin and where the burning seems to have extended back for an indefinite distance. Many extensive mesas are capped with clinker under a slight cover of soil and in such places it is difficult to distinguish the unburned from the burned areas. The unburned lignite, where it outcrops on grassy slopes, is usually covered with soil and is hidden. Its presence is here and there revealed by the burrowings of prairie dogs or by the cutting of streams, but such evidences are rare. That much of the burning occurred as early as Pleistocene time is indicated by clinker pebbles in the bench gravels of some of the canyons, as well as by the extensive erosion and dissection of the clinker beds. The topography produced offers an important line of evidence as to the extent of the burning. Many of the unburned areas occur in rounded hills, which are fringed with clinker-covered benches and low ridges, separated from the unburned areas by shallow valleys, a few rods wide, due to erosion. Such valleys have clinkers on one side and grassy slopes on the other. There are many variations of this feature, which depend on the amount of erosion since the burning and the relation of the general drainage. Many of the streams flowing from the unburned areas across the clinker rim have in their upper parts wide valleys with grassy slopes, which contract to box canyons in crossing the burned portions. An example of this feature can be seen at the edge of the Pine Hills, 10 miles out from Miles City on the Ekalaka road. This road crosses a clinker rim through a narrow canyon which widens into a small valley above the rim, and the wash in the side of the road here reveals the blossom of unburned coal at the level of the clinker.

There are probably many such small areas of unburned coal in the Pine Hills country, and some of them may be of economic value but could not be differentiated in the field for lack of evidence as to their extent.

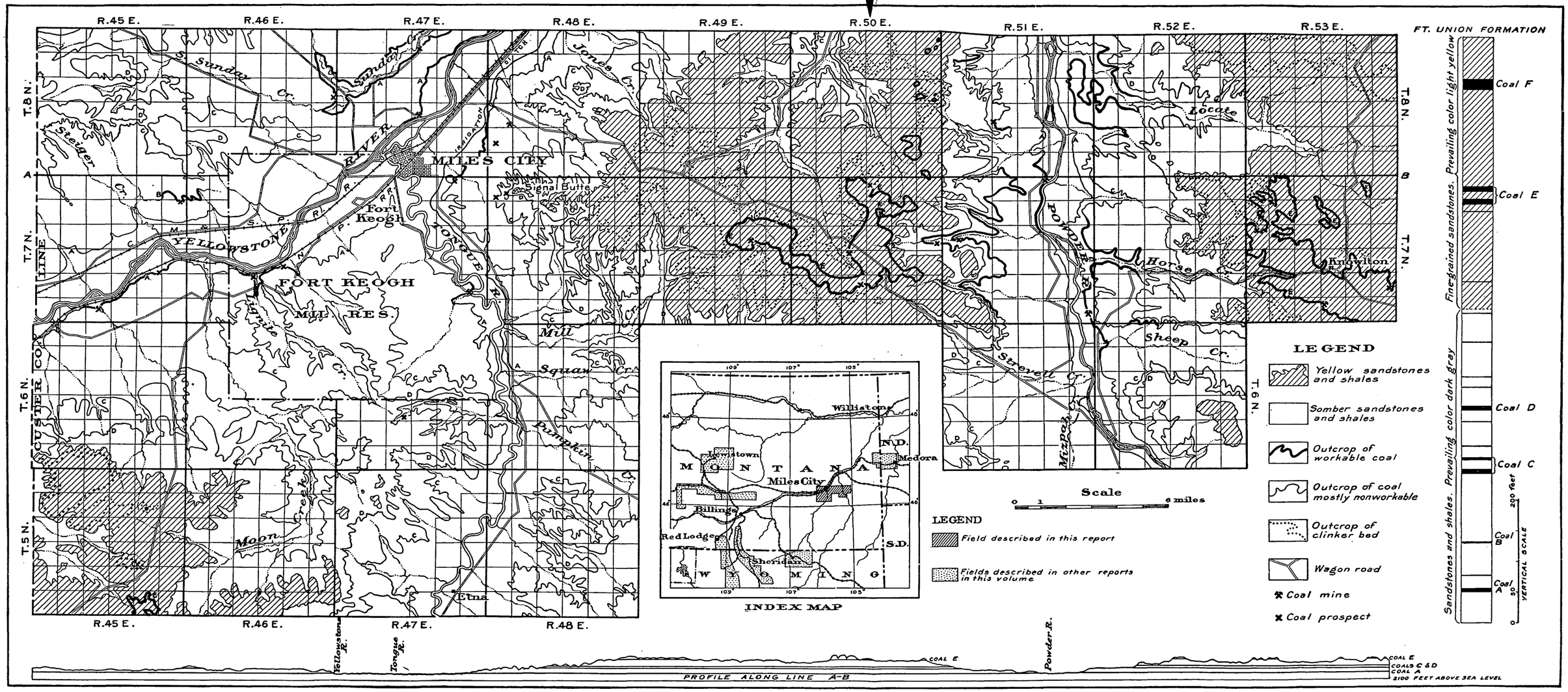
## EXPLANATION OF THE MAP.

On the accompanying map (Pl. III) the areas occupied by the lower and upper members are differentiated, the former being left blank and the latter ruled with parallel lines. The contact of these two members coincides with a contour line 2,850 feet above the sea, or 550 feet above the level of the Yellowstone. Owing to the intricate detail of topography this line is somewhat generalized. The outcrops of five of the more important coal beds designated by the letters A, C, D, E, and F are traced on the map and coincide with the contour lines at various levels indicated in the columnar section at the right. The stratigraphic relations are also shown in the profile at the bottom of the map. The character of the coal bed along the outcrop is indicated by the weight of the line. Wherever the coal bed has been found to be workable its outcrop is traced in a heavy line, and the detail is drawn with as great accuracy as possible, but where the bed is not known to be workable its outcrop is shown by a light line, which has been somewhat generalized. In the upper member the lignite in many places has been burned for an unknown distance back of the outcrop, and the limits of unburned and therefore workable lignite have been placed at a safe distance back of the outcrop indicated by clinkers. The edges or outcrops of the clinker due to the burning of the bed lettered E are shown by lines of dots, and a critical examination of the map will give an idea of the quantity of burned lignite in this bed as compared with that remaining in the district.

## COALS OF THE LOWER MEMBER.

### GENERAL OUTLINE.

The coals of the lower member are black and usually show little of the woody texture common to the lignite higher in the section. They are fairly brittle and have an even fracture. Joints and slips transverse to the bedding are not prominent, but such features have been observed in some of the mines and openings. When freshly mined the coal has a bright luster, but this is soon lost in the process of slacking, which begins as soon as the coal is exposed to the air. It is estimated that there is an average of at least one bed of coal or carbonaceous shale for every 50 feet of thickness in this part of the Fort Union formation, but less than 1 per cent of the coal exposed in outcrop is of workable thickness and purity, if no coal beds under




MAP OF THE MILES CITY COAL FIELD, MONTANA.

By A. J. Collier, C. D. Smith, and C. H. Wegemann.

3 feet thick or containing more than 20 per cent of ash are regarded as workable. Coal beds known to be locally workable occur at three rather definite horizons, which have been mapped and for convenience of reference have been given names. The lowest of these, marked A on the map, is called the Kircher bed, from a mine near Miles City. The second important bed, marked C on the map and called the Laney bed, is about 200 feet above the Kircher bed and 250 feet above Yellowstone River. The Weaver bed (D) occurs 100 feet above the Laney bed and has been mined locally in the badlands near Signal Butte. A fourth horizon, at which there is some workable coal, occurs 60 feet above the Kircher bed, but it is so small in extent that its outcrop has not been mapped except in one locality, which is marked B on Pl. III.

### KIRCHER COAL.

The position of the Kircher coal bed in the section and its line of outcrop are indicated on the map by the letter A. As it is situated near drainage levels, its croppings are usually covered by river gravel or wash from the hills, and it has been examined in only a few places. There are, however, sufficient exposures to indicate that the bed is exceedingly variable and workable only in small areas. This bed is well exposed in railroad cuts along the south bank of Yellowstone River, in the western part of the Fort Keogh Military Reservation, and between the boundary of the reservation and the western limit of the area examined. Some of these exposures show coal of workable thickness. The bed marked B on the map, 60 feet above the Kircher horizon, also attains workable thickness locally in the NW. ¼ sec. 25 and the SW. ¼ sec. 27, T. 7 N., R. 45 E., where it measures 3 feet and 3 feet 9 inches, respectively, without partings. Its line of outcrop so nearly coincides with that of the Kircher bed that it has not been mapped. The Kircher coal is workable for a few miles along its outcrop in T. 7 N., R. 45 E., where the following section was observed, but it is thin and unworkable on Moon Creek and for a mile east and west of its mouth:

*Section of Kircher coal bed in railway cut in the SE. ¼ sec. 33, T. 7 N., R. 45 E.*

| | Ft. | in. |
|---|---|---|
| Coal | 1 | 6 |
| Clay | | 2 |
| Coal | 1 | 8 |
| | 3 | 4 |

The same bed is thick enough to work in the banks of Lignite Creek and for several miles east of its mouth, on the Fort Keogh Military Reservation. It was formerly mined by the Northern Pacific Company at the head of Keogh Flat, but only one of the old openings

is in such condition that a section can be measured. The character of the bed here is shown by the following sections:

*Section of Kircher coal bed on Lignite Creek at county-road crossing, three-fourths mile south of Northern Pacific Railway, on Fort Keogh Military Reservation.*

| | Ft. | in. |
|---|---|---|
| Coal | 1 | 9 |
| Clay | | 1 |
| Coal | 1 | 6½ |
| Clay | | 4 |
| Coal | | 9¼ |
| Clay | | 2 |
| Coal | | 9 |
| Total coal | 4 | 9¾ |

*Section of Kircher coal bed at head of Keogh Flat.*

| | Ft. | in. |
|---|---|---|
| Coal | 1 | 2 |
| Clay | | 6 |
| Coal | 3 | 4 |
| Total coal | 4 | 6 |

Eastward from the head of Keogh Flat the outcrop of this bed follows the base of the hills to Tongue River, where it turns southward and follows up the west bank of the river for 6 or 7 miles. The coal shows a workable thickness at only one point in this stretch, viz, at what is called the Weaver mine, on the west bank of Tongue River, 5 miles south of Miles City, where it is 4 feet 4 inches thick, without partings, and has been opened by a number of short, temporary drifts, the product being hauled to Miles City in wagons. East of Tongue River the outcrop of this bed follows the base of the hills and practically coincides with the margin of the lowlands or river flat, but for several miles there is no evidence that the bed contains workable coal. It is of better quality, however, a short distance east of Miles City, and has been exploited by a number of small mines, only one of which is active at the present time. At the Kircher mine, in the SE. ¼ sec. 19, T. 8 N., R. 48 E., the bed is 60 feet below the surface and is reached by an incline. It averages 5 feet thick and has a 2-inch parting described as "grit" near the center. The floor is hard clay, which heaves when wet. The roof is also hard clay, and 8 inches to a foot of coal is usually left to support it. A section measured here is as follows:

*Section of coal bed at the Kircher mine, in sec. 19, T. 8 N., R. 48 E.*

| | Ft. | in. |
|---|---|---|
| Coal | 1 | |
| Shale | 6 | |
| Coal | | 4 |
| Shale | 2 | |
| Coal | 2 | 6 |
| Bone | | 1 |
| Coal | 2 | 6 |
| Total coal | 6 | 4 |

The mine is worked both winter and summer, and the product is hauled in wagons to Miles City, a distance of approximately 6 miles.

Northeast of the Kircher mine there are no exposures of this bed within the area examined, but it is reported that prospect holes have demonstrated that much of the coal is of no value. The same bed has been mined for many years north of Yellowstone River opposite Miles City, in sec. 22, T. 8 N., R. 47 E., at what was formerly known as the Comstock mine but is now called the Hedges mine. During the summer of 1907 a new opening was made on the coal bed from the river bank, and it is proposed to transport the coal from this opening across the river by means of a cable tramway. A section of the coal bed measured here is as follows:

*Section of the Kircher coal bed at the Hedges mine, in sec. 22, T. 8 N., R. 47 E.*

| | Ft. | in. |
|---|---|---|
| Coal | | 7¼ |
| Clay | | ¾ |
| Coal | 1 | 9½ |
| Clay | 1 | 9 |
| Coal | 1 | 6 |
| Total coal | 3 | 10¾ |

West of the Hedges mine the outcrop of the coal is traceable along the river bank for several miles, but within a short distance the bed is divided and contains partings, so that it does not show workable thickness. It has also been traced along the river bluffs northeastward from the Hedges mine, and in this direction also the parting increases in thickness until at the northern boundary of the area examined it is worthless for mining. What is regarded as the same bed outcrops along Sunday Creek, several miles north of the Hedges mine, where it has been worked by stripping at a number of places. The outcrop is about on a level with the creek, and there are few good exposures. A section measured near the forks of Sunday Creek showed about 5 feet of workable coal.

*Section of Kircher coal bed in sec. 13, T. 8 N., R. 46 E.*

| | Ft. | in. |
|---|---|---|
| Coal | 1 | 9 |
| Clay | | ¾ |
| Coal | 2 | 5 |
| Clay and bone | | 4 |
| Coal, base concealed | 1 | 1 |
| Total coal | 5 | 3 |

A section measured near the point where Sunday Creek crosses the northern boundary of the area examined showed a little over 4 feet of workable coal.

*Section of Kircher coal bed on Sunday Creek, near north line of T. 8 N., R. 46 E.*

| | Ft. | in. |
|---|---|---|
| Coal, bony | | 1 |
| Clay, blue | | 1½ |
| Coal, bony | | 2½ |
| Clay | | ½ |
| Coal | | 2 |
| Sand | | ½ |
| Coal | 2 | 2 |
| Shale, gray | 1 | |
| Coal | 1 | 9 |
| Total coal | 4 | 4½ |

Between Tongue and Powder rivers this bed is not exposed, and though it is no doubt workable in some places the areas in which it is of economic value can not be located without drilling. In the greater part of this district its depth is less than 600 feet, and it is nowhere more than 900 feet below the surface. It outcrops in workable thickness in the left bank of Powder River in sec. 2, T. 7 N., R. 51 E., where it is mined to supply fuel for a small irrigation plant. The section of the bed is as follows:

*Section of Kircher coal bed in sec. 2, T. 7 N., R. 51 E.*

| | Ft. | in. |
|---|---|---|
| Coal | 1 | 11 |
| Bone parting | | ¾ |
| Coal | 1 | 10 |
| Total coal | 3 | 9 |

The bed is exposed at intervals along the river bank for about 2 miles to the south, where it is probably workable but somewhat thinner than at the mine. North of the mine it is concealed for a considerable distance, but an exposure in sec. 23 in the same township shows less than 1 foot of coal. A bed which is of workable thickness locally has produced some coal from a short drift on Brown's ranch, in sec. 36, T. 7 N., R. 51 E., and has been traced for several miles along the bluffs. This bed is 10 to 20 feet above Powder River, and should possibly be correlated with the B coal bed, which lies about 60 feet above the Kircher bed. It contains over 3 feet of coal at Brown's ranch, as shown by the following section:

*Section of coal bed on Brown's ranch, sec. 36, T. 7 N., R. 51 E.*

| | Ft. | in. |
|---|---|---|
| Coal | 2 | 10 |
| Shale | | 1 |
| Coal | | 8 |
| Total coal | 3 | 6 |

At the mouth of Horse Creek, 1½ miles north of Brown's ranch, the bed is divided and of no value. It is of sufficient thickness for

mining at the mouth of Sheep Creek, in sec. 1, T. 6 N., R. 51 E., but is not over 1 foot thick in the river bluff at the county bridge in sec. 30, T. 6 N., R. 52 E.

### LANEY COAL.

A second zone in which there is a large quantity of coal that is workable in some places but generally too impure for mining lies from 160 to 200 feet above the Kircher bed and is marked C on the map and section (Pl. III). This zone is not a single bed, but usually is made up of two or more beds within a range of 50 feet vertically. As a rule the coals contain a great number of thin sandy-clay and bone partings. The largest bed is 10 feet thick in many places, but the utter impossibility of separating the thin partings from the coal unfits it for mining.

These beds have been opened at many places near Miles City, but operations have been discontinued on account of the impurities in the coal. They are also exposed on Cottonwood Creek, midway between Tongue and Powder rivers, where the thickest bed has been mined for local supply. The coal is generally of better quality, however, along Powder River, where it shows to the best advantage near Laney's ranch, from which it takes its name.

North of Yellowstone River, in the northwest corner of the field, these coals are extremely variable in thickness and always dirty, and in no place seen do they appear to be workable.

In the area west of Tongue River and south of the Yellowstone they are also extremely variable in thickness and purity, and appear as a conspicuous dark zone in the badlands of the Fort Keogh Military Reservation. In the western part of the reservation and between the reservation and the boundary of the area here mapped, the croppings of the beds are almost completely concealed by bench gravel, but on the divides east and west of Lignite Creek and thence eastward to the breaks of Tongue River their outcrops are almost continuously exposed in the bare bluffs of the badlands. The section given below shows the character of the beds:

*Section of the Laney coal bed in the southeast corner of Fort Keogh Military Reservation.*

| | Ft. | in. |
|---|---|---|
| Coal | 2 | |
| Clay and coal | 3 | 6 |
| Coal | 2 | 6 |
| Sandstone | 10 | |
| Coal | | 6 |
| Sandstone | 15 | |
| Coal | | 2 |
| Clay | 15 | |
| Coal, dirty | 2 | 6 |
| Clay | 3 | |
| Coal, dirty | 3 | 4 |
| Total coal | 11 | |

The uppermost coal bed in the above section becomes locally thicker and may be workable in places in T. 6 N., R. 47 E. A section follows:

*Section of Laney coal bed in the SE. ¼ sec. 22, T. 6 N., R. 47 E.*

| | Ft. | in. |
|---|---|---|
| Coal | | 8 |
| Bone | | 1 |
| Coal | 1 | 2 |
| Bone and dirt | | 8 |
| Coal | 2 | |
| Clay | 1 | |
| Coal | 1 | |
| Bone | | 7 |
| Coal | 1 | 6 |
| Total coal | 6 | 4 |

Southward from this locality the coal outcrops at many places, but is everywhere divided by thin clay partings which render it unworkable.

One of the beds is locally workable in the divides between Mill, Squaw, and Pumpkin creeks, in T. 6 N., R. 48 E., where it contains 3 feet 4 inches of workable coal near the northwest corner of sec. 25 and 4 feet near the east quarter corner of sec. 12. These measurements are exceptional, however, as many other exposures of the bed in the same vicinity show numerous clay partings in the coal. Some of the beds are probably also workable in a few places in T. 5 N., R. 48 E., but the presence of characteristic thin clay partings renders most of the coal unfit for mining.

Many attempts to work these coals have been made in Tps. 7 and 8 N., R. 48 E., but all the openings have been abandoned on account of the impurities in the coal. The following section of the beds at this horizon was measured near Signal Butte, in sec. 6, T. 7 N., R. 48 E.:

*Section of Laney coal beds near Signal Butte.*

| | Ft. | in. |
|---|---|---|
| Coal | 1 | 6 |
| Shale, light gray | 9 | |
| Limestone, weathering red | | 2 |
| Shale | | 3 |
| Coal | | 3 |
| Shale, blue | 8 | |
| Coal with three small streaks of bone | 3 | 4 |
| Sandstone | 6 | |
| Shale | 4 | |
| Sandstone | 2 | 6 |
| Shale | 3 | |
| Coal | | 7 |
| Shale | | 6 |
| Coal, dirty, with white partings, 6 inches to 1 foot thick | 4 | 5 |
| Total coal | 10 | 1 |

Some coal has probably been produced from the large bed at the base of this section, but the numerous thin bony layers are so uniformly distributed as to render it of little value. No sample of the coal was taken for analysis, but it was estimated in the field that the ash surely exceeds 25 per cent. In view of the quantity of better coal in other beds near at hand, it is hardly possible that this bed can ever be mined at a profit. The 3-foot bed which lies about 15 feet higher in the section has also been developed, but was abandoned on account of the bad roof and the impurities of the coal. Three miles southeast of Signal Butte, near the center of this township, the two upper beds of the section come nearly together, and the combined bed thus formed is probably barely of workable thickness.

The exposures of coal at the Laney horizon along Cottonwood Creek in T. 8 N., Rs. 49 and 50 E., show similar conditions. The thickest bed has been worked for local supply from cut banks of Cottonwood Creek, where it is 10 feet thick but contains many thin partings that can not be separated from the coal.

The Laney coal is generally of better quality where exposed in the bluffs and badlands of the Powder River valley, and the areas regarded as workable are indicated on the map (Pl. III). It is burned along the outcrop at many places in this district, producing a heavy clinker bed.

The coal is of workable thickness for several miles along the outcrop in T. 7 N., R. 51 E., west of the Laney ranch, where it shows to the best advantage, and an exposure in sec. 21, T. 7 N., R. 51 E., indicates approximately 15 feet of good coal.

*Section of Laney coal bed in sec. 21, T. 7 N., R. 51 E.*

| | Ft. | in. |
|---|---|---|
| Coal | 3 | 6 |
| Shale, carbonaceous | 2 | |
| Coal | 8 | 3 |
| Shale | | 9 |
| Coal | | 6 |
| Shale | 1 | |
| Coal | 1 | |
| Shale | | 2 |
| Coal | 2 | |
| Shale | | 3 |
| Coal | 2 | |
| Total coal | 17 | 3 |

The quantity of coal decreases north and south of this locality, and within a few miles in either direction the bed is too poor to be of value. East of Powder River the Laney bed is exposed in workable thickness at several places below the gravel of an extensive terrace 250 feet above the river. In general the exposures are poor, and it is possible that there may be more coal here than the map indicates.

Five feet of coal in one bench shows in sec. 13, T. 8 N., R. 51 E., and scattered exposures of part of the bed indicate that it is valuable as far as mapped. A bench containing 3 to 4 feet of coal is exposed at intervals for several miles in the east side of T. 7 N., R. 51 E., but the exposures are poor and no complete section of the bed can be given.

### WEAVER COAL.

At an elevation of about 100 feet above the Laney coal, or 350 feet above Yellowstone River at Miles City, a group of coal beds occur to which the name Weaver has been given. One of the beds of this group has been mined at the base of Signal Butte by Mr. Weaver, of Miles City. In distribution this bed conforms roughly to the Laney coal bed, but as it is higher in the section it underlies less territory.

In the northwest corner of the district, north of Yellowstone River, this coal bed is confined to the area south of South Sunday Creek, almost all of it occurring in T. 8 N., R. 45 E. The bed is usually divided into two benches and is filled with small partings, which spoil it for mining. In the area south of the Yellowstone and west of Tongue River it is also poor. Some sections follow:

*Section, including Weaver coal bed, in south-central part of Fort Keogh Military Reservation.*

| | Ft. | in. |
|---|---|---|
| Coal and clay in equal parts | 6 | |
| Clay | 30 | |
| Coal | | 6 |
| Clay, carbonaceous | 3 | 6 |
| Clay, sandy | 7 | |
| Coal, dirty | 2 | 10 |
| Total coal | 9 | 4 |

*Section of the Weaver coal bed in the southwest corner of T. 5 N., R. 47 E.*

| | Ft. | in. |
|---|---|---|
| Coal, dirty | 2 | 6 |
| Clay, sandy | 4 | 6 |
| Coal, dirty | 2 | |
| Total coal | 4 | 6 |

In Tps. 5 and 6 N., R. 48 E., this bed has a meager distribution, but is rendered worthless by partings.

At the old Weaver mine near Signal Butte, sec. 6, T. 7 N., R. 48 E., the bed contains 4 feet of coal, but is divided into several benches, and the coal, as shown by analyses, is very impure. The section is as follows:

*Section of coal bed at Weaver mine near Signal Butte, sec. 6, T. 7 N., R. 48 E.*

| | Ft. | in. |
|---|---|---|
| Clay, brown, carbonaceous | | 10 |
| Coal | 2 | 2 |
| Clay | | 1 |
| Coal | | 2 |
| Clay | | 3 |
| Coal | 1 | 5 |
| Clay, carbonaceous | | 4 |
| Coal | 1 | 2 |
| Clay. | | |
| Total coal | 4 | 11 |

Only the two upper benches are mined.

North of Signal Butte the Tongue River badlands contain no exposures of this bed that indicate a workable thickness.

On Cottonwood Creek, in T. 8 N., Rs. 49 and 50 E., a bed at this horizon was traced for many miles, but nowhere shows a thickness exceeding 2 feet 8 inches. The coal, however, appears to be of good quality and will doubtless be mined to some extent for local supply. West of Powder River, near the head of Laney Creek, in T. 7 N., Rs. 50 and 51 E., a bed at or near this horizon overlies the Laney coal and is regarded as workable for several miles along its outcrop, where it contains approximately 3 feet of coal without partings. East of Powder River no exposures of this bed were seen in which the coal could be regarded as workable.

## LIGNITES OF THE UPPER MEMBER.

### GENERAL OUTLINE.

The lignites of the upper beds are dark brown in color, usually tough and woody in texture, but relatively uniform in distribution and purity. In these respects they differ considerably from the black, nearly textureless coals, already described. Valuable beds are found generally at two horizons, the lower of which is 160 feet above the base of the upper member; the upper about 300 feet above the base. These horizons are indicated on the map and section (Pl. III) by the letters E and F. In the field their outcrops are indicated by clinkers, and there are large areas in which the lignite has been wholly destroyed by fire.

In addition to these more important lignite horizons there are many thin beds, one of which, about 70 feet above the base of the member, is thick enough to work in at least two places. It measures slightly over 3 feet in sec. 28, T. 7 N., R. 49 E., and 4 feet at the Hill ranch, in sec. 27, T. 8 N., R. 50 E. These occurrences are regarded as local, however, as no lignite beds thicker than 1 foot have been discovered elsewhere at or near this horizon.

### DOMINY LIGNITE GROUP.

The most important lignite in this field is that marked E on the map. It has been mined for local supply near Dominy's ranch, and is referred to as the Dominy lignite. It consists of a group of lignite beds having a vertical range of about 30 feet, some or all of which are workable wherever they have not been destroyed by burning.

Some idea of the former extent of this lignite group can be obtained from the distribution of the baked and fused material caused by its burning, from which it is inferred that lignite beds of this group formerly covered the whole area here described. The outcrop of these beds, except in a few places, is completely concealed by a fringe of clinker and baked material, which reaches in many localities a thickness of 100 feet. The areas in which this group of beds has not been destroyed are relatively small and many of them are difficult to locate.

Between Tongue and Powder rivers a comparatively large area in T. 7 N., Rs. 49 and 50 E., has been outlined, as shown on the map (Pl. III). The average thickness of workable lignite in this area is thought not to be less than 10 feet. In sec. 14, T. 7 N., R. 49 E., it measures 15 feet, and in sec. 28, T. 7 N., R. 50 E., 3 feet. Another section is given below:

*Section of Dominy lignite group in sec. 3, T. 7 N., R. 50 E.*

| | Ft. | in. |
|---|---|---|
| Lignite | 7 | |
| Shale, sandy | 13 | |
| Lignite | 3 | 6 |
| Shale, sandy | | 8 |
| Lignite | 5 | |
| Total lignite | 15 | 6 |

The lowest bench of this section is represented by sample No. 5962 of the table of analyses (p. 57).

East of Powder River the known areas of the Dominy lignite, as shown by the map, are confined to T. 7 N., R. 53 E., near the town of Knowlton. Several sections of the beds were measured here.

*Section of Dominy lignite bed in sec. 33, T. 7 N., R. 53 E.*

| | Ft. | in. |
|---|---|---|
| Lignite, dirty | | 6 |
| Lignite, good | 1 | 2 |
| Bone | | 4 |
| Lignite | 2 | |
| Parting, sandy | | 1 |
| Lignite | 1 | 10 |
| Total lignite | 5 | 6 |

In sec. 7, T. 7 N., R. 53 E., 4 feet of lignite are exposed with both top and bottom concealed.

*Section of Dominy lignite bed in sec. 18, T. 7 N., R. 53 E.*

| | Ft. | in. |
|---|---|---|
| Lignite | | 8 |
| Bone | | 8 |
| Lignite | 3 | 3 |
| Sand | | 3 |
| Lignite. | | |
| Bottom of section concealed. | | |
| Total lignite | 3 | 11 |

F LIGNITE.

The highest bed in the field, marked F on the map and section, has been so generally destroyed by fire as to be of little economic value. The only place where it was found in an unburned condition is in sec. 10 T. 7 N., R. 50 E. The bed evidently contains several feet of workable lignite, but its full thickness was not exposed. The total area of land containing the bed in workable condition does not exceed 5 or 6 acres.

## QUANTITY OF AVAILABLE COAL.

In addition to the five coal beds whose outcrops have been mapped, there are many others that show in the badland bluffs of this field, but only a relatively small proportion of the coal exposed is of workable thickness and quality. The valuable coal lands are confined to small areas whose boundaries can not be determined closely without thorough prospecting. The writers have estimated the total quantity of workable coal in the areas classified as coal land at 780,080,000 tons, which is approximately equal to the tonnage of a bed 0.68 foot thick covering the whole field, but owing to the extreme variability of the coal beds the limit of error in this estimate is necessarily high. The figures given above are conservative and represent the coal which actually outcrops in workable thickness and quality. On taking into consideration the general distribution of the small areas of workable coal and its probable occurrence in other areas where there are no natural exposures, it is reasonable to assume that the total quantity of coal that may be developed by prospecting will be considerably more than the above estimate.

## CHARACTER OF THE COAL.

### PHYSICAL PROPERTIES.

The coals of the upper member in this field are brownish in color and those of the lower member are nearly black, but all give a brown streak when cut or scratched and make a brown powder when crushed. The weathered outcrop or blossom of the coals of either type is black. In general the upper lignites retain their original

woody texture and are tough; the lower coals have more the texture of higher-grade coals, though nearly all the beds contain some woody material. Joints have been observed in all the beds wherever they are well exposed. The joint planes are invariably wide apart, but are of considerable importance in mining, and for blasting the holes are usually bored parallel to them. The lumps of coal produced are generally of irregular shape. They begin to crackle and lose moisture immediately after mining and finally slack to fine flaky powder under atmospheric influences.

In burning the coals decrepitate rapidly, and if disturbed the fire is easily smothered. To obtain the greatest efficiency, the coal must be spread thinly over wide grates. It burns with a long, yellow flame, but does not produce much smoke.

### CHEMICAL PROPERTIES.

All the samples of this coal which have been analyzed contain more than 29 per cent of moisture as they come from the mine, and after air drying they still retain from 10 to 18 per cent. The coals from the upper member usually contain from 8 to 10 per cent of ash and are apparently more impure than those from the lower member. The relative proportion of fixed carbon in the coal from the former is higher than in that from the latter. The fuel ratios (percentage of fixed carbon divided by percentage of volatile matter) of the lower coals average 1.20; those of the lignites higher in the section are considerably less. In efficiency the lower coals are greater than the higher lignites. From their obvious physical and chemical properties the former are classed as subbituminous and the latter as lignite.

Owing to the primitive nature of the developments in this field, only seven representative samples of unweathered coal were obtained for chemical analysis. These were collected from mines according to the method prescribed by the United States Geological Survey fuel-testing plant, as noted on pages 12–13.

Sample No. 5962 was collected near the outcrop where the lignite showed some indications of weathering. All the other samples represent unweathered coal. The samples collected last summer were not analyzed until several months after they were obtained, but all of them were sealed in air-tight cans. Before analyzing they were reduced to a uniform basis by exposing them to dry air, and the loss of moisture on air drying was determined. The analyses of the samples both as received and after air drying are given, but for purposes of comparison the analysis of the air-dried sample is preferable, as it represents more nearly the condition in which the coal would reach the consumer.

*Proximate analyses and calorific determinations of coals and lignites from the Miles City field, Montana.*

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

| Character of coal | Subbituminous. | | | | | | Lignite. |
|---|---|---|---|---|---|---|---|
| Name of bed | Kircher (A). | | | | | Weaver (C). | Dominy (D). |
| Location | Sec. 25, T. 7 N., R. 47 E. | Sec. 22, T. 8 N., R. 47 E. | Sec. 19, T. 8 N., R. 48 E. | | Sec. 2, T. 7 N., R. 51 E. | Sec. 6, T. 7 N., R. 48 E. | Sec. 3, T. 7 N., R. 50 E. |
| Laboratory No | 5780 | 783 | 5694 | [a]2425 | 5963 | [a]3701 | 5962 |
| Sample as received: | | | | | | | |
| Moisture | 29.52 | 29.21 | 29.60 | 30.25 | 31.75 | 29.13 | 35.51 |
| Volatile matter | 27.96 | 26.15 | 27.40 | 30.48 | 25.49 | 25.33 | 26.75 |
| Fixed carbon | 33.84 | 35.45 | 32.97 | 31.34 | 33.31 | 30.51 | 28.87 |
| Ash | 8.68 | 9.19 | 10.03 | 7.93 | 9.45 | 15.03 | 8.87 |
| Sulphur | .70 | .75 | .68 | .60 | .70 | .55 | .40 |
| Calories | 4,286 | 4,260 | 4,156 | ..... | 4,078 | 3,701 | 3,535 |
| British thermal units | 7,715 | 7,668 | 7,481 | ..... | 7,341 | 6,662 | 6,363 |
| Loss of moisture on air drying | 14.00 | 15.40 | 18.10 | 21.90 | 20.00 | 16.50 | 22.90 |
| Air-dried sample: | | | | | | | |
| Moisture | 18.05 | 16.32 | 14.04 | 10.69 | 14.69 | 15.12 | 16.36 |
| Volatile matter | 32.51 | 30.91 | 33.46 | 39.03 | 31.86 | 30.34 | 34.70 |
| Fixed carbon | 39.35 | 41.91 | 40.26 | 40.13 | 41.64 | 36.54 | 37.44 |
| Ash | 10.09 | 10.86 | 12.24 | 10.15 | 11.81 | 18.00 | 11.50 |
| Sulphur | .81 | .89 | .83 | .77 | .88 | .66 | .52 |
| Calories | 4,984 | 5,035 | 5,075 | ..... | 5,097 | 4,432 | 4,585 |
| British thermal units | 8,971 | 9,064 | 9,134 | ..... | 9,176 | 7,978 | 8,253 |

[a] Sampled in 1906 by A. G. Leonard, Bull. U. S. Geol. Survey No. 316, 1907, p. 205.

Only one sample, No. 3701 of the above table, has been tested by ultimate analysis. Its chemical composition after air drying is as follows:

*Ultimate analysis of air-dried sample from Weaver bed, Signal Butte.*

| | |
|---|---|
| Ash | 18.00 |
| Sulphur | .66 |
| Hydrogen | 4.51 |
| Carbon | 48.01 |
| Nitrogen | .65 |
| Oxygen | 28.17 |

## STEAMING PROPERTIES.

The engineers of the electric-lighting plant and the pumping station of the waterworks at Miles City report that clinkers are apt to form when these coals are burned with forced draft. If plenty of time is given, however, the results are satisfactory, but for this purpose larger furnaces are required than for coals of higher grade. The electric-lighting plant is equipped with two 150-horsepower boilers and common shaker grates without blast. The fire is never allowed to go out, and 4 to 5 tons of coal are consumed in twenty-four hours. Two tons of clean coal from Red Lodge are reported to be equal in efficiency to 3 tons of the local coal, but dirty coal containing much slack, which is sometimes shipped from Red Lodge, is no better than the average Miles City coal.

No samples of Miles City coal have been tested under boilers or with the gas engine by the United States Geological Survey, but such tests of two samples from the Bridger bed in the Red Lodge field, with which these coals are compared by Miles City engineers, are described on pages 174 to 177 of Survey Bulletin No. 332, and a gas-producer test of lignite from Williston, N. Dak., which resembles that from the upper member near Miles City, is described in Bulletin No. 261, page 105. These tests indicate that with the Bridger coal 5.04 pounds as fired are consumed per electric horsepower hour under boilers and 1.80 to 2.34 pounds by the gas producer and gas engine. With the Williston lignite 3.67 pounds as fired are consumed per electric horsepower hour by the gas producer.

## DEVELOPMENT.

One of the first attempts to develop the coals of this field was made by the Northern Pacific Company soon after the completion of the railroad, the point selected being near the edge of the right of way at the head of Keogh Flat, 6 or 7 miles above Miles City, where the company located a small mining village called Lignite. Operations here have been suspended for several years, the buildings having been moved away and the openings abandoned. The coal obtained was not suitable for use in locomotives.

At about the same time the Comstock mine, north of Yellowstone River, opposite Miles City, was opened and has been operated unsystematically from year to year. None of the development has been of a permanent character and most of the old drifts have caved in, though it is probable that several thousand tons of coal have been mined here and hauled to Miles City by a roundabout road crossing the river 2 miles above.

The many old openings on coal beds near Signal Butte indicate rather extensive but unsystematic mining there for many years, though in the summer of 1907 all the openings seemed to be abandoned. Similar conditions are to be observed on the left bank of Tongue River, 5 miles above town. In addition to these localities there are many country banks scattered over the field from which ranchmen obtain fuel for domestic use, the prevalent methods of mining such deposits being either by stripping or by undermining the coal in the cut banks of streams.

The Kircher mine, 6 miles northeast of Miles City, is on a somewhat more extensive scale. The coal bed here is 63 feet below the surface and is reached by a slope. The mine is worked by the room and pillar system, the mining being done by shooting off the solid with small charges of powder. Mine cars are pushed by hand to the foot of the slope, up which they are drawn by cable from a horse whim. Ventilation is accomplished by a fire box and mine water is pumped

out by a windmill. During the summer of 1907 five men were employed and the product of the mine was hauled in wagons to Miles City, where most of it was delivered to the electric-light company and steam laundry for $2.50 and $2.60 per ton.

Preparations were being made in 1907 for more elaborate operations at the Hedges mine, near the site of the old Comstock mine. The bed, which outcrops about 50 feet above the river, is opened by an incline in order to raise the coal to such an elevation that it can be sent across the river on a cable tramway. When visited late in July the deeper workings of the mine were reported to be filled with carbon dioxide and were not accessible. In this connection it may be noted that explosive gases have not yet been encountered in any of the mines of this field and that safety lamps have not been required at any place.

## CONDITION OF THE MARKET.

The coal mined near Miles City competes in the local market with that shipped in from other regions, and more especially with that from Red Lodge, Mont. It commands a lower price than the Red Lodge coal, but during the winter of 1906–7 the supply of the latter was cut off for lack of transportation, and the demand for Miles City coal greatly increased. With the increase of population which the agricultural possibilities of this field warrant, the demand for and use of these fuels near at hand will certainly be very much greater than it is now. Recent experiments have demonstrated that coals of this grade, when converted into producer gas and used in an internal-combustion gas engine, have an efficiency not less than that of the best bituminous coals under steam boilers. None of the Miles City coal has been tested in this way, but should power plants of this kind be successfully installed here the possibilities of usefulness and the value of these coals would be increased many times, and some of the beds now regarded as too impure for mining could probably be worked at a profit.

# THE BULL MOUNTAIN COAL FIELD, MONTANA.[a]

By L. H. Woolsey.

## INTRODUCTION.

The preliminary report on the coals of a portion of the Bull Mountain field, Montana, here presented, is based on a detailed survey made during the summer of 1907 by R. W. Richards, H. Bancroft, and the writer. The progress of the work was materially aided by the assistance and hospitality of the residents and of various companies interested in the field, for which acknowledgment can be made only in this general way.

The investigation was undertaken for the purpose of classifying by legal subdivisions of 40-acre tracts the public lands as coal land or noncoal land. The area covered in this manner comprises a strip of country approximately two townships wide, bordering the south side of Musselshell River and extending from the vicinity of Shawmut, Meagher County, to the Bull Mountains. The western and larger part of this area, or that lying roughly between Shawmut and Golden Creek, probably contains no coal of commercial importance. Two thin coal beds were found in the Eagle sandstone near Crawford's coal bank, on Fish Creek, near Cavill's ranch, and elsewhere, but they average only 23 inches in thickness, including a parting of shale 7 to 12 inches thick. The Judith River formation also contains a few thin beds of coal, ranging from 6 to 32 inches, but the beds are commonly lenticular or split by thin partings of shale. No coal beds are known to occur between this formation and the Eagle, above described, and between the former and the coal beds of the Fort Union formation in Bull Mountain no coals of value were observed. Thus, in the hilly country between the lower course of Painted Robe Creek and Golden Creek indications of coal were observed at only five or six horizons, and these beds carried 12 inches or less of coal or coaly shale.

The western part of the country surveyed may therefore be disregarded in a discussion of commercial coal fields. On the other hand,

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

the eastern part, lying roughly east of Golden Creek and including the Bull Mountains, contains a large quantity of coal of commercial value. This area is known as the Bull Mountain coal field, and the purpose of the present paper is to set forth briefly the information gathered in this field.

The first examination of any detail in the Bull Mountain coal field was made by the geologists of the Transcontinental Survey about 1881. At that time Waldemar Lindgren and the late George H. Eldridge examined the stratigraphy and coal beds of this general region, and the results of their studies are briefly given in the Report of the Tenth Census of the United States.[a] Two pages illustrated by columnar and cross sections are devoted to a description of the rocks and a discussion of the stratigraphy of the Bull Mountains and surrounding country. Though the authors group all the rocks in the "Laramie series," they describe them in units that correspond fairly well with the Fort Union "somber beds" and Laramie, which were traced and mapped during the last season as separate formations. The coals, which they call black lignites and which are "in every way much superior to the lignites farther east," are described in two pages dealing almost entirely with the Mammoth coal bed. Two plates of sections and 57 proximate analyses of this coal are given. The description of the coal is good, considering its brevity; it brings out carefully the essential facts concerning the extent, character, and thickness of the coal, as well as its general physical appearance. The sections of the Mammoth coal bed are given in detail, but, unfortunately, the locations of many of the sections are too brief for identification. Wherever identification was possible, however, the measurements checked well with those made by the Geological Survey party. The analyses give no calorific determinations, but in other respects they compare very favorably with the analyses given in the present paper. On the whole, therefore, in view of the difficulties under which this early work was carried on, owing to the rough, unsettled condition of the western country at that time, the work seems to have been carefully done, and the report, so far as it goes, may be regarded as generally reliable, except in the identification of the formations. This judgment, however, is based on a study of only about one-fourth of the Bull Mountain field examined by the geologists of the Transcontinental Survey.

## LOCATION AND EXTENT.

Practically all of the Bull Mountain coal field lies south of Musselshell River, which is roughly its northern boundary, and it extends southward, including Bull Mountains. Its length from north to

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

south is nearly 25 miles and from east to west 35 or 40 miles, its area being about 750 square miles. The rocks in which the coal beds occur extend as far west as Dean Creek, but the coals thin out in that direction, and hence the area underlain by workable coal beds may be regarded as bounded on the west by the divide between Golden and Wildhorse creeks. The area treated in this report covers about 140 square miles in the southwestern portion of the field, including Tps. 5 and 6 N., Rs. 26 and 27 E., with parts of bordering townships. (See Pl. IV.)

## TOPOGRAPHY.

The topography of this field is peculiar and distinct from that of the surrounding country. The divide between Musselshell and Yellowstone rivers extends through the Bull Mountains with a general north of east trend. Prominently rising above the general level of this divide stands an isolated group of flat-topped mesas whose blue bluffs and reddened caps are conspicuous features of the landscape; these are the Bull Mountains proper. To the north and to the south intermittent streams have carved radiating valleys that are canyon-like and sparsely tree clad. North of the mountains the rough country extends to Musselshell River, but on the south it shortly breaks into rolling hills, which extend to the Yellowstone. The mesas of the Bull Mountains consist of arborescent flat-topped ridges whose general axis has a west of north direction. There are three main ridges or mesas, with a few bordering buttes. The southernmost mesa has an extent of nearly 4 miles north and south and about 2 miles east and west. The two irregular mesas which make up the northern part of the mountains have general dimensions of 3 miles from north to south and a similar distance from east to west. These mesas rise from 600 to 700 feet above the surrounding country and attain an altitude of about 4,700 feet above the sea. The effect of the topography on the accessibility of the coals is discussed under "Development," page 75.

## GEOLOGY.

Throughout the Bull Mountain field coal of value occurs chiefly in the Fort Union formation. These rocks form the Bull Mountains and the surrounding country for a distance of 6 to 12 miles in three directions—that is, to Musselshell River on the north, Dean Creek on the west, and T. 5 N., inclusive, on the south. Their extent toward the east is not yet known, as that part of the field was not surveyed during the last season. In these rocks coal beds are most numerous in the upper part, that is, in the Bull Mountain mesas, where they occur at intervals of 50 feet or less; in the lower part the intervals are 100 feet or more.

## LEGEND

- Coals probably over 5 feet in thickness
- Coals probably 3 to 5 feet in thickness
- Coals probably 2 to 3 feet in thickness
- Coals probably under 2 feet in thickness
- Coals of doubtful thickness
- Main road
- Seconoary road
- Corner found
- 10° Dip and strike
- Drift

W F Strait

F A Rehder

Buckey

Dorrity Cr.

Halfbreed Cr.

Fattig Cr.

West Razor Cr.

Razor Cr.

East Razor Cr.

N P COAL MINE

R 25 E

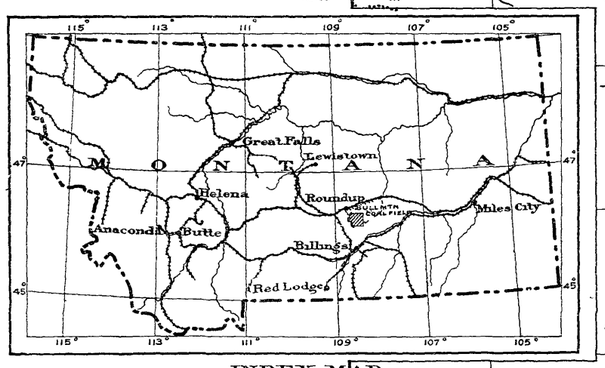
R 26 E

R 27 E

T 6 N

T 5 N

T 7 N



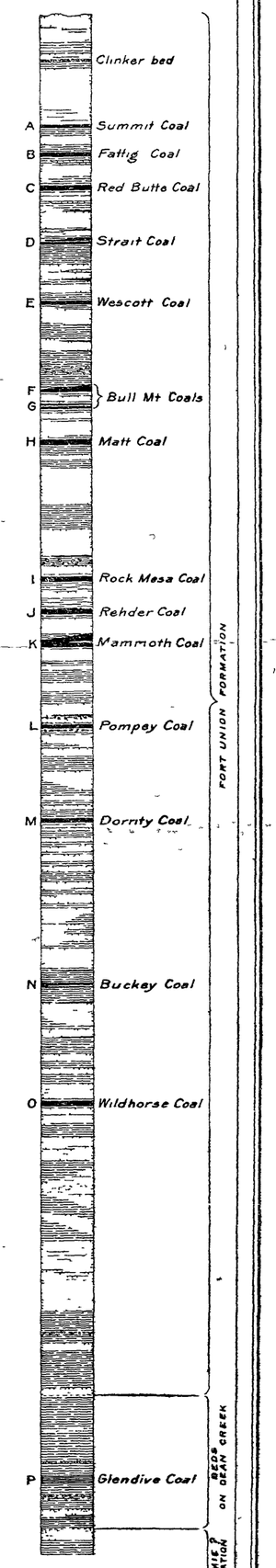

INDEX MAP

NOTE.—THE TRIANGULATION IN T 6 N, R 27 E, AND SOME TOPOGRAPHY NEAR THE MAMMOTH COAL ARE ADJUSTED TO THE SURVEYS MADE BY THE NORTHWESTERN IMPROVEMENT COMPANY IN 1906

THE SUBDIVISION OF T 7 N. R 27 E. HAS NOT BEEN ACCEPTED BY THE GENERAL LAND OFFICE, APRIL, 1908

Scale

1 ½ 0 1 2 3 miles




VERTICAL SCALE OF COLUMNAR SECTION
1/8 INCH = 20 FEET

MAP OF THE SOUTHWESTERN PART OF THE BULL MOUNTAIN COAL FIELD MONTANA

By L H Woolsey and R W Richards

In this locality the Fort Union formation presents a thickness of 1,400 feet, but this probably does not represent the whole formation, a portion having been removed by erosion, for it reaches a thickness of several thousand feet in neighboring localities, such as the Bighorn Basin on the south. It is composed chiefly of gray to buff sandstone alternating with gray shale. The sandstone, though extremely variable, is commonly massive and evenly distributed throughout the section. The base of the formation is strongly marked by contrast with a band of olive-green clay shale, which belongs to the next lower formation. This shale is well exposed along the Billings-Roundup road, 2 or 3 miles south of Buckey post-office, and may be traced westward across the various branches of Razor Creek, through Fratt's ranch, and down Dean Creek to Musselshell River. Some of the best exposures are found on the east side of Dean Creek, and the same greenish shale may be seen a short distance north of the river at Roundup. In a general way this shale outlines the extent of the rocks bearing important coal beds, though it must not be supposed that everywhere the Fort Union formation contains coal beds of workable dimensions.

A general section of the Fort Union rocks and the underlying olive-green shale given on Pl. IV shows the proportions of sandstone and shale and the relative positions of the various coal beds.

The geologic structure of this region is simple. In general, the rocks lie flat. Careful observations, however, disclose a slight and consistent dip of 1° to 3° in a northeasterly direction on the southwest margin of the field, but this dip flattens toward the mountains and turns northward at their eastern extremity. On the northeast side of the mountains near the head of Fattig Creek, the rocks dip slightly toward the southwest, and near Roundup the dip in this direction is very pronounced. Thus the structure of the field so far as surveyed suggests a gentle syncline plunging slightly toward the northwest.

## COAL.

### GENERAL STATEMENT.

All the coals in the Bull Mountain field, so far as studied, may be classed as a good grade of subbituminous[a] coal ("black lignite"). Most of the coal beds are lenticular in shape, showing a wide variation in thickness at different points on the outcrop. Still, this habit is more common with some coal beds than with others. In general it may be stated that the coal beds appear to thin toward the west, so that beds of considerable thickness in Rs. 26 and 27 E. present little or no coal west of R. 26 E. The average thickness, however, of all the coal beds in the portion of the field studied would probably reach a total of about 35 feet.

[a] For the sense in which the term subbituminous is used in this paper see p. 12.

Though the coals occur in lenses, an effort was made to locate and define the workable portions of the coal beds from a study of the outcrop alone. The method of work may be outlined briefly as follows: A careful search was made in coulees and ravines over the whole area for outcrops of the coal beds. All coals thus discovered were traced throughout the area, but only those having a thickness of 2 feet or more were mapped. The ordinary difficulties of mapping presented by the rough country, deeply cut by canyons, were further aggravated by grassed slopes, forested ridge, and slumping talus, which tend to obscure outcrops of the coal. There is a marked difference, however, in this respect between the two sides of the Bull Mountains, the coals being much more obscure on the north side than on the south side, where erosion seems to be more active. Wherever the outcrop was thus covered the horizon was traced by following adjacent rocks. The traverses of the coal outcrops were made by compass and pacing, on foot in rough country and on horseback in open areas, each traverse being tied to section and quarter-section corners. The error in such work was found rarely to exceed 550 feet per mile, and in nearly every case it was within 270 feet per mile. It was impossible to find corner stones at every desired point, especially in townships that were surveyed fifteen or twenty years ago, for the reason that many of the monuments then set have been obliterated by the elements. The map (Pl. IV) shows the number of corners found. It was found that traverses of 3 or 4 miles could be made within a reasonable closing error, which was distributed along the traverse. The traverses of the outcrops of the most important coal beds are plotted on Pl. IV by means of solid, broken, and dotted lines, which represent within certain rough limits the thicknesses 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 up in order, beginning with the lowest workable bed and continuing upward to the highest bed in the Bull Mountains proper. Named in this order the coal beds are as follows: Glendive, Wildhorse, Buckey, Dorrity, Pompey, Mammoth, Rehder, Rock Mesa, Matt, Bull Mountain, Wescott, Strait, Red Butte, Fattig, and Summit.

The Glendive coal is of very poor quality, though the bed reaches a general thickness of 3 to 6 feet. It occurs in the southern portions of T. 5 N., Rs. 26 and 27 E. (P coal, Pl. IV), and at one point extends about three-fourths of a mile south of the southern boundary of the latter township. It forms on weathered exposures a conspicuous black band in the soil, which is well shown along the Billings road, about 3 miles south of Buckey post-office. Like many of the higher

coal beds, it thins toward the west, so that in the SW. ¼ T. 5 N., R. 26 E., it measures less than 2 feet. A typical section of this bed measured near the southeast corner of T. 5 N., R. 27 E., is as follows:

*Section of Glendive coal bed near southeast corner T. 5 N., R. 27 E.*

| | Ft. | In. |
|---|---|---|
| Coal and shale | | 10 |
| Coal with partings up to one-half inch | 2 | 3 |
| Shale | | 2 |
| Coal | | 6 |
| Shale | | ½ |
| Coal | | 2 |
| Sandstone | | ¼ |
| Coal | | 2 |
| Shale, brown | | 1 |
| | 4 | 2¾ |

As this section shows, partings are numerous and so thin and close together as largely to destroy the value of the coal. This bed has been stripped and certain portions burned with good results, though it is said not to furnish so good a fuel as almost any of the higher beds.

The Wildhorse coal is of much better quality than the Glendive, but its extent is somewhat less. The portion studied lies wholly within T. 5 N., R. 27 E., where it extends roughly across the middle of the township from east to west (O coal, Pl. IV). This coal bed is in the Fort Union formation, at a vertical distance of 450 feet above the Glendive bed. Its average thickness is 35 to 40 inches, and this measurement is surprisingly constant throughout its extent, except in the eastern part of the township, where the bed is only a few inches thick. This is possibly the same bed as that now being mined by the Republic Coal Company on Musselshell River, 2 miles east of Roundup. At this point it is reported to be about 6 feet thick, but in a slope 1 mile to the west the same bed measures 4 feet. A sample taken at the latter point shows that the coal has a fuel value of over 11,000 B. t. u. Owing to the fact that mining in this locality must be carried on down the dip, development is greatly hindered by underground water. The following may be given as a typical section of the Wildhorse coal bed:

*Section of Wildhorse coal bed in sec. 24, T. 5 N., R. 27 E.*

| | Ft. | In. |
|---|---|---|
| Coal and shale | | 7 |
| Coal | 2 | 11 |
| Shale | | 2 |
| Coal | | 2 |
| | 3 | 10 |

Above the Wildhorse coal there are one or two thin beds of coal, but the next important bed is the Buckey coal (N coal, Pl. IV), lying

about 140 feet above the Wildhorse bed. This is a very erratic bed, but in places reaches considerable thickness and appears to be of good quality. Its outcrop roughly follows that of the Wildhorse coal, throughout T. 5 N., R. 27 E., lying to the north of that bed. It continues farther west than the Wildhorse, cutting across the northeast corner of T. 5 N., R. 26 E. Near the center of the northern boundary of T. 5 N., R. 26 E., it shows its greatest thickness of more than 6 feet, but within a mile to the southwest it thins to a feather edge. It is extremely irregular in thickness in certain portions of the field, but may be said to average about 3 feet. This coal bed is characterized by one or two partings near the middle, as shown in the following representative section:

*Section of Buckey coal bed in sec. 20, T. 5 N., R. 27 E.*

| | Ft. | in. |
|---|---|---|
| Coal | | 6 |
| Coal and shale | | 6 |
| Coal | 1 | 1 |
| Shale | | 6 |
| Coal | 2 | 4 |
| | 4 | 11 |

Above the Buckey coal the rocks are practically barren of coal beds for a distance of 200 feet to the Dorrity coal. This is a very persistent bed, uniform both in thickness and quality. It extends throughout Rs. 26 and 27, occurring along the northern border of T. 5 N., R. 27 E., and in the southern part of T. 6 N., R. 26 E. It lies to the south of the outcrop of the Mammoth bed and is about 200 feet below the latter in the stratigraphic column. (See Pl. IV.) The thickness of the Dorrity coal bed ranges between 2 and 3 feet. On the eastern edge of T. 6 N., R. 26 E., like most of the other coals, it thins to less than 2 feet. The following section is representative of this coal bed:

*Section of Dorrity coal bed in sec. 36, T. 6 N., R. 26 E.*

| | Ft. | in. |
|---|---|---|
| Coal with bony layers | | 9 |
| Coal | 1 | 11 |
| | 2 | 8 |

Between this coal bed and the Mammoth bed above there are two or more thin beds of coal which in places may reach 2 feet in thickness. The most important of these, the Pompey coal, occurs 110 feet above the Dorrity and is most prominent along the northern border of T. 5 N., R. 27 E., and in the southeast-central part of T. 6 N., R. 26 E. (L coal, Pl. IV). It is, however, very irregular, and in many places its value is utterly destroyed by partings; consequently it does not deserve further description.

The Mammoth bed is the most important coal in the region studied (K coal, Pl. IV), presenting a greater thickness than any other bed.

It is well developed at the southern base of the Bull Mountains proper, in or near the southern and southeastern portions of T. 6 N., R. 27 E. It also extends westward into T. 6 N., R. 26 E., where it crosses the main divide near the center of the township, and is exposed at the point where the Roundup road crosses the summit of the divide. From this point it turns northward, crossing Dorrity Coulee near the northeast corner of this township, sweeping northeastward around the northern group of the Bull Mountains and swinging back into the head of Fattig Creek, in the northeast corner of T. 6 N., R. 27 E. Thence it extends eastward, probably crossing the main divide in R. 28 E. and returning to connect with the outcrop on the south side of the mountains. The eastern portion, however, was not investigated during the last season. Throughout the area studied the coal is of workable thickness except in T. 6 N., R. 26 E. In this locality it is from 3 to 5 feet thick on the main divide in the south-central part of the township, but as the outcrop continues northward the thickness decreases to 2 or 3 feet and probably less. The exposures in this locality were largely concealed by grass and soil so that measurements could not be made, but in fresh cuts the bed measured in places only a few inches. In T. 6 N., R. 27 E., however, the coal has a thickness ranging from 8 to 15 feet, the eastern portion of the township showing usually 15 feet of coal. It is burned at some points, but it is believed that this burning extends only a short distance back from the outcrop where the cover is reasonably thick. The Mammoth bed usually carries three or four thin partings, whose relative position and thickness are shown in the following section, measured at the head of Fattig Creek:

*Section of Mammoth coal bed at head of Fattig Creek.*

| | Ft. | in. |
|---|---|---|
| Coal | 1 | 10 |
| Shale | | 3 |
| Coal | 3 | 10 |
| Coal, shaly | | 2 |
| Coal | 2 | 1 |
| Shale and clay | | 6 |
| Shale, coaly | | 6 |
| Coal | 2 | 7 |
| Shale | | 2 |
| Coal | 3 | 3 |
| | 15 | 2 |

At a point in sec. 30, T. 6 N., R. 26 E., where this bed measures 8 feet 6 inches, different portions of it were sampled for analysis. The lower 7 feet gave a fuel value of 10,121 B. t. u. in the sample as received, and the upper remaining portion of the bed over 6,200 B. t. u.

The Rehder coal bed (J coal, Pl. IV) is unimportant in the area surveyed. It occurs about 25 feet above the Mammoth bed, from which it is separated by a massive sandstone, and its best development is at the head of Halfbreed Creek, in the northeast corner of T. 6 N., R. 26 E. It is very lenticular, and at this point only does it reach a thickness of more than 2 feet. It is probably nowhere more than 3 feet thick.

About 25 feet above the Rehder coal there is a more persistent bed named the Rock Mesa coal (I coal, Pl. IV). This bed is almost everywhere present, and follows closely the outcrop of the Mammoth bed. It is, however, erratic in that its persistent partings here and there thicken to proportions which destroy the value of the coal bed for commercial purposes. In T. 6 N., R. 26 E., this coal locally develops a thickness between 2 and 3 feet. It attains a like thickness in the southwest corner of T. 6 N., R. 27 E., but from this point eastward the bed is usually less than 2 feet thick. North of the Bull Mountains, however, especially in the northeast corner of T. 6 N., R. 27 E., the bed is remarkably uniform in character and thickness, presenting almost everywhere 2 to 3 feet of good coal. In this vicinity, too, the coal is particularly free from partings, whereas on the southwest side of the mountains partings are more numerous. The following section is typical of the latter locality:

*Section of Rock Mesa coal bed in sec. 30, T. 6 N., R. 27 E.*

| | Ft. | in. |
|---|---|---|
| Shale, bituminous | | 6 |
| Coal | | 11 |
| Shale | | 2 |
| Coal | | 7 |
| Shale | | 1 |
| Coal | | 8 |
| | 2 | 11 |

For 170 feet above the Rock Mesa coal the rocks are destitute of coal beds of any value, but at this distance appears the Matt coal, which is very persistent throughout the area. On the south side of the mountains its usual position is about 20 or 30 feet above the massive sandstone which skirts the foot of the bluffs. Generally it is less than 2 feet thick, except at the head of Dorrity Coulee, in the northwestern portion of T. 6 N., R. 27 E., where it is best developed on the southeast branches and northeast side of the main coulee. In the former, especially those locally known as Strait and John Matt coulees, it is between 4 and 5 feet thick, though generally the lower measurement prevails. Toward the northwest, along the northeast side of Dorrity Coulee, the coal is thinner, ranging between 2 and 3 feet. This coal bed is generally free from partings, but in places has commonly one thin parting, as shown by the following section:

*Section of Matt coal bed in sec. 6, T. 6 N., R. 27 E.*

| | Ft. | in. |
|---|---|---|
| Shale, coaly | | 5 |
| Coal | 2 | 6 |
| Coal and brown shale | | 5 |
| Coal | | 7 |
| | 3 | 11 |

At a distance of 45 feet above the Matt coal, and usually separated from it by a bed of sandstone, occur the two Bull Mountain coals (F and G coals, Pl. IV). These beds are very persistent and in general they mark the base of the high bluffs of the southern Bull Mountain mesas. To the northwest, however, a slight dip in the rocks brings the coals down 100 feet or so below the bold bluffs of the northern mesas. These coal beds are usually separated by only 15 or 20 feet of sandstone and a little shale. Accompanying the upper bed and lying upon it is generally a conspicuous dark-gray clay shale 20 to 30 feet thick. In places one or the other of the coal beds is of insignificant size, but generally the remaining bed is of workable thickness. Thus in the southeastern half of T. 6 N., R. 27 E., usually only one of the coal beds measures over 2 feet thick, and this is in most places the lower bed. In the northeastern portion of the township, however, both beds are regular and of workable thickness. In the former locality the thickness ranges from 2 to 5 feet, the average being a trifle over 3 feet. In the northeast corner of the township the upper bed is uniformly 2 or 3 feet thick, and 3½ feet in T. 7 N., R. 27 E. On the other hand, the lower coal approaches 3½ feet in thickness in sec. 14, T. 6 N., R. 27 E., and from this point thins in both directions, being 2 feet or less in T. 7 N., R. 27 E. Partings of shale are not numerous, and the following is, perhaps, a common section in the northeast corner of the township:

*Section of Bull Mountain coal bed in sec. 13, T. 6 N., R. 27 E.*

| | Ft. | in. |
|---|---|---|
| Coal | | 2 |
| Shale, brown | | 2 |
| Coal | 2 | 4 |
| Shale and sandstone | 12 | |
| Coal | 1 | 5 |
| Shale | | 3 |
| Coal | 1 | 3+ |
| | 17 | 7+ |

In some localities one or the other of these beds is burned on the outcrop, in which case the horizon is marked by 10 or 12 inches of reddish to gray ashes.

Above the Bull Mountain coal beds the section of rocks presents a series of thin coal beds occurring at intervals of 15 to 40 feet. The Wescott coal (E coal, Pl. IV), about 100 feet above the upper Bull Mountain coal, is the next higher bed to reach significant thickness.

Its irregularity and lenticular form, however, render it of so little value that practically the next important coal above the Bull Mountain coals is the Strait coal (D coal, Pl. IV). This bed averages 200 feet above the lower Bull Mountain coal and always outcrops near the base of the steep slopes of the Bull Mountain mesas. Hence the outcrop of the Strait coal as shown on the map outlines the extent and shape of the mesas. The outcrop of the Strait coal lies within T. 6 N., R. 27 E., except where the northern group of mesas extends beyond the northwest corner of that township. A massive sandstone 30 to 40 feet thick usually overlies this coal and forms a prominent protruding ledge or bench along the bluffs. The Musselshell road, where it crosses the divide between Fattig and Dorrity creeks, passes through a notch in this sandstone and the underlying coal bed, which is exposed on either side of the road. In the southernmost mesa this bed generally measures 2 feet or less in thickness, though at some points, especially in the southern half of the mesa, it is nearly 3 feet thick. Toward the northern mesas the thickness is less, and at their base the coal is generally only a few inches thick. The coal around the northern mesas of the Bull Mountains is not deemed sufficiently important to be represented on the map. An average section of the Strait coal is given below:

*Section of Strait coal bed in sec. 32, T. 6 N., R. 27 E.*

| | Ft. | in. |
|---|---|---|
| Coal | | 5 |
| Shale | | 1 |
| Coal | 1 | 6 |
| Shale | 1 | 6 |
| Coal | 1 | 6 |
| | 5 | |

The lower parting indicated in this section increases eastward from this point to a thickness of 5, 8, and even 15 feet.

Above the massive sandstone which overlies the Strait coal occurs a series of coals, the most important of which are the Red Butte, Fattig, and Summit beds (C, B, and A coals, Pl. IV). These lie 35 or 40 feet apart, the lowest one being 65 feet above the Strait coal. All three, consequently, have the same general extent as the Strait coal, and follow the tops of the main mesas which form the Bull Mountains. One of the thinner coal beds intermediate between the Red Butte and Strait coals presents a thickness of nearly 3 feet in sec. 32, T. 7 N., R. 27 E., but this is probably a local development, as such dimensions were not observed elsewhere. The three coal beds named above do not exceed 3 feet in thickness so far as known. The lowest or Red Butte bed is not well exposed, owing to the heavy talus fringing the steep bluffs of the mountains. Where exposed it measures generally 2 feet or less, and rarely exceeds that figure. The Fattig coal is commonly thicker than the Red Butte bed, measuring between 2 and 3

feet almost everywhere. In the northern part of the main north mesa it is exposed at few places, and hence its thickness here is questionable. The Summit coal is very similar to the Fattig in general thickness, but the distribution of dimensions is different. It presents, roughly, less than 2 feet of coal in the southern portions of the mesas and between 2 and 3 feet in the northern portions. In the northwest mesa, however, it is generally less than 2 feet. These three coal beds are commonly free from thick partings. Their position, however, high up in the mountains makes them the least accessible of all the coal beds of the region surveyed.

Near the crest of the Bull Mountains, and averaging about 70 feet above the Summit coal, or 40 to 60 feet below the tops of the mesas, occurs a mass of clinkers and brecciated rock which has been indurated and reddened for a vertical distance of about 30 feet. This doubtless marks a bed of coal of considerable thickness, which, owing to the thin cover, has been burned through its entire extent.

### PHYSICAL CHARACTER.

As already noted, the coals of this region are soft and rather easily reduced to a fine granular mass on exposure to rain and sun. This disintegration is accompanied by the escape of gases, which may be detected for some distance from the outcrop. Though no instances of resulting spontaneous combustion were observed, it is believed that this is perfectly possible and has been the cause of burning of some of the beds. The coals on fresh surfaces present generally a lustrous black appearance. Still, the close observer may detect the bedding by minute alternate layers of dull and lustrous coal. These are seen to best advantage on clean reflecting joint planes. The jointing of the coals in the earlier stages of disintegration results in fragments having a more or less cubical form. As disintegration progresses, however, the cubes tend to break down generally along the bedding into small square plates. Bedding planes, however, are not always, or perhaps even in the majority of cases, the lines of cleavage, but rather the disintegration of the cubes is by conchoidal fracture roughly parallel with the bedding planes. Indeed, the fracture of the coals is markedly conchoidal. If the coals are rubbed against unglazed porcelain the resulting streak is found to be uniformly grayish or blackish brown. They burn with a yellowish flame of moderate length and give off a strong, pungent odor of sulphur. The remaining ash is fine, grayish, and not inclined to be clinkery unless the coals are dirty. Some of the coals contain small globules of amber-colored resin and also small amounts of pyrite. The latter is in places distributed in thin flakes along the joint planes. Even the best coals of the region contain fragments of plants that are still brown and apparently unaffected by the carbonization which the coal beds have undergone.

## CHEMICAL CHARACTER.

In order to ascertain the quality of the coals of the Bull Mountain field, an effort was made to collect samples for chemical analysis, but owing to the difficulty of getting fresh exposures few samples of much value were obtained. The samples were collected in a uniform manner and in compliance with specifications used by the fuel-testing plant of the United States Geological Survey, as given on pages 12–13. Analyses of these samples were made by F. M. Stanton in the chemical laboratory at Pittsburg, and the results are given in the following table:

*Analyses of coal samples from the Bull Mountain field, Montana.*

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

| Name of coal bed | | Mammoth. | | Wild-horse? | Dorrity. | |
|---|---|---|---|---|---|---|
| Laboratory No. | | [a] 5797 | [b] 5799 | 5800 | [a] 5798 | [a] 5801 |
| Sample as received: | | | | | | |
| Prox. | Moisture | 24.59 | 17.45 | 12.69 | 16.95 | 16.91 |
| | Volatile matter | 32.86 | 31.16 | 28.71 | 30.78 | 33.05 |
| | Fixed carbon | 27.94 | 45.05 | 50.90 | 39.64 | 39.15 |
| | Ash | 14.61 | 6.34 | 7.70 | 12.63 | 10.89 |
| Ult. | Sulphur | .41 | .49 | .54 | .49 | .34 |
| | Hydrogen | 4.83 | 5.45 | 5.44 | ..... | ..... |
| | Carbon | 41.41 | 59.00 | 64.26 | ..... | ..... |
| | Nitrogen | .69 | .89 | .88 | ..... | ..... |
| | Oxygen | 38.05 | 27.83 | 21.18 | ..... | ..... |
| Calories | | 3,449 | 5,623 | 6,130 | 4,776 | 4,640 |
| British thermal units | | 6,208 | 10,121 | 11,034 | 8,597 | 8,352 |
| Loss of moisture on air drying | | 4.30 | 3.00 | 2.70 | 3.20 | 3.60 |
| Air-dried sample: | | | | | | |
| Prox. | Moisture | 21.20 | 14.90 | 10.27 | 14.20 | 13.81 |
| | Volatile matter | 34.34 | 32.12 | 29.51 | 31.80 | 34.28 |
| | Fixed carbon | 29.19 | 46.44 | 52.31 | 40.95 | 40.61 |
| | Ash | 15.27 | 6.54 | 7.91 | 13.05 | 11.30 |
| Ult. | Sulphur | .43 | .50 | .56 | .51 | .35 |
| | Hydrogen | 4.54 | 5.28 | 5.28 | ..... | ..... |
| | Carbon | 43.27 | 60.82 | 66.04 | ..... | ..... |
| | Nitrogen | .72 | .92 | .91 | ..... | ..... |
| | Oxygen | 35.77 | 25.94 | 19.30 | ..... | ..... |
| Calories | | 3,604 | 5,797 | 6,300 | 4,934 | 4,813 |
| British thermal units | | 6,487 | 10,434 | 11,340 | 8,881 | 8,664 |
| | | *Ft. in.* | *Ft. in.* | *Feet.* | *Ft. in.* | *Feet.* |
| Thickness of bed | | 8 6 | 8 6 | 4 | 2 8 | ..... |
| Thickness of part sampled | | 1 6 | 7 0 | 4 | 2 8 | 2 |

[a] Badly weathered. [b] Slightly weathered.

5797. Upper 18 inches of Mammoth coal bed in NE. ¼ SW. ¼ sec. 30, T. 6 N., R. 27 E.
5799. Lower 7 feet of Mammoth coal bed in NE. ¼ SW. ¼ sec. 30, T. 6 N., R. 27 E.
5800. Full thickness (4 feet) of Wildhorse (?) coal, 1 mile northeast of Roundup.
5798. Full thickness (2 feet 8 inches) of Dorrity coal in NE. ¼ NW. ¼ sec. 36, T. 6 N., R. 26 E.
5801. Upper 2 feet of Dorrity coal in NE. ¼ NE. ¼ sec. 27, T. 6 N., R. 26 E

These analyses differ more widely in British thermal units than perhaps should be expected from coals of the same field having very similar physical characters and occurring under the same conditions. The differences are probably due to the fact that the samples represent different stages in the deterioration of the coals consequent upon their exposure to the deleterious effects of the elements. Strictly fresh samples for analysis were not procurable except from the Wildhorse coal. A sample of this bed was taken from a new opening recently made by the Republic Coal Company, at a point 1 mile north-

east of Roundup and at least one-half mile back from the outcrop of the coal bed. The sample of the Mammoth coal, No. 5799, which ranks next to the Wildhorse in freshness, was taken from the bed beneath a sandstone cover and about 8 feet horizontally back from the outcrop. The Dorrity samples were collected practically on the outcrop of the coal. Hence probably none of the analyses, except that of the Wildhorse coal, represents the true chemical composition and heating value of the coals. It is believed that fresh samples of the other coal beds would approach very closely and probably exceed 10,000 B. t. u. Indeed, a sample from the Mammoth bed comparable in freshness with that of the Wildhorse coal would, with little doubt, reach 11,000 B. t. u. Sample No. 5797, which represents the upper 18 inches of the Mammoth coal bed, has apparently suffered great deterioration from percolating waters, besides being cut by many small partings. To the latter fact may be due a percentage of ash double that of the lower portion of the bed. Both samples were taken along the same vertical line in the Mammoth bed.

An examination of the analyses of air-dried samples, excluding No. 5797, shows that these coals contain an average of 44 per cent of fixed carbon, 32 per cent of volatile matter, 9.7 per cent of ash, and 0.48 per cent of sulphur. The amount of sulphur is considerably less than that of the Great Falls coals, which average 3 per cent. The moisture content is rather large, averaging about 3 per cent, and this has a deleterious effect on the fuel value of the coal. From the association of chemical and physical characters, such as the heating value, which ranges between 10,000 and 12,000 B. t. u.; the disintegration into thin plates on exposure; the brownish streak; the lack of gray, leaden luster; the lack of coking qualities, etc., we may safely conclude that the coals of this field should be classed at least as high-grade subbituminous.

When the analyses are compared with those of coals from Great Falls, Miles City, Red Lodge, Bear Creek, and the Bighorn Basin,[a] it may be said that the Bull Mountain coals rank well. Few of the others have a greater fuel value and many have somewhat less.

## DEVELOPMENT.

So far as known no extensive mining has been carried on during the last year in the Bull Mountain field. In the area surveyed nothing better than three or four dilapidated coal pits was seen, except the old workings of the Northern Pacific Railway at the head of Railroad Creek, in sec. 24, T. 6 N., R. 27 E. During the last season, however, the projection of the coast extension of the Chicago, Milwaukee and St. Paul Railway along Musselshell River has caused considerable prospecting along that stream, which has resulted in the establishment

[a] See papers on these fields in this bulletin.

by the Republic Coal Company of a well-equipped mine 2 miles northeast of Roundup. This company first began to operate during the fall of 1907, and its shaft is probably the first of any considerable size ever excavated in the Bull Mountain field. The company attempted to reach the coal bed through a slope extending beneath Musselshell River, but the coarse character of the beds through which such a slope must extend allowed the entrance of great quantities of water, which was fatal to the project. Thereupon a shaft was sunk on the south side of the river to a depth of more than 100 feet. The coal bed penetrated by the shaft is possibly the Wildhorse, and it is overlain by an excellent roof of heavy sandstone. The floor is clay shale, which may be readily removed if necessary in mining. The coal bed is reported to be over 6 feet thick, and it is said that at the present writing 150 tons of coal are removed daily. Some of the output is put to local uses, but much the larger part is utilized for steam purposes on the new line of railroad.

The further development of this field will be to some extent controlled by the topographic features, the water supply, and the structure of the rocks or lay of the coal beds. The accessibility of the coals depends largely on the topography. The main divide, on which are situated the mesas constituting the Bull Mountains, separates the field into two natural portions—a northern slope toward the Musselshell and a southern slope toward the Yellowstone. Coals outcropping on the south slope are most accessible from that direction, for railroad spurs sufficient to tap the field may be extended from the main line of the Northern Pacific Railway, which is 12 miles from the nearest coal bed. The coals which would thus be mined on the south slope extend through the divide and outcrop on the north slope. This slope has the advantage of a more plentiful water supply and closer proximity to railroad facilities. The coal which is at least 12 miles from the Northern Pacific Railway on the south slope outcrops on the north slope along the line of the Chicago, Milwaukee and St. Paul Railway, and is the one now being mined at Roundup. Furthermore, for the higher coal beds on the north railroad spurs may be projected up the various creeks heading in the Bull Mountains.

Water is notably scarce in some parts of the field. On the south side of the mountains, as already stated, the supply is very scanty during the dry season. On the north side, owing to the general northward dip of the rocks, springs are fairly abundant and water may be had by drilling. It may therefore be necessary in mining some of the coals in this region to use electricity generated at some distant point, possibly along Musselshell or Yellowstone River. This method of mining is probably the only available one for the coals on the south slope, unless, inasmuch as the same beds outcrop on both sides of the mountains, the coal is taken out by mines situated on the north side.

The flow of the ground waters is controlled chiefly by the geologic structure; consequently the northward dip of the coals on the south slope of the mountains accounts, as already suggested, for the scarcity of springs in that portion of the field. Nevertheless, drifts down the dip of the coal beds, even in this locality, would probably fill with water, which would have to be removed by some artificial means. For this purpose the siphon may be used to advantage. On the north slope of the mountains, however, the northerly dip of the rocks would form natural drainage for mines on the upper coals. Indeed, it is believed that coal beds occurring high up in the mesas should be mined chiefly from the north side. The lower coals of the north slope, including the one now mined at Roundup, lie on the northeast limb of the syncline and have a general southerly dip. Hence for mines on these beds a pumping plant is a necessity. Furthermore, the siphon method, owing to the flatness of the country, could not be used so advantageously as on the south slope.

The place at which it would be most economical to locate a mine with a view to natural drainage is the lowest point on the axis of the syncline, which crosses the field between the Bull Mountains and Roundup. A mine so located might work the lower coals up the rise toward the north, east, and south, and thus obtain a natural westerly or northwesterly drainage. The ideal position for such a mine can not be given from the present partial knowledge of the field. Any plan for the development of the whole field along the most economical lines presupposes cooperation among the various operators. For example, a drainage tunnel or a shaft and pumping plant located at the lowest point of the syncline, the expense being borne in common by all operators, might save outlays for the construction and maintenance of pumping plants at each mine.

The geographic position of the coals of the Bull Mountain field, together with their character and relation to those of other fields, shows that there is every likelihood of their increasing development in the near future. The territory to be supplied about the Bull Mountains is not thickly populated, and Billings is the largest town of importance. The towns on Musselshell River, though at present small, will increase in population with the advent of the new transcontinental railroad, but owing to the fact that the agricultural region is naturally restricted by lack of water, it is doubtful if these towns will grow to the size of those on Yellowstone River. Agriculture in this region is largely limited at present to grazing, but the rural population also will no doubt be augmented along the line of railroad. Moreover, irrigation of narrow strips of land along some of the main tributaries of Musselshell River is feasible and will probably be extended in the near future. The resulting increase in population will therefore help enlarge the demand for coal.

# COAL NEAR THE CRAZY MOUNTAINS, MONTANA.

By R. W. STONE.

## INTRODUCTION.

The belt of sedimentary rocks extending around the north and west sides of the Crazy Mountains in central Montana was examined by the writer in the summer of 1907. This belt has been reported[a] to contain several workable coal beds, and the main purpose of the season's work was the investigation of the coal resources, with the idea of determining as accurately as possible their distribution, extent, and value.

The supposed coal belt was mapped from Shawmut westward to the head of Musselshell River and southward to Clyde Park. A large part of this belt is included in the Little Belt Mountains quadrangle and the geology is described in the folio covering that area.[a] A topographic map covering 1,000 square miles was completed on the basis of the General Land Office surveys. Streams, highways, and contour lines expressing the relief of the country were drawn with relation to township and section lines. All township and range lines were ridden, and all the section lines in a township running in the same direction, either north and south or east and west, were traversed in the construction of the field maps, which were prepared on a scale of 2 inches to the mile, with a 100-foot contour interval.

Much information regarding the location of coal prospects was obtained from the ranchers. It was found on examining the prospects, however, that there are no coal beds of commercially workable thickness in the area. Coal beds are present and small amounts of coal are taken for domestic use, but all the beds are too thin for mining on a commercial scale. The few ranchers between Shawmut and Summit, on the south side of Musselshell River, who dig an occa-

[a] Little Belt Mountains folio (No. 56), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

sional load of coal, get it by stripping beds from 5 to 14 inches thick. In the ridges between Potter Creek and Shields River, 15 miles southeast of Dorsey, there is a bed 3 to 7 feet thick, but clay partings are numerous and crushing has reduced a large part of the coal to slack, so that it is of little value and as yet has not been mined successfully, even on a very small scale. The economic result of the summer's work, then, was to disprove the presence of a coal field in this part of Montana.

The writer was assisted in the mapping by M. I. Goldman, J. H. Cather, and F. D. Morrison.

## GEOGRAPHY.

The area here to be described is L-shaped, and lies in Meagher, Sweetgrass, Park, and Gallatin counties. It extends from Shawmut on the east to Dorsey on the west, a distance of 60 miles, and the north-south extent of the western limb of the field is 40 miles. Work was begun at Shawmut, below Harlowton on Musselshell River, and progressed westward between the Crazy Mountains and the river. At the divide between the Missouri and Yellowstone River drainage the course was turned southward down Potter Creek and Shields River to Clyde Park, where the season's work ended.

Relatively, the topography of the area is gentle, being of low relief with but few salient features. It is flanked, however, by mountains several thousand feet high. Aside from the mountain bases the most prominent topographic features are Coffin Butte and Gordon Butte, both of which rise several hundred feet above the surrounding more or less level country. Although some of the streams are deeply incised in their upper courses, the valleys for the most part are open, and it is possible to drive over the greater part of the area regardless of roads. The country is not closely fenced.

Musselshell River is the northern boundary of the area examined as far west as Martinsdale. Fish Creek, American Fork, and Lebo Creek are its principal tributaries from the south. The south fork of Musselshell River, Potter Creek, and a part of Shields River are the main watercourses in the western part of the field. All these streams except Musselshell River can be forded easily.

The region is devoted largely to grazing, and settlement is scanty. Naturally, most of the people live along the main streams or routes of travel. Harlowton, with a population of 500, is the largest village. The Montana Railroad, which runs from Lombard to Lewistown, crosses this area from Dorsey to Harlowton. This line was recently acquired by the Chicago, Milwaukee and St. Paul Railway Company, which has built a new main line up Musselshell River connecting with the old line at Harlowton.

## GEOLOGY.

### SEDIMENTARY ROCKS.

In his description of this area in the Little Belt Mountains, Weed divides the Cretaceous system into four formations—the Cascade, Yellowstone, Laramie, and Livingston. In recent years the Cretaceous has been further subdivided, and in place of Weed's four formations the writer mapped seven. This division into smaller units is based on lithologic and paleontologic evidence obtained by various geologists and paleontologists in the last few years. The distribution of the Laramie as mapped by Weed suggests that the structure is somewhat irregular, but the results of the work here described show that the structure is still more complex than was supposed. The geology of the area is further complicated by the intrusion of igneous rocks in the form of dikes, sills, and laccoliths. These are most numerous in the vicinity of the Crazy Mountains.

The Cretaceous and Tertiary rocks of this area are divided into nine formations, as follows:

| | |
|---|---|
| Tertiary..... | Fort Union formation. |
| | Livingston formation. |
| Cretaceous..... | Laramie formation. |
| | Montana group: |
| | Bearpaw shale. |
| | Judith River formation. |
| | Claggett formation. |
| | Eagle sandstone. |
| | Colorado shale. |
| | Kootenai formation. |

The lowest rocks of Cretaceous age belong to the Kootenai formation, which has a thickness of 235 feet and is composed of green and red shales in the lower half and brown, gray, and pink sandstones in the upper half. The base of the massive sandstones in the middle of the formation is coarse grained and contains thin layers of quartz and chert pebbles. In some places also the débris from this bed is conspicuous for its numerous slickensided faces and iron staining. Below this conglomerate is a black shale, slightly bituminous, which may be a foot or more thick. It is at this horizon that the workable coal occurs in the Lewistown and Great Falls fields.

The Colorado shale, lying next above the Kootenai, has according to measurements by the writer a thickness of approximately 1,300 feet. It is composed largely of dark shale. The prevailing color is green, although the lower part in places is nearly black. A massive gray sandstone may be present in the lower third of the formation; its thickness varies greatly, ranging up to nearly 200 feet. The upper part of the formation shows transitional stages of deposition from deep to shallow water by the occurrence of numerous beds of sandstone in the shale.

Overlying the Colorado shale is the Montana group, composed of four formations—the Eagle, Claggett, Judith River, and Bearpaw, all of which are of Cretaceous age. The Eagle sandstone, composed very largely of massive gray sandstone, is from 100 to 250 feet thick and presents a marked contrast to the underlying dark Colorado shale. One of the coal horizons of this region is in the Eagle sandstone, but the bed is not of workable thickness. This sandstone is a conspicuous ledge maker and for that reason and because of its whiteness and tendency to weather in stools is easily traced.

The Claggett formation where well exposed produces as a whole a light-brown or tan effect with pronounced ribbing due to thin beds of hard sandstone in the shale that makes up the greater part of the formation. It is a marine and brackish-water deposit and carries abundant invertebrate fossils. Its thickness ranges from 400 to 800 feet. The top member of the Claggett formation is a massive gray sandstone which in many places makes a conspicuous cliff. It closely resembles the massive Eagle sandstone and may be readily mistaken for it.

The Judith River formation, lying next above the Claggett and having about the same range in thickness, is prevailingly sandy. When tilted it forms a low ridge and appears dark gray; where horizontal it tends to weather in badland forms and is banded with light-colored beds. Near the head of Musselshell River the top bed of the Judith River formation is a sandstone which ranges up to 15 feet in thickness and is full of oyster shells; in places, especially around Gordon Butte, the bed is practically a solid mass of shells, 8 feet thick. Seams of coal a few inches thick are known to occur in this formation, which was laid down mainly in fresh water, with an occasional recurrence of brackish conditions. Besides shells it contains fossil bones and wood.

Above this mass of prevailingly fresh-water beds are strata ranging in thickness from 700 to 1,100 feet and composed almost entirely of dark-gray and greenish shale. The color when wet is nearly black, and contrasts strongly with that of the formations above and below. This shale constitutes the upper part of the Montana group and is termed the Bearpaw shale. It is so thick and weathers so readily that where it lies flat it forms an area of very low relief, and where it is tilted a valley is developed in it between ridges of the harder Judith River formation below and the red sandstones above. A feature of some note is the occurrence of limy concretions about a foot in diameter, which are found commonly in the upper part of the formation and which are as a rule highly fossiliferous.

The red and greenish sandstones overlying the Bearpaw shale constitute a distinct lithologic unit, ranging in thickness from 200 to 460 feet, and, although containing some shale members, are

sufficiently sandy and hard to form a conspicuous ridge. This formation is particularly well exposed as a ridge along the western side of T. 5 N., R. 17 E., and crosses Fish Creek at the George Moore ranch. A mile farther north it swings to the west and can be traced readily all the way to Lennep. A peculiarity of this formation is its general reddish color and the occurrence of a layer of red, sandy, cannon-ball nodules near the middle. Its age has not been definitely determined, but lithologically it belongs to the overlying formation and hence it will be provisionally regarded as a part of the Laramie.

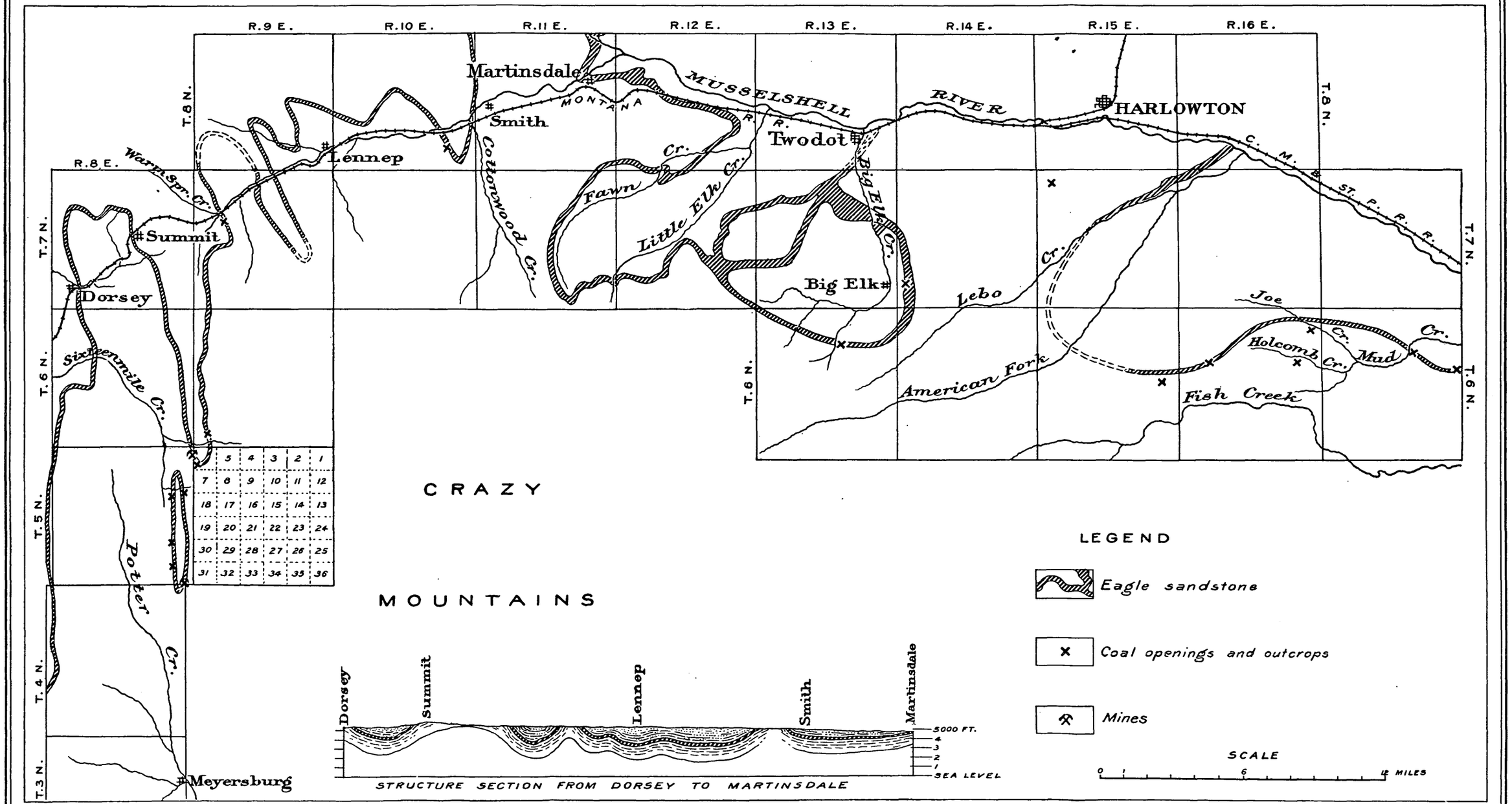
Taken as a whole, the upper part of the Laramie formation is distinguished from the formations above and below by its light-gray color in comparison with their somber hues. It is composed largely of soft gray sandstone and variegated shale. The gray beds, from 1,000 to 2,400 feet thick, make a conspicuous valley across the middle of T. 6 N., Rs. 13 to 16 E. As a whole the formation weathers so readily that it normally forms low country, and for some miles in this area it coincides with the valley of Fish Creek. The gray beds of the Laramie formation are overlain, possibly with unconformity, by somber-colored sandstone and shale which may represent the Livingston formation. Sufficient paleontologic evidence has not been obtained, however, to determine the limits of these stratigraphic units. A section measured by C. A. Fisher and T. W. Stanton on a fork of Big Elk Creek gives a thickness of 5,592 feet from the base of the Laramie to the base of the sandstone and grit of probable Fort Union age, and of 10,324 feet for the beds above the Bearpaw shale. Further field work is necessary before the lithologic and paleontologic distinctions of the Laramie and Livingston formations can be determined.

The Fort Union formation, of unknown thickness, but exceeding 4,300 feet, is the youngest in this area. It is composed largely of sandstone, alternating with shale. The base of the formation is a particularly massive, coarse-grained sandstone which forms pronounced wooded ridges. Fort Union beds underlie the southern part of T. 6 N., Rs. 12 to 16 E., and compose the north and east bases, at least, of the Crazy Mountains.

The character, distribution, and thickness of the above-described formations will be discussed much more fully in a report now in preparation by L. H. Woolsey and the writer.

## IGNEOUS ROCKS.

Surrounding the Crazy Mountains, which are formed by diorite stocks breaking through a basin of sedimentary rocks, is a zone of igneous intrusions. These occur as dikes, sheets, and laccoliths and were probably injected at the time of the folding to which the rocks of this area have been subjected. The most noticeable occurrences




MAP SHOWING OUTCROP OF THE EAGLE SANDSTONE NEAR THE CRAZY MOUNTAINS, MONTANA.

By R. W. Stone and M. I. Goldman.

are the masses of theralite and theralite porphyry which cap Coffin Butte; the 6,400-foot hill 2 miles to the northeast of it; a small butte 2 miles west of the Miller ranch, on the west range line of T. 7 N., R. 12 E., and Gordon Butte. These igneous masses are believed to be the remnants of laccoliths. Near Lennep, which is close to the Crazy Mountains, dikes and sheets of andesite porphyry and theralite are particularly numerous. On the west side of Comb Creek sheets of igneous rock in upturned shaly beds weather as parallel walls and resemble dikes in appearance.

### STRUCTURE.

As mentioned above, the Crazy Mountains are composed of granitic rocks intruded through sediments that dip gently toward the mountains. Coincident with the intrusion of the great masses of igneous material which form the mountains, the region was subjected to strains which produced folds and domes, the former in some places many miles in extent.

The upturned edges of the higher rocks down to and including the Judith River formation describe a fairly regular concentric belt around the base of the mountains, toward which these rocks dip. Out in the valley, where these beds have been worn away and the Claggett, Eagle, and Colorado formations underlie the surface, the structure is less regular, consisting of gentle folds and low domes. Erosion has reduced these forms, cutting away the less resistant beds and leaving the harder ones standing out as ridges. The outcrop of the Eagle sandstone shown on the accompanying map (Pl. V) suggests the complexity of the structure in the upper valley of the Musselshell. The southern half of an eroded anticline having a northeast-southwest axis is indicated by the outcrop of the Eagle sandstone which crosses the river near the mouth of American Fork and again 8 miles below Shawmut. South of Twodot and Martinsdale the structural features are round domes, but farther west, toward the north end of the Crazy Mountains, folds are most pronounced. On the west side of the Crazy Mountains, however, the structure is simpler. Close to the mountains a number of parallel folds form the ridges between Shields River and Potter Creek, but the Potter Creek valley is a syncline, the rocks on the east side dipping west, those on the west side dipping east, and those lying in the middle of the valley being practically flat.

## THE COAL.

### GENERAL DESCRIPTION.

Although the area included in the Little Belt Mountains quadrangle has been reported[a] to contain several coal beds of workable thickness, none was found. Coal has been discovered and prospected at

[a] Op. cit.

several points, but nowhere has it proved of sufficient value to develop except in a small area west of the Crazy Mountains, on the head of Sixteenmile Creek, where a bank has been operated for a number of winters but is now idle.

Coal or coaly shale was discovered in the Eagle sandstone at short distances throughout the area examined, but at too few places to determine if it occurs in more than one part of the formation or if it is a continuous bed. The writer believes that the Eagle coal may be absent in many places. In the Judith River formation lenses of coal of short lateral extent and a few inches thick are not uncommon. Beds of similar character are also found in the Laramie and Fort Union formations.

The localities where coal is found in the area here discussed are so few that they can be enumerated and described in detail. Beginning at the east, the first known occurrence is a prospect south of Shawmut, from which Mr. Crawford[a] has taken a few loads of coal. It is situated on a small branch of Mud Creek which cuts through ridges of upturned rocks in sec. 13, T. 6 N., R. 17 E. The coal is exposed on the south flank of the northernmost ridge close to the stream and is inclined at an angle of 30°. There are two beds of coal, each less than 1 foot thick and separated by several feet of shale. As the coal makes the flank of the ridge, it can be obtained by stripping a small amount of soil. There is not enough within easy reach, however, to induce near-by ranchers to mine it for regular use. It is subbituminous in character and would be of some value if it had a greater thickness.

Two miles northwest of this locality, in sec. 10, where Mud Creek cuts through the ridges formed by the upturned Eagle and Claggett formations, this same coal bed, or one in relatively the same position, has been exposed on the east side of the creek south of the first ridge. The outcrop of the coal was hidden when the locality was visited, but it is believed to be not over a few inches thick.

On Joe Creek, a branch of Mud Creek, in sec. 1, T. 6 N., R. 16 E., there is a prospect drift in the bluff below a sheep shed which shows a coal bed 28 inches thick. As the bed includes an 18-inch band of bone and very dirty coal, the amount of fuel is not over 10 inches, and therefore it has no value. It lies under a massive sandstone in the lower part of the Judith River formation. On Holcomb Creek, 1 mile south of this locality, the same bed is exposed in the south bank of the stream for a few rods and has a thickness of about 30 inches. It appears to be subbituminous in quality and is variable in thickness, decreasing within a few rods to less than 2 feet.

Where the Eagle sandstone crosses Joe Creek, in sec. 2 of the same township, the presence of coal or coaly shale is shown by fragments

[a] Stanton, T. W., and Hatcher, J. B., The geology and paleontology of the Judith River beds: Bull. U. S. Geol. Survey No. 257, 1905, p. 60.

around gopher holes. Three miles farther along the outcrop, in Widdicombe Brothers' 80-acre field in sec. 17, T. 6 N., R. 16 E., a coal bloom was seen at the point where a small gully cuts across the Eagle sandstone south of the road. The coal bed may be at the top of the formation, for three massive sandstones separated by shale and having a thickness of about 216 feet lie below it. It seems to be nothing more than a streak of coaly material, perhaps 6 inches thick. Two miles farther west, in sec. 13, T. 6 N., R. 15 E., a coal bloom was uncovered close to the top of the ridge along which runs an east-west road. The outcrop, which ranges from 26 to 28 inches in thickness, suggests a low-grade, dirty coal, probably subbituminous. As the exposure occurs at the grass roots and the rocks stand at an angle of 50°, the quality of the coal was not definitely determined. Certainly the bed is too thin to be of value, and the steep dip makes it difficult of access. It occurs at the base of the Judith River formation.

Four miles southeast of Harlowton, in the eastern part of sec. 1, T. 7 N., R. 15 E., there is a 5-inch bed of coal in the Eagle sandstone. At Harlowton it was reported that Joseph La Brie stripped several tons of coal on his ranch, in T. 6 N., R. 15 E., in the winter of 1906–7; but on investigation it was found that, although the statement was true, the bed of coal is only 4 inches thick. This coal is in the northwest corner of the township, and is believed to be in the Judith River formation.

A coal bed having a total thickness of 2 feet 2 inches, half a mile east of Big Elk post-office, among the ledges of Eagle sandstone, has been uncovered by Frank Williams. An 8-inch clay parting reduces the amount of coal to 4 inches at the top and 14 inches at the bottom, and takes it out of the class of workable beds. What little coal there is here is subbituminous. Farther down Big Elk Creek, on the Shoemaker ranch, coaly shale has been found in two or three places, but nowhere is it more than 4 or 5 inches thick. It is black sandy shale, with paper-thin laminæ of carbon, and consequently is not combustible. On a branch of Big Elk Creek which flows through a small canyon in sec. 10, T. 6 N., R. 13 E., the Cretaceous beds are well exposed and the Eagle sandstone makes the first ridge, the rocks dipping south at a high angle. In a small coulee on the east, 150 yards from the stream, C. A. Fisher found in the Eagle sandstone a coal bed having a thickness of 7 feet. It is composed, however, of alternating 1 to 3 inch bands of shale and low-grade coal, and hence has no commercial value.

Coal prospects are reported at the north end of the Crazy Mountains, in sec. 21, T. 7 N., R. 10 E., but on investigation they were found to be pits driven on black shale and showing three or four bands of bright coal not over one-half inch thick. These are in the Fort Union formation. The Eagle coal was discovered in the NE. ¼

NE. ¼ sec. 35, T. 8 N., R. 10 E., a few feet south of the highway, on the bank of a small creek. It lies above a gray sandstone having Eagle characteristics, but is only 3 inches thick. In a small canyon in sec. 23 of the same township, where coal is reported, a foot of black shale was found in the trail on the west bank of the stream. This carbonaceous shale is in the Kootenai formation, and probably represents the horizon of the coal which is mined in the vicinity of Lewistown, Fergus County, and Great Falls, Cascade County.

Prospects at the mouth of Warm Spring Creek, on the south fork of Musselshell River, attract attention because they are close to the road and show black dumps, but on examination it was found that the bed consists of 3 or 4 feet of black shale containing about 1 foot of coal which appears to be of low grade. The rocks at this point stand at an angle of 69° and thus add to the difficulty of obtaining fuel. The coal is believed to be in the Eagle sandstone. Weed says of this locality:[a]

> At the mouth of Warm Spring Creek a coal seam has been exposed. The seam is of sufficient thickness and purity to be workable, but the attitude is not favorable, the beds being vertical and the exposure but a few feet above probable water level. The outcropping sandstones can, however, be traced up the slopes southward, and the area will furnish an abundance of fuel when the demand warrants exploitation.

In another place[b] Weed says of the coal on Warm Spring Creek: "A coal seam exposed on the bench land adjoining Warm Springs Creek has been opened at several places, but has so far proved too impure to encourage development."

Reports of the occurrence of coal on Checkerboard Creek, on the north flank of Castle Mountain, 12 miles northwest of Lennep, led to inquiries which resulted in the following information from Postmaster Hull, of Delpine, on the north fork of Musselshell River. Twelve or fifteen years ago a coal bed about 18 (?) inches thick was opened and operated on the head of Checkerboard Creek. The locality is about 4 miles up the creek, three-fourths of a mile above a limestone canyon, 300 yards up a steep drain on the left near the old Castle road. Several hundred tons of coal were taken to White Sulphur Springs for domestic use and proved fairly satisfactory except that the quantity of sulphur contained in the coal gave off fumes that pervaded the town. On account of the high percentage of sulphur, the coal is not good for blacksmithing. Mining was abandoned because of the thinness and poor quality of the coal.

Weed says of this locality:[c]

> A thin seam of coal occurring beneath the Dakota quartzite near the forks of Checkerboard Creek has been mined in a small way for Messrs. Spencer, Main & Heitmann, of White Sulphur Springs. The seam is hardly thick enough or the product of sufficiently

[a] Weed, W. H., and Pirsson, L. V., Geology of the Castle Mountain mining district, Montana: Bull. U. S. Geol. Survey No. 139, 1896, p. 148.

[b] Little Belt Mountains folio (No. 56), Geologic Atlas U. S., U. S. Geol. Survey, 1899.

[c] Bull. U. S. Geol. Survey No. 139, 1896, p. 148.

high grade to warrant working under ordinary circumstances; but owing to the distance of White Sulphur Springs from the railroad the cost of transportation of coal from other points has been prohibitive, and this seam furnished the only available source of supply.

In the Potter Creek valley coal is reported in sec. 17, T. 6 N., R. 8 E., with a thickness of 6 inches. On top of the cliff just west of Harry Blair's house, in sec. 24, T. 4 N., R. 7 E., the Eagle coal has been found, but the thickness is less than 1 foot and the bed is consequently of no value as a source of fuel. Streaks of this sort may be found in the Eagle sandstone on either side of the valley.

The only locality where coal approaching workable thickness has been discovered in the area here described is at the head of Sixteenmile Creek, in the ridges of folded rocks east of Potter Creek. It was reported by Weed in the Little Belt Mountains folio that a mine had been operated here for several years, a small amount of coal being taken every winter. The mine, which is in sec. 6, T. 5 N., R. 9 E., and is the property of Rees & Bangor, of White Sulphur Springs, was abandoned in 1906. It is south of the road along the creek and is marked by a cabin. As the bed stands at an angle of 35°, a tunnel was driven to undercut it and the coal was taken by drifting and stoping. The drift is about 200 feet long and is open yet, so that the character of the bed can be seen. Portions of the lagging have rotted, however, and caving has begun, so that the mine may soon be closed. The bed ranges in thickness from 2½ feet to 4½ feet. It contains at the top 17 inches of subbituminous coal which is hard and bright and mines in blocks; below this is 1 to 5 inches of plastic clay, underlain by 1 to 3 feet of crushed and dirty coal which makes such fine slack as to be objectionable for steaming purposes. It is said to be a good blacksmithing coal, however. According to John Rees, one of the owners, the comparatively poor quality and the thinness of the solid, black coal and the cost of the long wagon haul necessary to deliver the product at the nearest market make mining unprofitable. From 1883, when this coal was discovered, until the mine was abandoned in 1906 about 500 tons were mined.

Two shafts were sunk to this coal bed at the head of the coulee about one-fourth of a mile south of the above-described mine in 1889, but at a depth of 75 feet the bed decreased in thickness to 6 inches and water came in so copiously that the undertaking was abandoned. These shafts are now caved full. The location of these openings on the crest of a sharp anticlinal fold probably accounts for the disturbed and crushed condition of a portion of the bed, and may in part explain the marked thinning of the coal.

Several other attempts to develop this coal bed have been made along the eastern outcrop on the north side of this fork of Sixteenmile Creek, but nowhere did the prospecting reveal sufficient coal to induce mining. Only one measurement of the bed was obtained

north of the creek and that was at a point on the west slope of a ridge three-fourths of a mile N. 12° E. from the Rees mine mentioned above.

*Section of coal bed on Sixteenmile Creek.*

| | Ft. | in. |
|---|---|---|
| Shale. | | |
| Coal | 1 | 9 |
| Shale, brown | 2 | 4 |
| Coal | | 3 |
| Clay, sandy | | 2 |
| Coal | | 2 |
| Clay, sandy | | 1 |
| Coal | 3 | |
| Sandstone. | | |
| | 7 | 9 |

Although the bed contains over 5 feet of coal, it is so broken and separated by partings as to be economically unworkable, and it stands at so high an angle that it can not readily be developed. The section was measured at the grass roots and so is not very reliable. It is possible that the thick benches of coal at the top and bottom of the section contain small partings or other impurities that make them of little value. Prospecting to some depth is necessary to determine this point.

Development of this same coal bed has been attempted on the head of Cottonwood Fork of Sixteenmile Creek in secs. 12 and 13, T. 5 N., R. 8 E. The outcrop is marked by several small pits, in one of which the bed can be seen now, but the dumps suggest that although coal was found in these prospects it was too thin to mine. Farther south along the same outcrop, in the southwest corner of sec. 24, a slope was driven to cut the coal and a shaft was sunk. The slope is completely closed and the shaft, which is well timbered and covered with a cabin, is partly filled with water. The expense of keeping the shaft free from water was probably the cause of its abandonment.

Still farther south along the outcrop, which is the narrow crest of an anticline, other pits have been dug and abandoned at a depth of a few feet. The composition of the dumps suggests that although a small amount of apparently fair subbituminous coal was found, the value of the bed is greatly affected by carbonaceous-sandstone binders. The coal has been mined and can be seen in the southeast corner of sec. 36, T. 5 N., R. 8 E. At this point, in the stream bank, close under the township standard corner stone, a tunnel was driven west for 140 feet to undercut the coal bed, which dips at an angle of 65° E. Drifts were run for 20 to 40 feet along the coal in both directions, and it is said that about 200 tons was sold, but the bed ranged in thickness from 2 to 3 feet and lay so close to the surface that it showed the effects of surface weathering. The opening is said to have been abandoned because the coal bed pinched out. This statement was not verified, but considering the fact that there is a demand for steaming coal for the traction engines used for plowing and harvesting

in the neighborhood, it seems that some difficulty with the thickness or character of the bed must have stopped the mining. As there is no place in the vicinity where the bed can be undercut at a depth sufficient to get a considerable amount of coal to stope down, and as shafting necessitates pumping, none of the undertakings have been successful.

The coal horizon dips below the surface at the southern line of sec. 36, T. 5 N., R. 8 E., near Ed Potter's home, and there are no other known coal outcrops to the south as far as the survey was carried. Coal is reported at a number of points near Shields, but nowhere did it prove to be more than a mere pocket a few inches in extent.

## ANALYSES.

Five samples of the coal in this region were subjected to chemical analysis. All but one were taken according to Survey regulations, the coal being obtained by cutting a groove across the whole thickness of the bed, and excluding partings over one-fourth of an inch thick. The quantity thus obtained was crushed to ½-inch size and quartered until a 3-pound sample remained. Each sample was sealed in a galvanized-iron can and sent to the chemical laboratory of the United States Geological Survey testing plant at Pittsburg, Pa. Sample 5723 was taken from a bin where it had air dried for eight or ten months. These samples were analyzed under the direction of F. M. Stanton, chemist. The first two samples are from the Judith River formation and the last three from the Eagle sandstone.

*Proximate analyses of coal samples from region near the Crazy Mountains.*

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

| Location | Joe Creek. | Holcomb Creek. | Big Elk. | Head of Sixteen-mile Creek. | Sec. 36, T. 5 N., R. 8 E. |
|---|---|---|---|---|---|
| Section of bed | Coal...8″<br>Crushed coal.18″<br>Coal...2″ | Coal..30″ | Coal...4″<br>Clay...8″<br>Coal..14″ | Coal..17″<br>Clay...2″<br>Crushed coal.26″ | (a) |
| Part sampled | All. | All. | Omitting clay. | Omitting clay. | |
| Laboratory No. | 5735 | b 5732 | b 5734 | 5733 | 5723 |
| Sample as received: | | | | | |
| Moisture | 10.37 | 25.26 | 29.35 | 6.69 | 2.45 |
| Volatile matter | 22.28 | 23.51 | 27.47 | 25.32 | 30.83 |
| Fixed carbon | 32.06 | 36.68 | 31.57 | 35.75 | 51.75 |
| Ash | 35.29 | 14.55 | 11.61 | 32.24 | 14.97 |
| Sulphur | .58 | .41 | .29 | .47 | .63 |
| Calories | 4,007 | 3,546 | 3,541 | 4,744 | 6,854 |
| British thermal units | 7,213 | 6,383 | 6,374 | 8,539 | 12,337 |
| Loss of moisture on air drying | 5.00 | 13.90 | 14.00 | 4.10 | .60 |
| Air-dried sample: | | | | | |
| Moisture | 5.65 | 13.19 | 17.85 | 2.70 | 1.86 |
| Volatile matter | 23.45 | 27.31 | 31.94 | 26.40 | 31.02 |
| Fixed carbon | 33.75 | 42.60 | 36.71 | 37.28 | 52.06 |
| Ash | 37.15 | 16.90 | 13.50 | 33.62 | 15.06 |
| Sulphur | .61 | .48 | .34 | .49 | .63 |
| Calories | 4,218 | 4,118 | 4,117 | 4,947 | 6,895 |
| British thermal units | 7,590 | 6,949 | 7,411 | 8,904 | 12,411 |

a Coal-bin sample. b Badly weathered.

The sample from Joe Creek, in sec. 1, T. 6 N., R. 16 E., was cut in the face of the drift about 12 feet from the surface and includes the whole bed, which is 28 inches thick. There are 10 inches of solid coal, separated into two benches by 18 inches of crushed and dirty coal. It is probable that the greater portion of the high percentage of ash shown in the analysis is contained in this crushed portion of the bed. If this part is omitted there is not enough good coal to pay for digging. The same bed was sampled by cleaning the outcrop on the south bank of Holcomb Creek, in sec. 13, T. 6 N., R. 16 E., where for a few rods it has a thickness of 30 inches. The excessive moisture in this analysis is due to the fact that the coal was taken from the outcrop. Aside from the bed being too thin for working, the percentage of ash is objectionably high.

The third sample is from a prospect in the Eagle sandstone at Big Elk. It represents the lower 14-inch bench of a bed which is too small to mine. The high percentage of moisture and ash may be explained in part by the fact that the sample was taken very near the outcrop.

At the head of Sixteenmile Creek a sample was obtained by cutting a groove across the 17-inch upper bench of solid coal and the 26 inches of crushed and dirty coal. The high percentage of ash shown by the analysis is probably contained in this lower part. The exclusion of this lower bench leaves less than 1½ feet of coal, which, although it may be of fair grade, is too thin for exploitation.

The coal-bin sample was intended to represent the character of the coal at the southeast corner of sec. 36, T. 5 N., R. 8 E. Drying for several months under cover has reduced the percentage of moisture, and it is possible that there is less ash than would have been found in a sample cut from the entire thickness of the bed. Although the analysis shows a coal of fair quality, the bed is too thin to mine with profit.

## CONCLUSIONS.

The outcrop of the Eagle sandstone shown on the accompanying map (Pl. V), if compared with the geologic maps of the area in Folio 56, will be seen to resemble the outcrop of the Laramie formation. The discrepancy in age determination is due probably to a lack of fossil evidence on the part of the author of the folio, and the difference in mapping to the difference in the degree of refinement in the field work. Weed was mapping the complex igneous and sedimentary geology of a very large area with one assistant, whereas the writer was studying the Cretaceous of only 1,000 square miles with three assistants. Furthermore, the writer had the benefit in the field of the cooperation of T. W. Stanton, F. H. Knowlton, and A. C. Peale in determining the formation limits, and of Stanton, Knowlton, and

Girty's determinations of a large number of collections of fossils. Considering the manner in which the work was done and the paleontologic evidence which supports it, the writer feels that this later work is more nearly correct. This point will be fully discussed in a bulletin now being prepared by R. W. Stone and L. H. Woolsey on the geology of the Musselshell Valley.

In the legend on the maps in Folio 56 Weed describes the Laramie formation (meaning the Eagle sandstone) as "containing several workable coal seams." In the text he says that the coals have rarely been prospected sufficiently to prove either their character or their thickness. On the basis of Weed's statement that the Laramie is coal bearing in this region and on his acceptance of rumors that the beds are workable, maps of the coal areas of Montana for many years have shown a belt of workable coal beds around the west and north sides of the Crazy Mountains and extending southeastward to Billings. The results of the investigation of this area by the writer seem to prove that although coal is present it does not occur in beds thick enough to mine and consequently has not sufficient economic value to warrant classifying the land as coal land.

# THE RED LODGE COAL FIELD, MONTANA.

By E. G. WOODRUFF.

## INTRODUCTION.

The paper here presented is a preliminary report of a detailed survey of the Red Lodge coal field of Montana.[a] This field receives its name from the town of Red Lodge, which was the place of original development of the field and still continues to be the chief mining center. The investigation of this field was made by the writer under the general supervision of C. A. Fisher and with the assistance of J. E. Carman and E. L. De Golyer. The primary purpose of the survey was to determine the amount of land in the area underlain by workable coal and to segregate and classify such land in plats of 40 acres each. In this investigation the method adopted in the field was to traverse each township on the east-west section lines, locating land corners wherever possible. The outcrops of the various coal beds were meandered in order to locate them with respect to section corners, and their thickness was measured at short intervals. The location of the coal outcrops, the sections measured, and the principal mines in the field are shown on Pl. VI.

The first account of this coal field was given by J. E. Wolff[b] in 1886, and later it was described by W. H. Weed[c] and by G. H. Eldridge.[d] More recent statements concerning it have been written by L. S. Storrs,[e] J. P. Rowe,[f] C. A. Fisher,[g] and N. H. Darton.[h]

## LOCATION AND EXTENT.

The Red Lodge coal field is situated at the foot of the Beartooth Mountains, in Carbon County, Mont. It lies northeast of the Yellowstone National Park, between Yellowstone River and Clark Fork, one

[a] A detailed report is now in course of preparation, to be issued as a separate bulletin of the United States Geological Survey.

[b] Rock Creek coal field: Tenth Census, vol. 15 (report on mining), 1886.

[c] Coal fields of Montana: Eng. and Min. Jour., vol. 53, 1892, pp. 520–522.

[d] A geological reconnaissance in northwest Wyoming: Bull. U. S. Geol. Survey No. 119, 1894, p. 53.

[e] The Rocky Mountain coal fields: Twenty-second Ann. Rept. U. S. Geol. Survey, pt. 3, 1902, pp. 462–463.

[f] Montana coal and lignite deposits: Bull. No. 37, Univ. Montana, 1906, p. 23.

[g] Development of the Bear Creek coal field, Montana: Bull. U. S. Geol. Survey No. 285, 1906, pp. 269–270.

[h] Coals of Carbon County, Mont.: Bull. U. S. Geol. Survey No. 316, 1907, pp. 174–193.

of the main tributaries of the Yellowstone. It extends for a distance of 8 miles from north to south and an equal distance from east to west. About one-half of the area, or 32 square miles, is underlain by workable coal. The beds are known to extend to the northwest beyond Red Lodge, but adjacent to that city they are concealed by material washed down from the mountains. Therefore the western limit of the field as discussed in this report is arbitrarily drawn near that place. Within the coal field there are two centers of production—Red Lodge, a city of 2,000 inhabitants, the terminus of a branch of the Northern Pacific Railway, and Bear Creek, a small coal-mining town on the Yellowstone Park Railroad. These two railroads, which enter the field one from the north and the other from the east, are less than 2 miles apart, but they are separated by topographic features which prevent their connection.

## SURFACE FEATURES.

The Red Lodge coal field consists mainly of hilly country, with a few small interstream areas composed of level, gravel-capped terraces in the southwestern part and on both sides of Rock Creek. The rough country in the eastern and central parts of the field consists of deep, narrow valleys between high, irregular ridges and spurs that have a general northeasterly trend. The area is so irregular that it is traversed with difficulty except along the valleys, and even there travel is interrupted at many places by the steepness of the valley sides or the projection of ledges of rock. To the southwest the hilly country merges into a terrace plain which rises gradually to the foothills of the Beartooth Mountains. To the west also rugged topography gives way to a high terrace remnant which forms a narrow divide between the head of Bear Creek and the valley of Rock Creek. West of Rock Creek there is a broad, gravel-covered terrace considerably lower than the one on the east, which slopes gently northward.

Rock Creek, the largest stream of the field, emerges from a mountain canyon 3 miles above Red Lodge and flows northeastward in a valley one-half mile wide bordered by steep bluffs 100 to 200 feet high. It drains that portion of the field west of the high divide; to the east the drainage flows into Bear, Wolf, and Grove creeks. Bear Creek rises in the west-central part of the field and flows northeastward in a depression which is shallow near the mountains, but which rapidly deepens until in the center of the field this stream and its branches occupy narrow valleys 600 to 700 feet below the valley of Rock Creek at Red Lodge. Wolf Creek, the next stream to the south, is similar to Bear Creek, but much smaller. Grove Creek occupies a broad, shallow valley on the southern edge of the coal-bearing area.

Owing chiefly to the topographic features, two separate mining districts have developed in this field. The first development occurred

at Red Lodge, in the Rock Creek valley, along which a railroad found a natural route. This railroad was barred from entry into the Bear Creek area by the high divide east of Rock Creek and by the relative depression of Bear Creek. Previous to the entry of the other railroad into the Bear Creek district development was very slow, for to deliver coal to the railroad at Red Lodge it was necessary to haul it by teams over the divide above described, which materially increased the cost of production. This difficulty has recently been overcome by the construction of the Yellowstone Park Railroad, which enters the Bear Creek area from the east. Reverse conditions are now to be met, however, in the delivery of mine timber from Red Lodge to the Bear Creek district.

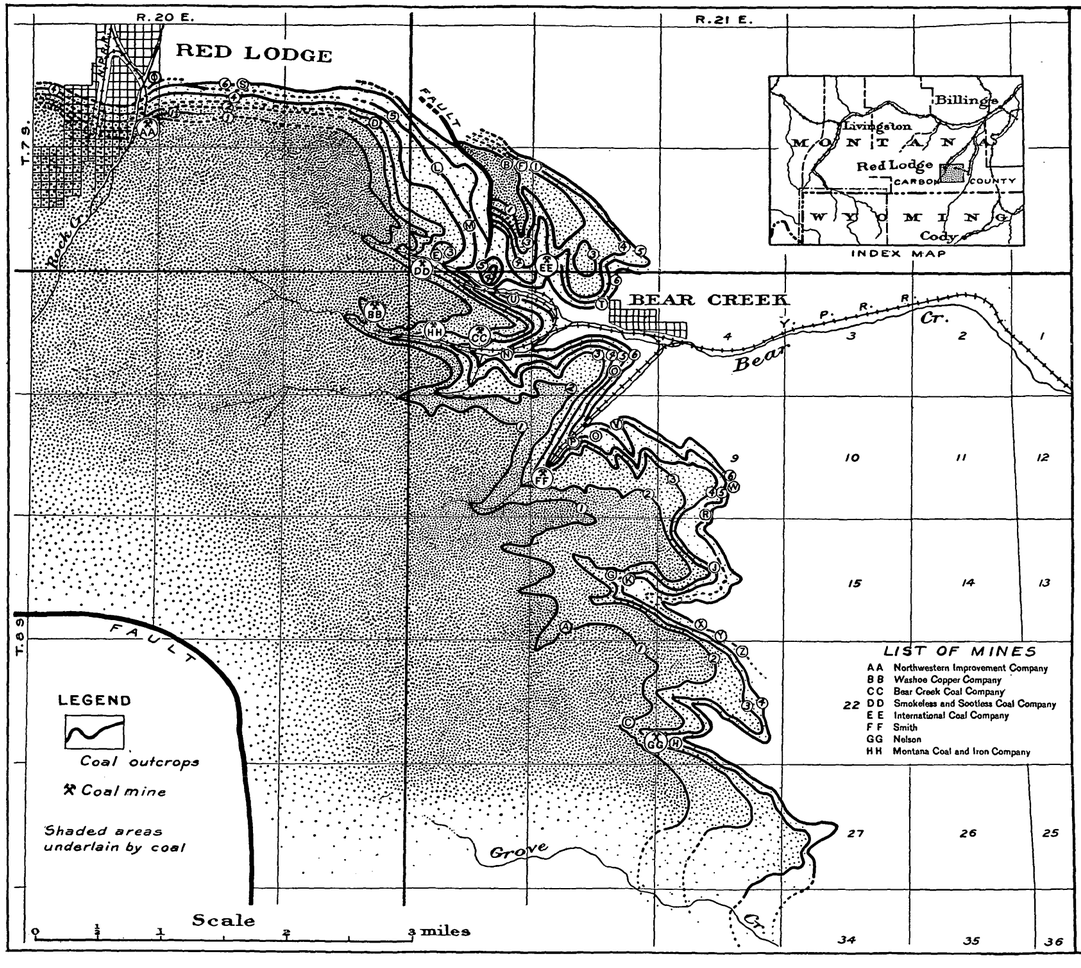
## GEOLOGY.

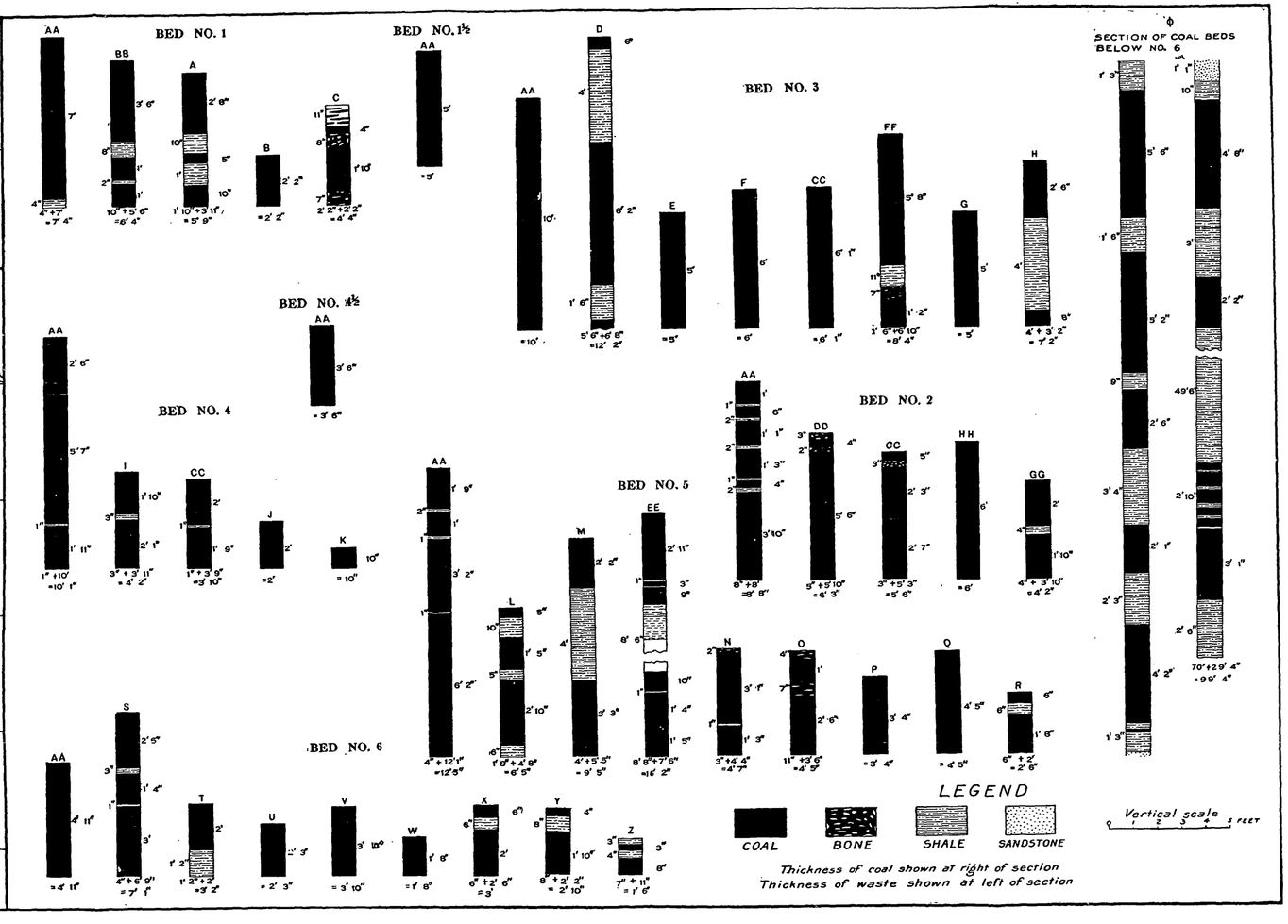
### STRATIGRAPHY.

The sedimentary rocks outcropping in the Red Lodge coal field consist mainly of sandstone and shale of the Fort Union formation, which are cut in a few places by igneous intrusions and are covered in the valleys by alluvium and on some of the interstream areas by gravel. The sandstone and shale of this formation comprise a mass of rocks 8,500 feet thick, in which carbonaceous shale and coal beds are intercalated at various horizons. Workable coal beds, however, are confined to a zone above the middle of the section. For the sake of convenience, therefore, in the following discussion the formation is divided into three parts, depending on the presence or absence of workable coal beds: (1) A lower barren member 5,700 feet thick, the lower part of which is not exposed in the field discussed in this report, but outcrops to the northeast in the region between Bear Creek and Bridger; (2) a middle productive member 825 feet thick; and (3) an upper barren member 1,975 feet thick.

The lowest member is composed mostly of yellowish sandstone and shale. Beginning 1,650 feet above the bottom of the formation is a group of beds 1,000 feet thick, composed of varicolored sandy shale with a few beds of soft yellowish sandstone, numerous beds of carbonaceous shale, and in the upper part a few coal beds, one of which contains 18 to 24 inches of coal. Above this group carbonaceous shale and coal beds occur at diminishing intervals as the productive member is approached, but none of these beds is of workable thickness, and they are therefore not given special consideration in this report.

In the middle productive member of the formation the sandstone and shale resemble the sandstone and shale of the lower member and do not seem to indicate any essential difference in conditions of depo-




MAP AND SECTIONS OF THE RED LODGE COAL FIELD, MONTANA.

By E. G. Woodruff, J. E. Carman, and D. E. Winchester.

sition, but the carbonaceous shale and workable coal beds intercalated with the other rocks serve to distinguish the member. As indicated above, the coal beds of the middle member do not begin abruptly, but are presaged in the lower member by thin beds of coal. At the upper limit of the middle member, however, there is a sharp transition from the productive measures to the barren beds above.

The coal beds were apparently deposited in basins which are believed to have been shallower toward the southwest, because all the coals thin in that direction or merge into carbonaceous shale, whereas to the northwest the beds thicken to the western limit of the field. The present survey was not sufficiently extended to locate the western boundary of the basins in which the coal was laid down, but the indications are that the thickest deposits are at Red Lodge, or possibly a short distance farther west. A section of the productive member of the Fort Union formation as it is exposed on the east side of Rock Creek at Red Lodge is given below.

*Section of coal-bearing beds exposed in east bluff of Rock Creek at Red Lodge, Mont.*[a]

| | Ft. | in. |
|---|---|---|
| Shale, yellowish, with layers of tan sandstone | 22 | |
| Shale, carbonaceous | 5 | |
| Shale alternating with layers of yellowish sandstone | 43 | |
| Shale, carbonaceous, with a few thin layers of coal | 4 | |
| Coal (bed No. 1), not well exposed | 7+ | |
| Shale, carbonaceous | 4–6 | |
| Sandstone, tan, and shale, in alternating layers | 25 | |
| Shale, bluish, with thin layers of rusty sandstone | 35 | |
| Sandstone, gray, with a few thin shale partings | 70 | |
| Shale, drab, with unio shells | 1 | 6 |
| Coal (bed No. 1½) | 5 | |
| Shale, carbonaceous | | 8 |
| Sandstone, yellowish | 2 | |
| Shale, sandy | 17 | |
| Sandstone, yellowish, shaly | 6 | |
| Sandstone, yellow, massive | 18 | |
| Shale, bluish, with carbonaceous material at base | 8 | |
| Coal (bed No. 2), with several thin shaly partings | 4 | 7 |
| Shale, sandy, alternating with thin layers of sandstone | 25 | |
| Sandstone, gray, shaly at top | 12 | |
| Shale, sandy, alternating with layers of sandstone | 16 | |
| Coal (bed No. 3), unexposed; thickness in mine | 10 | |
| Coal, in thin layers, alternating with thick layers of carbonaceous shale | 12 | |

[a] This section was measured along the bluff east of Rock Creek by J. E. Carman. The thicknesses of many of the members disagree with those given in the section on page 181 of Bull. U. S. Geol. Survey No. 316. Mr. Darton informs the writer that the latter section was furnished him by Mr. Pettigrew, manager of the Northwestern Improvement Company's mine. As the coal beds vary in thickness from place to place, measurements taken at different points do not agree, and the difference in the thickness of the coal beds in the two sections may be thus explained.

| | Ft. | in. |
|---|---|---|
| Shale, yellowish, with layers of tan sandstone, more abundant toward the bottom | 26 | |
| Sandstone, with layers of shale showing on weathered surface. In fresh exposures sandstone is massive; gradual transition to more shaly beds toward base | 40 | |
| Sandstone, yellowish, shaly | 5 | |
| Coal (bed No. 4) | 10 | |
| Sandstone, with partings of shale | 7 | |
| Sandstone and shale, thin bedded, 2 to 4 inches, in alternating layers | 9 | |
| Sandstone, gray | 2 | |
| Coal (bed No. 4½) | 5–6 | |
| Shale, yellowish, and rusty sandstone, in alternating layers | 33 | |
| Shale, bluish, sandy | 6 | |
| Shale, sandy, and soft sandstone, in alternating layers | 11 | |
| Shale, bluish, with thin sandy layers | 25 | |
| Shale, carbonaceous | 2 | 6 |
| Coal (beds Nos. 5 and 6), burned out on surface | 6 | |
| Sandstone, tan, massive | 22 | |
| Unexposed, probably shale | 18 | |
| Sandstone, tan, massive | 10 | |
| Shale and standstone in alternating layers | 28 | |
| Shale, bluish | 15 | |
| Coal (this and the following coal beds are included in No. 7) | 5 | 6 |
| Shale, bluish | 1 | 6 |
| Coal | 5 | 2 |
| Shale, carbonaceous | | 9 |
| Coal | 2 | 6 |
| Shale, bluish | 3 | 4 |
| Coal; contains a 3-inch seam of bone near center | 2 | 1 |
| Shale, drab | 2 | 3 |
| Coal | 4 | 2 |
| Shale, carbonaceous, with a 2-inch seam of coal | 1 | 3 |
| Sandstone, gray | 1 | 1 |
| Shale, drab, carbonaceous | | 10 |
| Coal | 4 | 8 |
| Shale, carbonaceous | 3 | |
| Coal | 2 | 2 |
| Shale, dark, carbonaceous | 3 | |
| Sandstone, tan, weathering rusty | 8 | |
| Shale, blue, unexposed in upper part | 36 | |
| Shale, carbonaceous | 2 | 6 |
| Coal; contains several layers of shale | 2 | 10 |
| Coal, good | 3 | 1 |
| Shale, brown, carbonaceous | 2 | 6 |
| Coal, bony at top; contains several partings | 1 | 5 |
| Shale, brown, carbonaecous | 3 | |
| Sandstone | 2 | |
| Sandstone and shale in alternating layers, poorly exposed | 75 | |
| Total coal | 81+ | |
| Total sandstone and shale | 814 | |

The upper barren member of the Fort Union formation is composed, like the lower member, of sandstone and shale, with a very little carbonaceous material. Shale predominates in the lower portion and sandstone in the upper portion. As previously stated, no workable coals are present in this member.

Since the Fort Union sediments were deposited they have been tilted and eroded and in places covered by gravel and alluvium. The terrace deposits, which consist mostly of coarse sand and gravel with bowlders here and there, are spread as a thin covering over the older rocks. They conceal the coal on the flat-topped divide between Bear Creek and Red Lodge, and cover the beds on the west side of Rock Creek. The alluvial deposits are confined to the Rock Creek valley, where they cover the coal beds to a slight extent about Red Lodge.

Small dikes cut the sedimentary rocks and outside of the gravel-covered area form low dark-colored ridges extending in a northwest-southeast direction across the field. The rocks composing these dikes have been examined by Albert Johannsen, of the United States Geological Survey, and found to be camptonite. The dikes are so thoroughly disintegrated that they interfere very little with coal mining where they have been encountered. They seem to have caused no displacement of the strata and to have had little metamorphic effect on the surrounding rocks. Where the beds are cut the coal is affected only for a very short distance from the dike, and anthracitization was not observed at any place, though charred coal was found near the contact.

## STRUCTURE.

Structurally the rocks form part of an eroded monocline which dips southwestward from the Pryor Mountains to the Beartooth Range, where it is terminated by a fault having a throw of several thousand feet. The dip of the beds, which is 18° at Red Lodge, decreases southeastward to 9° in the western part of the Bear Creek region and to 3° a short distance farther south. Near the southern limit of the field the beds are horizontal. They show minor undulations in many parts of the field, and between the International and the Smokeless and Sootless mines are lifted into a small dome, which is slightly elongated in outline and is less than a quarter of a square mile in area. The beds are steeply tilted on the flanks of the dome and arched sharply over the top. A fault breaks the beds on the northwest side near the south line of the SE. ¼ sec. 31, T. 7 S., R. 21 E., and extends irregularly N. 70° W. into sec. 30, where it passes beneath a deposit of gravel. The fault seems to be nearly vertical, with the downthrow on the east. The displacement of the strata on the north side of sec. 31 is between 500 and 600 feet, or sufficient to bring

coal bed No. 1 in contact with coal bed No. 7. The location of the fault and its known extent are shown on Pl. VI, and its effect on the strata is represented in fig. 2. The general structural features from Bridger westward past the International mine to the base of the mountain slope are also shown in the same figure.

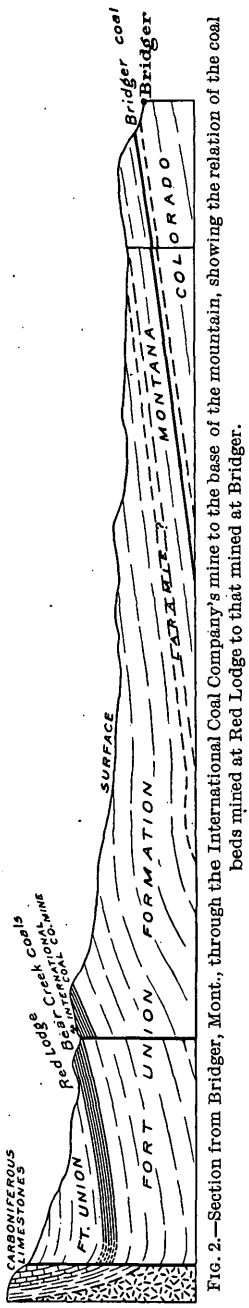



FIG. 2.—Section from Bridger, Mont., through the International Coal Company's mine to the base of the mountain, showing the relation of the coal beds mined at Red Lodge to that mined at Bridger.

## THE COAL.

### GENERAL CONDITIONS.

The coal field is limited on the south by the gradual thinning and pinching out of the beds, on the east and north by the line of outcrop of the lowest bed, and on the southwest by a great fault along the foot of the mountain slope. Northwest of Red Lodge the beds pass beneath the gravel covering of the terrace and continue westward beyond the boundary of the area surveyed. The workable coals have a vertical range of about 800 feet, as shown by the above section, and are limited both above and below by a thick mass of barren strata. Greater detail of the coal-bearing strata may be obtained by reference to the section.

This section shows a total of 71 feet of coal in beds more than 3 feet thick. From point to point the coal beds differ somewhat in thickness and character, but they are not sufficiently variable to be classed as lenticular deposits. In general the individual beds show a tendency to decrease in thickness from northwest to southeast, a condition which is shown by a comparison of the sections given on Pl. VI. Another general characteristic is the predominance of shale as a roof of the coal, though sandstones are of common occurrence. The sandstone roofs are generally wavy and contain weak domelike areas from 1 to 15 feet in diameter, from which the interior easily falls, rendering mining below dangerous. Very little gas accompanies the coal beds, and water is present only in small quantities except where mining is carried beneath streams. Outcrops of coal beds may be traced continuously throughout the field, except where the edge of the bed is covered for short distances by gravel or talus. The coal beds are easily accessible at

many points, but mines are located only along stream courses, where they can be reached by railroad lines. Stratigraphically the coal beds at Red Lodge and Bear Creek are identical and are not of the same age as the coal bed mined at Bridger and Fromberg, being several thousand feet higher. They are, however, of the same geologic age as the coal of the Bull Mountain field and that mined at Sheridan, Wyo. As first worked at Red Lodge the beds were numbered in consecutive order from the top downward, but since these numbers were established a bed (No. 1½) has been found between 1 and 2 and another bed (No. 4½) between 4 and 5. The numbers of the beds given on Pl. VI correspond to those used in the field. As exposed at Red Lodge bed No. 1 contains 7 feet of coal overlain by carbonaceous shale and underlain by 4 to 6 inches of shale above sandstone. Bed No. 1½ contains 5 feet of bright coal with many thin partings and has a sandstone roof and shale floor. Bed No. 2 contains 8 feet of coal in six benches, with partings of shale one-half to 1 inch thick. It rests upon shale and is covered by sandstone. Bed No. 3 contains 10 feet of dirty coal not worked at present. Bed No. 4 has 10 feet of good coal occurring in three benches, with a parting 1 inch thick 23 inches below the top. This bed is underlain by sandstone and covered by gray shale. Bed No. 4½ is composed of 3½ feet of coal which occurs in several benches and has shale both above and below, rendering mining so difficult that little coal is now taken from this bed. Bed No. 5 contains 12 feet 1 inch of coal in four benches, with partings one-half to 2 inches thick, and lies between beds of hard shale. Bed No. 6 shows 4 feet 11 inches of coal in a single bench, with both roof and floor composed of sandstone. The coal below bed No. 6 is not worked at present and is placed in one group because the interval between the beds is not sufficient to allow any one coal to be mined without disturbing those above.

Mining is generally conducted by the room and pillar system, the size of the rooms and pillars varying according to local conditions. Water is pumped from the mine at Red Lodge and from one mine in the Bear Creek district; the other mines are dry enough for mining but contain sufficient moisture to obviate sprinkling. As gas is present only in small quantities, open lights are used in all the mines. Most of the mines require powder, but in two of them the coal is so jointed that vertical columns may be extracted by undermining and prying down. Mining is done by hand except in the mine of the Bear Creek Coal Company on bed No. 3, where electric machines are also used. About 1,000 miners are now employed in the field, working under the wage scale fixed by the Montana Coal Operators' Association and the United Mine Workers of America in joint convention.

Owing to the peculiar topographic features discussed above the development of this field began on the west side of the divide, around Red Lodge, and has recently been extended to the east side, on the headwaters of Bear Creek and its branches.

### RED LODGE DISTRICT.

Coal has been mined in the Red Lodge district for more than twenty-five years. The first mine was opened previous to 1882, but up to 1889 operations were conducted on a small scale. In the latter year the output was 6,000 tons, and it has steadily increased until in 1905 590,035 tons were mined in a working period of 302 days, with 480 men employed inside and 120 outside.[a]

The mine at Red Lodge owned by the Northwestern Improvement Company is located on the east side of Rock Creek. The main opening of the mine is in a bluff that rises steeply back of the mine buildings. The underground workings are reached by one main gangway, which extends 2,500 feet down the dip on bed No. 4. Crosscuts lead to the beds above and below and entries extend along the strike. The entries are mostly worked near the main gangways, but one long entry extends 1½ miles to the east and another passes beneath Rock Creek, extending an equal distance to the west. A large number of entries have been opened along the beds, and the adjacent rooms have been worked out, so that now the underground workings cover a considerable area. Coal has been mined from beds Nos. 1, 1½, 2, 3, 4, 4½, 5, 6, and 7, but the main operations have been confined to Nos. 1, 2, and 4.

The mine is well equipped, with electric and mule haulage in the rooms and entries and cable haulage in the main gangway. Water is removed from the mine by a pump operated by electricity, installed at a low point near the bottom of the main gangway, and all the main entries are provided with electric lights. The mine cars are brought from the mine to the tipple, where they are unloaded by rotary dump into a chute which leads to a shaking screen, from which the coal passes to picking tables where the lump coal is assorted for shipment. The lump coal is loaded directly into coal cars or into box cars by a gravity box-car loader, and the screenings are sent to a washer, where the impurities, which consist of shale, bone, and pieces of sandstone, are removed. Steam and electricity are generated by an extensive power plant located near the mouth of the mine.

During the fall of 1907 a new mine was opened and buildings were constructed at the edge of the terrace on the west side of the town. From this mine it is planned to work the various beds to the west. The foundations for a large tipple and other outside buildings have been laid, and when this plant is completed and in operation it

[a] McDermott, J. B. Bienn. Rept. Inspector of Coal Mines of Montana, 1905-6.

will materially increase the total coal production of the Red Lodge district.

## BEAR CREEK DISTRICT.

*General statement.*—Five coal companies are operating in the Bear Creek district. They are the Washoe Copper Company, Montana Coal and Iron Company, Bear Creek Coal Company, Smokeless and Sootless Coal Company, and International Coal Company. In addition to the mines of these companies, development for an extensive mine is in progress in Foster Gulch, and a small opening known as the Nelson mine is operated in Taggart Gulch. The location of these mines is shown by the double-letter symbol on Pl. VI.

*Washoe Copper Company.*—The Washoe Copper Company owns two mines known as No. 1 and No. 2, in the N. ½ sec. 1, T. 8 S., R. 20 E., near Washoe, a post-office recently established between Red Lodge and Bear Creek. Mine No. 1, the larger of the two, is on bed No. 1, which at this mine has a thickness of 6 feet. The beds dip slightly to the southwest and the main gangway extends to the northeast, so that the coal is easily brought to the surface. In February, 1908, the main gangway east had been extended 1,000 feet with 13 rooms, the main gangway north 1,100 feet with two entries and 33 rooms, and the main gangway south 425 feet with 17 rooms. Mine cars are hauled by horses from the mine to the tipple, which is fitted with a tip and screens with bars 1½ inches apart.

During the fall of 1907 mine No. 2 was opened in the valley of Kicking Creek by a double-entry slope 375 feet long on a 30° dip to bed No. 1, where entries were opened, but no mining had been done previous to February, 1908. This mine is equipped with hoisting engine, boilers, etc. According to reports it is the plan of the company to carry the slope to lower beds and operate extensively from this one slope. Pumps are necessary, for water is encountered where the workings extend below the bed of the creek. A force of about 170 men is now employed at both mines, and it is reported that this company has already produced over 15,000 tons of coal for the Butte market.

*Montana Coal and Iron Company.*—The mine of the Montana Coal and Iron Company is located near the center of the W. ½ sec. 6, T. 8 S., R. 21 E., on a spur of the Yellowstone Park Railroad. It consists of a main gangway and air course 925 feet long, extending toward the northwest. Two entries run east, one only a short distance, the other 550 feet, with 19 rooms. The mine is provided with tipple, box-car loader, shops, and necessary buildings. About 40 miners and 15 outside men are employed. It is reported that 18,000 tons of run-of-mine coal have been sold for domestic and steaming purposes, most of which was shipped to towns along the Northern Pacific Railway.

*Bear Creek Coal Company.*—The mines of the Bear Creek Coal Company are located on the north side of Bear Creek, 1½ miles west of the mining town of the same name. Beds Nos. 2, 3, and 4 have been opened, and Nos. 2 and 3 are now worked. The conditions for mining these beds are very favorable, because they lie nearly horizontal and carry no water and little gas. In the first entry east on bed No. 3 there is one of the small folds mentioned on page 97, in which the crest rises only a few feet above the level and the steepest limb dips 13° NE. It elevates the coal slightly, but does not interfere materially with mining. The most extensive underground workings are on bed No. 3, where a main gangway has been driven 1,200 feet and three entries and 62 rooms have been opened. Mining is done by hand and by two electric chain machines. Electricity is used to light the main passageways, to propel the haulage motors, and to run the ventilating fans. The mine on bed No. 2 has similar but less extensive development than the one on No. 3. The columnar jointing of bed No. 2, previously described, aids in taking out the coal. The outside equipment of these mines consists of a large tipple, inclined stationary screens, a box-car loader, and an extensive power plant. Tram tracks upon which motor engines are operated connect the tipple with the mines. The output of screened coal from these mines is about 500 tons per day.

*Smokeless and Sootless Coal Company.*—The mine of the Smokeless and Sootless Coal Company, on bed No. 2, is located near the head of Virtue Creek, on the north side of the Bear Creek district. This mine is now being developed. Two main gangways are being driven, one of which leads to the west and the other to the southwest. A tipple, screens, and a power plant have recently been built near the mouth of the mine, on a spur of the Yellowstone Park Railroad. The coal is undercut by hand and shot down with powder. It is brought to the surface by mule and rope haulage. Columnar structure is exhibited in this mine, but is not of particular service in mining the coal, as it is in other mines in this district, because the jointing is not sufficiently developed to permit the columns to loosen readily. As the coal comes from the mine it is separated into lump and nut sizes. The nut is sold for steaming purposes, and the lump goes to the domestic trade. From this mine the coal is shipped to towns along the Northern Pacific Railway between Billings and Missoula and in northern Idaho. Since the mine was opened, about two years ago, 10,000 tons of coal have been produced. A force of 30 miners and 10 outside men is employed.

*International Coal Company.*—The mine of the International Coal Company is in the northwestern part of the Bear Creek district, in

the S. ½ secs. 31 and 32, T. 7 S., R. 21 E. The mine, which is on bed No. 5, has one main gangway, with numerous side entries. The room-and-pillar system of mining is commonly used; the long-wall method was tried and proved unsuccessful, because of the bad character of the roof. The coal is mined by bearing in at a small parting 8 inches above the floor and by prying down the columns, which are formed by two sets of intersecting joints. This structure is so well developed that when the beds are worked along the cleat only a small amount of powder is necessary in mining. A tipple is located on a spur of the Yellowstone Park Railroad about 1,000 feet from the mine entrance. An incline, on which the mine cars are operated by gravity, leads from the mine to the tipple. The total production is about 15,000 tons, most of which has been the result of development work. The company employs 50 miners and 10 outside men.

*Foster Gulch prospect.*—Preliminary development is now in progress in Foster Gulch, which lies southwest of Bear Creek. Two main entries have been opened on bed No. 3, a railroad spur has been constructed, and preparations have been made for a larger plant.

*Nelson mine.*—The Nelson mine is a small opening on bed No. 2, in Taggart Gulch, 3½ miles south of Bear Creek. This mine is worked by hand to supply coal to neighboring ranches. About 600 tons a year are sold at $3 per ton.

## CHARACTER OF THE COAL.

### PHYSICAL PROPERTIES.

The coals in this field have a black color, pitchy luster, and well-developed though irregular joints. They are medium in hardness and relatively free from injurious impurities. They are about as bright in appearance as some of the bituminous coals of Pennsylvania, and, unlike some of the subbituminous coals, do not lose their luster when exposed to the air for a short time.

The coal breaks along smooth joint faces with no pronounced conchoidal fracture. There is an exception, however, in the coal from bed No. 2, which breaks with an irregular surface, giving a granular appearance to fresh fractures very similar to that of some of the coals of West Virginia. In mining the coal breaks into small blocks or columns. In certain beds, as No. 2 in the mine of the Bear Creek Coal Company, the columnar structure is highly developed. In that mine the columns, which are irregular in basal outline, range from 1 inch to 24 inches in diameter and extend across the bench. When taken from the mine they can be piled up like sticks of wood. In general the coal is so well jointed that it can be broken into marketable

sizes with only a small percentage of fine coal or slack. The coals are about equal in hardness to the average subbituminous coals. They are about the same in this respect as the coals mined at Bridger, Mont., harder than those at Sheridan, Wyo., and softer than the bituminous coals of the East. They are indistinctly banded with layers of dull coal. Small accretions of clear brown resin are distributed irregularly through the coal. They appear generally in globular form less than one-fourth inch in diameter, though some exceptionally large ones measure as much as 1½ inches. When broken they appear as brown spots in the black coal.

The coal is free from pyrite nodules, but contains other impurities which produce ash on burning. Dirt occurs as partings too thin to be separated in mining and mixed with coaly matter in thin dull-colored lenses in the good coal. Some of these impurities can be taken out by washing, and in that way coals which are not mined at present could be put on the market. The Red Lodge mine is the only one in the field equipped with a washing plant, and there, as at other mines, it is found to be more economical to leave untouched the beds containing much dirt than to mine and clean the coals before shipment.

According to the classification of coal adopted by the United States Geological Survey, these coals are high-grade subbituminous,[a] closely approaching the bituminous class. The coal usually cleaves in small blocks and at some places breaks into prisms, but weathering generally develops the platy structure along the bedding planes. They do not stock well and are therefore placed below the bituminous class, though in heat value they approach some of the bituminous coals of the Mississippi Valley.

## CHEMICAL PROPERTIES.

The composition of the coal of the Red Lodge field is shown by the following analyses, made under the direction of F. M. Stanton, of the United States Geological Survey. Samples were taken according to the method described by M. R. Campbell in the introduction to this volume (pp. 12–13). The table shows the analysis of each sample as received and also after air drying. The former represents the coal as it comes from the mine, and the latter more nearly indicates the condition of the coal in the market and as it is burned. For the sake of comparison, therefore, the analyses of the air-dried samples should be used.

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

*Analyses of coal samples from the Red Lodge field, Montana.*

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

RED LODGE DISTRICT.[a]

| Name of coal bed | No. 1. | No. 1½. | No. 2. | No. 4. | | No. 5. | No. 6. |
|---|---|---|---|---|---|---|---|
| Laboratory No | 3590 | 3592 | 3588 | 3595 | 3591 | 3593 | 3594 |
| Sample as received: | | | | | | | |
| Prox. Moisture | 11.69 | 14.07 | 11.26 | 11.33 | 11.22 | 10.38 | 10.55 |
| Prox. Volatile matter | 36.14 | 33.46 | 34.08 | 34.22 | 36.43 | 35.98 | 36.39 |
| Prox. Fixed carbon | 40.19 | 42.51 | 43.26 | 44.04 | 45.38 | 40.62 | 43.02 |
| Prox. Ash | 11.98 | 9.96 | 11.40 | 10.41 | 6.97 | 13.02 | 10.04 |
| Ult. Sulphur | 1.05 | 2.05 | 1.14 | 1.59 | .83 | 1.89 | 2.23 |
| Ult. Hydrogen | 5.26 | ..... | ..... | ..... | ..... | ..... | ..... |
| Ult. Carbon | 55.46 | ..... | ..... | ..... | ..... | ..... | ..... |
| Ult. Nitrogen | 1.20 | ..... | ..... | ..... | ..... | ..... | ..... |
| Ult. Oxygen | 25.05 | ..... | ..... | ..... | ..... | ..... | ..... |
| Calories | 5,437 | ..... | ..... | ..... | ..... | ..... | ..... |
| British thermal units | 9,787 | ..... | ..... | ..... | ..... | ..... | ..... |
| Loss of moisture on air drying | 4.70 | 5.60 | 4.00 | 4.40 | 4.00 | 4.20 | 3.90 |
| Air-dried sample: | | | | | | | |
| Prox. Moisture | 7.34 | 8.97 | 7.56 | 7.25 | 7.52 | 6.45 | 6.92 |
| Prox. Volatile matter | 37.92 | 35.45 | 35.50 | 35.79 | 37.95 | 37.56 | 37.87 |
| Prox. Fixed carbon | 42.17 | 45.03 | 45.06 | 46.07 | 47.27 | 42.40 | 44.76 |
| Prox. Ash | 12.57 | 10.55 | 11.88 | 10.89 | 7.26 | 13.59 | 10.45 |
| Ult. Sulphur | 1.10 | 2.17 | 1.19 | 1.66 | .86 | 1.97 | 2.32 |
| Ult. Hydrogen | 4.97 | ..... | ..... | ..... | ..... | ..... | ..... |
| Ult. Carbon | 58.20 | ..... | ..... | ..... | ..... | ..... | ..... |
| Ult. Nitrogen | 1.26 | ..... | ..... | ..... | ..... | ..... | ..... |
| Ult. Oxygen | 21.90 | ..... | ..... | ..... | ..... | ..... | ..... |
| Calories | 5,705 | ..... | ..... | ..... | ..... | ..... | ..... |
| British thermal units | 10,270 | ..... | ..... | ..... | ..... | ..... | ..... |

[a] All sampled by J. P. Rowe.

BEAR CREEK DISTRICT.

| Name of coal bed | No. 1. | No. 2. | | No. 3. | | No. 4. | No. 5. |
|---|---|---|---|---|---|---|---|
| Laboratory No | [a] 5821 | [b] 3620 | [a] 5820 | [c] 4008 | [d] 5822 | [c] 4007 | [d] 5823 | [d] 5819 |
| Sample as received: | | | | | | | | |
| Prox. Moisture | 8.74 | 10.05 | 9.67 | 9.60 | 8.60 | 8.97 | 9.80 | 9.31 |
| Prox. Volatile matter | 34.99 | 37.22 | 35.92 | 36.88 | 34.52 | 36.11 | 34.74 | 34.14 |
| Prox. Fixed carbon | 45.72 | 46.71 | 46.39 | 47.10 | 43.57 | 43.18 | 47.19 | 45.87 |
| Prox. Ash | 10.55 | 6.02 | 8.02 | 6.42 | 13.31 | 11.74 | 8.27 | 10.68 |
| Ult. Sulphur | 2.93 | 1.44 | 1.64 | 2.35 | 2.78 | 3.02 | 2.17 | 1.99 |
| Ult. Hydrogen | 5.49 | 5.41 | 5.52 | ..... | 5.05 | ..... | 5.20 | 5.24 |
| Ult. Carbon | 59.59 | 59.64 | 61.66 | ..... | 56.94 | ..... | 60.20 | 59.54 |
| Ult. Nitrogen | 1.24 | 1.40 | 1.48 | ..... | 1.43 | ..... | 1.42 | 1.34 |
| Ult. Oxygen | 20.20 | 26.09 | 21.68 | ..... | 20.49 | ..... | 22.74 | 21.21 |
| Calories | 5,891 | 6,219 | 6,018 | ..... | 5,657 | ..... | 6,046 | 5,818 |
| British thermal units | 10,604 | 11,194 | 10,832 | ..... | 10,183 | ..... | 10,883 | 10,472 |
| Loss of moisture on air drying | 2.50 | 2.00 | 4.10 | 2.60 | 2.50 | 2.10 | 3.30 | 3.40 |
| Analysis of air-dried sample: | | | | | | | | |
| Prox. Moisture | 6.40 | 8.22 | 5.81 | 7.19 | 6.26 | 7.02 | 6.72 | 6.12 |
| Prox. Volatile matter | 35.89 | 37.98 | 37.46 | 37.86 | 35.40 | 36.88 | 35.93 | 35.34 |
| Prox. Fixed carbon | 46.89 | 47.66 | 48.37 | 48.36 | 44.69 | 44.11 | 48.80 | 47.48 |
| Prox. Ash | 10.82 | 6.14 | 8.36 | 6.59 | 13.65 | 11.99 | 8.55 | 11.06 |
| Ult. Sulphur | 3.01 | 1.47 | 1.71 | 2.41 | 2.85 | 3.08 | 2.24 | 2.06 |
| Ult. Hydrogen | 5.35 | 5.29 | 5.28 | ..... | 4.89 | ..... | 5.00 | 5.03 |
| Ult. Carbon | 61.12 | 60.86 | 64.30 | ..... | 58.40 | ..... | 62.25 | 61.63 |
| Ult. Nitrogen | 1.27 | 1.43 | 1.54 | ..... | 1.47 | ..... | 1.47 | 1.39 |
| Ult. Oxygen | 18.43 | 24.81 | 18.81 | ..... | 18.74 | ..... | 20.49 | 18.83 |
| Calories | 6,042 | 6,346 | 6,275 | ..... | 5,802 | ..... | 6,252 | 6,023 |
| British thermal units | 10,876 | 11,422 | 11,295 | ..... | 11,444 | ..... | 11,254 | 10,841 |

[a] Sampled by J. E. Carman.
[b] Sampled by J. P. Rowe.
[c] Sampled by N. H. Darton.
[d] Sampled by E. G. Woodruff.

A comparison of the analyses in the above table indicates that the Red Lodge coals have more moisture than the Bear Creek coals. It

should be noted, however, in making these comparisons, that the samples are from different parts of one field, and not from beds which occupy different stratigraphic positions. In volatile matter there is only a slight difference between the Red Lodge and the Bear Creek coals. The fixed carbon of the Red Lodge samples is slightly below that of the others in the table. The ash content is about the same in all the samples. In general, the analyses show that the Bear Creek coals are better than the Red Lodge coals, though there is only a slight difference.

The coals of the Red Lodge field contain an average on air-dried samples of 36.8 per cent of volatile matter and 46 per cent of fixed carbon. Sulphur ranges from 0.86 to 3.18 per cent. The amount of ash is rather high. The coal ignites readily and burns freely without fusion. Analyses of coals from adjacent and competing fields are given by other writers in this volume, and by means of these the coals from the Red Lodge field may be compared with other coals entering the same market.

### AMOUNT OF COAL AVAILABLE.

Only a general estimate of the amount of coal available in the Red Lodge field can be made, because of the meager knowledge of the beds at places where they are covered. Their condition along the fault at the foot of the mountains is also uncertain. If we consider that none of the coal in the field lies below workable depths, and that the exposures represent the general condition over the field, an approximation may be obtained by assuming that a layer of coal 45.3 feet thick[a] is spread evenly over 24 square miles, the area of the productive part of the field, and that the specific gravity of the coal is 1.3. Such an assumption gives 1,238,896,581 short tons. As this enormous tonnage conveys only a vague notion of the amount of coal within the field, perhaps a clearer idea may be obtained by supposing that the coal if placed in a single block would form a body 1 mile square and one-fifth mile high.

### MARKETS.

The mines of the Red Lodge field supply coal extensively to the Northern Pacific Railway, to smelters near Butte and Anaconda, and to an extensive domestic trade. The output of the Northwestern Improvement Company's mine at Red Lodge is shipped to points as far east as Bismarck, N. Dak., and west to the Idaho-Washington line. The coals shipped from this field come into competition with the product of several fields in Montana and northern Wyoming, but they are of sufficiently high grade to be successful in the competition.

[a] An average of the coal sections measured throughout the field gives 45.3 feet.

In the area over which the coal is distributed there are no extensive coal-consuming plants except the smelters at Butte and Anaconda, hence it is probable that the utilization of the coal will remain as it is now for locomotive fuel, smelting, and domestic purposes. The price at the mine for lump coal averages about $2.50, but some nut coal is sold as low as $1 per ton.

## FUTURE DEVELOPMENT.

The field described in this report is entering on a period of extensive development, with promise of continued and steady production for many years. The coal lies in a structural basin the form of which as described above probably permits mining under the entire area. It is expected that only a small amount of water and little gas will be encountered. The adjacent mountain slopes are covered by forests which will furnish mine timber for a long period. With the quantity of coal certain and the possibility of extraction assured, the remaining important factor—a field of consumption—is of importance. Domestic consumption is continually being increased by the establishment of many irrigation plants, which aid the growth of population, with an accompanying demand for fuel. The climate of the region is such that fuel for heating is required during the greater part of the year. The coals are best adapted to domestic use. They fire readily, break easily into lump and nut sizes, and are not very sooty. They are good steaming coals, but in locomotives the strong draft forces many of the small unburned particles out of the stacks.

# THE LEWISTOWN COAL FIELD, MONTANA.

By W. R. CALVERT.

## INTRODUCTION.

The present paper, which is to be considered as a preliminary statement,[a] sets forth briefly the results of a detailed survey of the Lewistown coal field made in the summer of 1907 by Eugene Stebinger, J. B. Umpleby, and the writer, under the general supervision of C. A. Fisher. As the primary object of the investigation was the classification of the public lands with respect to coal, the work was conducted with a view of ascertaining the extent of coal areas and their relation to legal land subdivisions. In the central and western parts of the field railroad profiles gave excellent vertical control; in the northeastern part the Geological Survey has run several lines of level and determined many elevations. The accompanying map (Pl. VII) is introduced chiefly to show the relation of the coal outcrop and coal areas to land subdivisions. The detailed information acquired in the course of the work, concerning the geology and coal resources of the region, will appear in the final report.

The Lewistown coal field has not been examined in detail by previous workers. In 1879 Eldridge[b] traced the coal outcrop westward from Judith River to Belt Creek, but only brief mention of the coals of the Lewistown field is made in his report. Weed and Pirsson,[c] in their report on the Judith Mountains, discuss at some length the coal in the vicinity of that uplift. Various other geologists also have made brief reference to this coal field.

## LOCATION AND EXTENT.

The Lewistown coal field, as herein described, comprises not only the limited district near Lewistown, where considerable development has taken place, but also the western extension of that district, connecting with work done the previous year in the Great

[a] A full report on this coal field is now in course of preparation, and will appear as a separate publication of the Geological Survey.

[b] Eldridge, G. H., Montana coal fields: Tenth Census, vol. 15, 1886, pp. 740–757.

[c] Weed, W. H., and Pirsson, L. V., Geological and mineral resources of the Judith Mountains, Montana; Eighteenth Ann Rept. U. S. Geol. Survey, pt. 3, 1898, pp. 443–621.

Falls areas.[a] The territory investigated lies between longitude 109° and 110° 15′ W., and the 47th parallel divides it into two nearly equal portions. It is thus located in the center of Montana, including the west-central part of Fergus County and a few square miles of northeastern Meagher County. The greater part of the field lies in the Judith Basin, a name applied to the upper drainage area of Judith River, but it also includes a strip along the headwaters of McDonald Creek and a portion of the Great Plains region lying east of Judith Mountains. The Little Belt and Big Snowy mountains are in the southern part of the field and the Judith and South Moccasin groups lie well within its northern borders. The area as described includes about 1,500 square miles.

## TOPOGRAPHY.

The topography of the field is somewhat diversified. In the western half the surface features are essentially those of a plains region, which is but slightly dissected. Judith River and its main tributary from the south, Ross Fork, flow through this district and, with their branches, have accentuated the surface of the structural basin formed by the encircling uplifts of the Little Belt, Big Snowy, Judith, and South Moccasin mountains. The Little Belt Range, bordering the southwestern part of the field, presents a bold northern face, and there is, in consequence, but a narrow transitional zone between plains and mountain topography in that district.

In contrast to the Little Belt Range, the Big Snowy Mountains recede to the north in long slopes which are deeply trenched by streams. This dissected surface is characteristic of much of the eastern part of the field, especially in the vicinity of the connecting ridge between the Big Snowy and Judith mountains, which will be referred to in this report as the McDonald Creek divide. The Judith and Moccasin mountains are fairly rugged and rise rather abruptly from the plains. Higher peaks in the Judith uplift approximate 6,000 feet in altitude; those of the Moccasin Mountains are somewhat lower. The greatest altitude is in the Little Belt Range, where two summits reach 7,400 feet above sea level. The plains range in altitude from 3,600 to 5,000 feet.

In general the topography of the field favors development of the coal, as the streams cut across the coal zone in many localities, allowing access to the outcrop, and the valleys serve as natural routes for transportation. The broad terraces in the western part of the field afford easy routes for railroads, and as a result the Montana Railroad reaches Lewistown from the southwest through Judith Gap with scarcely a cut or fill within the field.

[a] Fisher, C. A., The Great Falls coal field, Montana: Bull. U. S. Geol. Survey No. 316, 1907, pp. 161–173.

## GEOLOGY.

### STRATIGRAPHY.

The rocks of the Lewistown coal field range in age from lower Carboniferous to Quaternary, inclusive. Workable coal in this region occurs at only one horizon, which is near the base of the Kootenai formation, of Lower Cretaceous age. In one locality a thin bed of coal was noted in the Quadrant formation, the upper part of the Carboniferous (?). A lignitic shale also occurs just below the heavy bed of the Eagle sandstone, the lowest member of the Montana group, but it is improbable that either the Quadrant or the Eagle formation will yield coal of workable thickness anywhere within the area described. The succession of the rocks and the relation of the principal coal-bearing beds to strata above and below are shown in the following generalized section:

*Generalized section of sedimentary rocks in the Lewistown coal field.*

| | Feet. |
|---|---|
| Claggett formation (Upper Cretaceous): White and brown sandstone in lower part and greenish, sandy shale above. | |
| Eagle sandstone (Upper Cretaceous): | |
| Shale, dark bluish, containing carbonized wood fragments | 5 |
| Sandstone, soft, yellowish, cross-bedded, containing iron concretions and woody fragments | 53 |
| Sandstone, soft, white, usually without bedding | 170 |
| Sandstone, white, with coaly layer at top | 10 |
| Colorado shale (Upper Cretaceous): | |
| Shale, dark gray to black, with a few thin, sandy members | 720 |
| Sandstone, hard, greenish, weathering brown, fine grained, ferruginous | 3 |
| Shale, dark gray to black, with a hard bed 420 feet above base | 675 |
| Sandstone, grayish brown, thinly bedded, containing an abundance of fish scales (supposed Mowry) | 47 |
| Shale, dark gray to black, alternating hard and soft layers | 890 |
| Sandstone and shale, alternating, brownish in color throughout | 25 |
| Kootenai formation (Lower Cretaceous): | |
| Shale, maroon, argillaceous | 200 |
| Sandstone, grayish, coarse grained, cross-bedded | 8 |
| Shale, maroon, argillaceous | 60 |
| Sandstone, gray, coarse grained, cross-bedded | 25 |
| Shale, maroon, argillaceous | 72 |
| Sandstone, massive, coarse grained to pebbly, weathering soft gray | 50 |
| Coal and coaly shale | 10 |
| Shale and sandstone, alternating; the shale is sandy and the sandstone thinly bedded | 87 |
| Morrison formation (Jurassic?). | |

The above section, being compiled from measurements made in several places in the field, should not be considered as a type of any one locality.

# MAP OF THE LEWISTOWN COAL FIELD, MONTANA

By W R Calvert and E Stebinger

## LIST OF MINES

| | | | |
|---|---|---|---|
| 1 SHOWAN | 10 BLACK DIAMOND | 19 LEWIS | 28 PEIPER |
| 2 DOVER (Abandoned) | 11 COX | 20 SHEARSON | 29 HILL |
| 3 WILLIAMS | 12 HAMILTON | 21 SHIPLEY (Abandoned) | 30 HOBSON |
| 4 SAAGER CANYON | 13 SHARP | 22 SHEARSON | 31 MUSHER (Abandoned) |
| 5 SHARP | 14 " | 23 CLIFFE | 32 BREW & PARSON |
| 6 COOPER | 15 FLAHERTY | 24 (Abandoned) | 33 NEVIN |
| 7 RAND | 16 " | 25 | 34 NEW YEAR |
| 8 KNOX | 17 MC D Cr F Co (Abandoned) | 26 " | 35 MACE |
| 9 SPRING CREEK | 18 COMPANY | 27 SHERMAN | 36 (Abandoned) |
| | | | 37 FERGUS (Abandoned) |

## LEGEND

- Outcrop of coal-bearing formation above coal zone, which is indicated by heavy line
- Area probably underlain by workable coal
- Spring deposit
- Dip and strike
- Coal mine
- Coal prospect
- Road

Scale 1 0 1 2 3 4 5 6 miles

INDEX MAP

The Colorado shale decreases in thickness northward from the Big Snowy Mountains, for a section of that formation to the south of the uplift shows that the interval between the Kootenai red shale and the Eagle sandstone is 2,400 feet, whereas the same interval 15 miles northeast of Lewistown is less than 1,600 feet.

Throughout the field the Kootenai is fairly uniform in thickness, although the individual members comprising the formation vary locally. As a formation it is readily distinguished by the bright, maroon-colored shales and by the coarsely cross-bedded sandstone just above the coal. This sandstone in many places produces marked topographic features, standing out in bold ridges, which are usually timbered with pines. So characteristic is the association of pines and other vegetation with this sandstone, especially where it is exposed over a considerable area, that the growth serves as a valuable guide in the search for coal.

In the vicinity of the Moccasin Mountains and to the south of the Judith uplift, along the McDonald Creek divide, certain areas are overlain by a massive white limestone from 50 to 250 feet thick, which locally resembles the upper member of the Madison limestone. Its structural relations, however, as well as the character of the rock, preclude the possibility that it belongs to the Carboniferous system; it represents instead remnants of a formerly extensive hot-spring deposit. The fact that hitherto it has been considered as Madison limestone has delayed to some extent the development of coal in certain localities. This is especially true with reference to Flat Mountain, the southernmost extension of the Judith uplift, where it was believed that the coal bed would be cut off by the limestone within a short distance from the outcrop. Wherever the spring deposit overlies the coal-bearing formation, however, there seems no reason to conclude that mining conditions are rendered especially unfavorable thereby.

## STRUCTURE.

### MAJOR FEATURES.

The structure in the western part of the Lewistown coal field is relatively simple, the beds dipping at a slight angle away from the Little Belt and Big Snowy mountains. In general this relation prevails throughout the area west of Judith River and Ross Fork up to the very base of the Little Belt Range, where the strata stand practically vertical or even dip at a high angle to the south. The structure of the east end of this range, therefore, is that of an anticline overturned to the north. The Big Snowy Mountains are also anticlinal in structure and are apparently slightly overturned to the south near their west end. North of these mountains the strata in general dip away from the uplift at a low angle. The ends of the

Little Belt and Big Snowy anticlines extend somewhat past each other and are connected across Judith Gap by a sharply folded anticline with curving axis.

In contrast with the ranges above described the Judith and Moccasin mountains present quite different structural features, being laccolithic in type. Erosion has removed the softer Mesozoic strata from these uplifts, exposing Paleozoic or igneous rocks, and as a result the coal-bearing rocks encircle them, the continuity of the coal outcrop being broken here and there by irregular igneous masses.

### MINOR FEATURES.

*Folds.*—In addition to the large folds of the Little Belt and Big Snowy ranges, numerous smaller folds are developed in their vicinity, one of which is cut through by Saager Canyon. Near Judith Gap there has been considerable folding, the convolutions usually not influencing the topography to any great extent. In the district southeast of Lewistown minor folds also occur.

*Faults.*—Ten faults of considerable magnitude were noted in the field. The most disturbed district is between the forks of Big Spring Creek in T. 14 N., R. 19 E., where a block fault about 6 miles long, trending northeast-southwest, ends suddenly in sec. 3 in an anticline with its axis at right angles to the line of fault. To the west the faults run together near the southern limits of the field in sec. 36, T. 14 N., R. 18 E. The block is about half a mile wide. A third fault also ends near the anticline above mentioned and extends northeastward to sec. 23, T. 15 N., R. 19 E. Several faults occur in the vicinity of the Moccasin Mountains, and one of considerable length crosses Deer Creek in T. 17 N., R. 19 E. A rather unusual fault occurs near the south end of the Judith Mountains, and is known as the Kelly Hill fault.[a] It is about 2 miles long, is curving, with the convexity toward the north, and has a maximum displacement of nearly 1,000 feet. The fault scarp, of Madison limestone, is a prominent feature as viewed from the Lewistown-Giltedge stage road. Only one fault of the thrust type was encountered in the field. It occurs in sec. 15, T. 12 N., R. 13 E., is about 2 miles in length, trends almost east and west, and to the east is finally lost in the Saager Canyon anticline. A rather peculiar feature in connection with the faults described is that in almost every one the displacement is about 300 feet. None of these faults affect areas of workable coal, although in certain localities minor displacements have been encountered in underground workings.

*Domes.*—In the eastern part of the field domes are of common occurrence. The locality of most pronounced doming is south of

[a] Weed, W. H., and Pirsson, L. V., Geology and mineral resources of the Judith Mountains of Montana: Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 3, 1898, p 499.

the Judith Mountains, although there is another similar area in T. 17 N., R. 19 E. These domes are believed to be small laccoliths, and are probably related in some way with the main igneous mass of the Judith uplift. As they are in an area of workable coal they are of considerable importance, viewed from the standpoint of the coal miner. All the domes are cut across by streams and the coal bed is thus exposed near the periphery. Although several square miles of coal have been removed by the dissection of these minor uplifts, yet the domes are a beneficial factor in mining, as they bring the coal into a favorable attitude for working.

## THE COAL.

### DISTRIBUTION.

Although coal-bearing rocks of the Kootenai formation outcrop over a large part of the Lewistown field, and in general underlie the entire region, the coal is not continuous throughout the area. A feature noted in the Great Falls field to the west is that the coal occurs in limited districts with unproductive areas between, and it was seen early in the season that the Kootenai coal has the same habit to the east. For convenience the several coal areas of the Lewistown field will be discussed as separate units—termed the Sage Creek, Buffalo Creek, Rock Creek, Warm Spring Creek, and McDonald Creek districts. The location and approximate extent of these districts are shown in Pl. VII.

### DESCRIPTION OF COAL DISTRICTS.

#### SAGE CREEK DISTRICT.

*General conditions.*—The Sage Creek district has been described in a previous report[a] as lying mainly in Tps. 15 and 16 N., Rs. 11 and 12 E., but including portions of Tps. 15 and 16 N., R. 13 E. The latter two townships were included in the area investigated the last season, and hence are mapped as a portion of the Lewistown field, though coal does not show in outcrop within them, and even on their extreme western edge it probably lies at least 500 feet beneath the surface. At this locality the beds dip to the east at a moderately low angle, so that within a short distance the coal passes beyond a depth at which it can be mined economically under present conditions. Although it is not probable that the coal mined near Utica, in sec. 24, T. 14 N., R. 13 E., is properly to be considered as belonging in the Sage Creek district, it is tentatively included as such. The extent of this portion of the district is limited to only a square mile or so northwest of Utica, for to the south the coal thins rapidly, and to the east it is carried to great depths by dips in that direction.

[a] Fisher, C. A., The Great Falls coal field, Montana: Bull. U. S. Geol. Survey No. 316, 1907, pp. 161-173.

As exposed near Utica the coal outcrop shows that there are three coal beds about equally separated in a vertical range of 35 feet, the middle bed being the only one in which workable coal occurs. A section of this middle coal bed is as follows:

*Section of middle coal bed at Utica, Mont.*

| | Ft. | in. |
|---|---|---|
| Shale. | | |
| Coal | 1 | 6 |
| Shale, carbonaceous | 1 | 3 |
| Coal, impure | | 8 |
| Shale | | 10 |
| Coal, upper 6 inches bony | 2 | 2 |
| Shale. | | |
| | 6 | 5 |

The coal of both lower and upper benches is soft and slacks readily on exposure to the air. Small nodules and lenses of iron sulphide are present in the coal.

*Development.*—There is only one mine in the part of the district here considered. This is owned and operated by M. A. and H. A. Showan. The mine was first opened about twenty years ago, and coal was taken out desultorily for several years; the mine was then abandoned, and finally reopened by the Showans in the fall of 1906. Only a small amount of coal is mined for local use, the greater part of the fuel supply for Utica and vicinity coming from the Sage Creek mines to the northwest.

### BUFFALO CREEK DISTRICT.

*General conditions.*—The Buffalo Creek coal district is situated in T. 12 N., R. 14 E., and includes the area between Buffalo Creek and the Little Belt Mountains along either side of Saager Canyon. The district is limited on the south by the coal outcrop which lies along the base of the Little Belt Range, and along Buffalo Creek steep dips carry the coal too deep for practical working; west of Saager Canyon the coal thins, and to the east it is deeply covered by overlying formations.

The workable coal in this district ranges from 30 to 48 inches in thickness. It is underlain by sandstone and overlain by dark bone. Forty feet above this bed occurs another coal which, although of good quality, is too thin to work.

*Development.*—At present two small mines are in operation in Buffalo Creek district, both in Saager Canyon. One, known as the Williams mine, located in the NE. ¼ sec. 20, was opened in the fall of 1906, and the other, which has been opened recently, is situated in the NW. ¼ sec. 28. It is operated by a company of which the members are J. F. Lester, J. D. Kipe, E. E. Pearl, and William Gordon. These two mines supply a small amount of coal to near-by

ranches and to the settlements in the vicinity of Judith Gap. There is an abandoned mine on Buffalo Creek, owned by J. A. Dover.

### ROCK CREEK DISTRICT.

*General conditions.*—The Rock Creek district is located in T. 13 N., R. 17 E. The coal outcrop on the north side of Rock Creek in its east-west course through secs. 15 and 16 marks the southern limit of the district. Thinning of the coal limits the district in other directions, and the area of workable coal includes less than 3 square miles.

There is apparently but one coal bed in this district. It occurs in two benches, separated by a parting of dark bone. In some places the coal is overlain by bone; in others sandstone rests upon the upper bench. A representative section of the coal bed in this district is given below.

*Representative section of coal bed in Rock Creek district.*

| | Ft. | in. |
|---|---|---|
| Sandstone. | | |
| Bone | | 10 |
| Coal | 1 | |
| Bone | 1 | 1 |
| Coal | 2 | 2 |
| | 5 | 1 |

*Carboniferous coal.*—The only locality in the Lewistown field where coal was noted below the Cretaceous is in the vicinity of Rock Creek. Here a prospect in the NW. ¼ sec. 23 has discovered a 6-inch bed in the Quadrant formation, of Pennsylvanian (?) age. It is improbable that workable coal will be found at this horizon anywhere in the field, although its presence has led to some prospecting in the district between the Big Snowy Mountains and the mines on Rock Creek.

*Development.*—There are four mines in the Rock Creek district. Three of these—the Sharp, Cooper, and Rand mines—are along Rock Creek, and the fourth, the Knox mine, is on the west fork of Beaver Creek in sec. 3. All are small producers, supplying fuel to ranchers near by and also to the town of Moore.

### WARM SPRING CREEK DISTRICT.

*General conditions.*—The Warm Spring Creek district comprises the northern part of T. 16 N. and the southern part of T. 17 N., R. 19 E. In a measure the limits of the district are ill defined, except where the coal outcrops in the embayment on the northwestern side of the Judith Mountains. To the north the district extends across Warm Spring Creek, but the coal thins in that direction, as shown by exposures in several small laccolithic uplifts north of the creek. To the northwest the coal-bearing rocks are overlain

by the entire thickness of the Colorado shale; hence no information could be obtained concerning the thickness of the coal bed. Workable coal is found only in a very narrow strip to the north of the outcrop along the base of the Judith Mountains and a small area on the south side of Warm Spring Creek.

In the southern part of the Warm Spring Creek district there appears to be but one bed of coal, which splits to the north into three members, that number having been observed in exposures near Deer Creek. The coal bed varies greatly in character and thickness in the district, so that no representative section can be given. It is usually about 30 inches thick and is underlain and overlain by clay. Near Warm Spring Creek the coal bed thickens locally to 43 inches and occurs in two benches with a 4-inch bone parting between.

*Development.*—The Mace mine, in the NW. ¼ sec. 32, T. 17 N., R. 19 E., is the chief producer of the Warm Spring Creek district. The greater part of the coal obtained in this mine is taken by wagon to Kendall, a town outside of the territory mapped, in the gold-mining district of the North Moccasin Mountains. The Nevin mine, in the SE. ¼ sec. 7, T. 16 N., R. 19 E., yields a small tonnage. An abandoned mine, owned by the New Year Mining Company and formerly furnishing that company with fuel, is located near the New Year mill, in sec. 10 of the same township. The workings of this mine are being kept in repair, in view of possible resumption of metal mining in the district. There is an abandoned mine about half a mile east of the Mace mine, and another, known as the Fergus mine, is located near the center of sec. 20, T. 17 N., R. 19 E.

### M'DONALD CREEK DISTRICT.

*General conditions.*—The largest district in the Lewistown field containing workable coal is that to the south of the Judith Mountains, the greater part of it lying near the headwaters of McDonald Creek. The northern limit of the district is defined by the coal outcrop along the base of the Judith Mountains. The outcrop along South Fork of McDonald Creek marks the southern boundary east of the McDonald Creek divide. West of this divide the coal does not extend south of the Lewistown-Forest Grove wagon road, and along the outcrop between the divide and the mines above Lewistown workable coal does not appear to be present. The producing area along Big Spring Creek affords no data regarding the extent of workable coal in any direction except to the south and southeast, so that it can not be stated definitely that this area is in reality a part of the McDonald Creek district. In the present paper, however, it is so treated.

The eastern limit of the McDonald Creek district also is indefinite. East of Forest Grove the coal outcropping along McDonald Creek indi-

cates that the Kootenai may possibly be coal bearing beyond the territory represented on the map, and the extent of the coal bed north from the outcrop can only be conjectured. In the vicinity of Giltedge, however, the coal thins; hence the district is fairly well defined in that direction. From present evidence it would seem that the McDonald Creek district includes about 75 square miles, although the coal either has been removed by erosion or is too deep for working in a considerable part of that area.

In the McDonald Creek district, as elsewhere in the Lewistown coal field, there is but one workable bed, which occurs, also as in other parts of the field, in close association with and immediately underlying the massive gray or pinkish sandstone in the lower part of the Kootenai. Below this workable bed, at a distance ranging from 15 to 40 feet, occurs another coal bed, which, because of its characteristic alternation of coal and bone in thin layers, is locally termed the "dirty vein." Above the main bed there are several coaly layers, at least in the eastern portion of the district, where seams a few inches thick were noted in the sandstone overlying the workable coal. In the vicinity of Giltedge a bed just beneath the second sandstone of the Kootenai has been prospected in several localities, but nowhere has coal more than a few inches thick been discovered. This bed is about 90 feet above the main coal bed.

Though much of the McDonald Creek district is underlain by workable coal, the thickness of the bed varies to such a degree that no representative section can be given. In all the mines but two, the Peiper and the Black Diamond, where there is only one bed without parting, the coal is in two distinct benches. For the purpose of comparison, sections from a number of localities in the area are given below.

*Sections of coal beds in McDonald Creek district.*

SPRING CREEK MINE.

| | Ft. | in. |
|---|---|---|
| Shale, gritty. | | |
| Coal | 2 | 2 |
| Bone | | 6 |
| Coal | | 10 |
| Coal, bony | 1 | 4 |
| Clay. | | |
| | 4 | 10 |

BLACK DIAMOND MINE.

| | Ft. | in. |
|---|---|---|
| Bone. | | |
| Coal | 4 | 4 |
| Clay. | | |

BREW & PARSON'S MINE.

| | Ft. | in. |
|---|---|---|
| Bone | | 5 |
| Coal | 3 | 2 |
| Shale | 2 | 2 |
| Coal | 2 | 6 |
| Clay. | | |
| | 8 | 3 |

HILL'S MINE.

| | Ft. | in. |
|---|---|---|
| Sandstone. | | |
| Coal, impure | 1 | 2 |
| Clay | | 4½ |
| Coal | 2 | 4 |
| | 3 | 6½ |

*Development.*—Development in the McDonald Creek district has been both tardy and desultory. Coal was mined on Big Spring Creek

above Lewistown and on McDonald Creek in the early eighties, but as the demand was purely local, mining operations were not extensive, and this limited demand remained without material increase until the completion of the Montana Railroad into Lewistown in the spring of 1904. Since then this railroad has obtained its steam coal from the Spring Creek mine, and is now using about 125 tons per day. Practically all the coal mined by the Spring Creek Company is loaded direct on cars at the mine for the use of the railroad, the small remainder being sold chiefly in Lewistown. The greater amount of fuel supply for that town comes from Brew & Parson's mine at the base of the Judith Mountains, or from a number of small mines—the Sharp, Flaherty, Cox, Hamilton, and Black Diamond—near the head of McDonald Creek.

An opening known as the Harmon mine is located about three-fourths of a mile southeast of the Spring Creek Company's property. Formerly this supplied a small amount of coal, but of late years it has been practically abandoned. At the time the investigation was made, however, the mine was under lease and renewal of mining operations was expected.

Other mines near Giltedge supply that vicinity. These are the Sherman, Shearson, Cliffe, and Company mines, the latter so called because it is owned and operated by the Gold Reef Mining and Milling Company. Three other mines, the Hill, Peiper, and Hobson, are located on McDonald Creek or its branches near the southern limits of the field. All the mines in the McDonald Creek district, except those operated by the Spring Creek and Gold Reef companies, are worked but little during the summer months.

The mines of the McDonald Creek district have been the chief factor in the coal production of Fergus County. The following table shows the amount of coal produced in this county for the period from 1889 to 1906, inclusive:

*Coal production of Fergus County, Mont., from 1889 to 1906, inclusive.*[a]

| Year. | Short tons. | Year. | Short tons. |
|---|---|---|---|
| 1889 | 460 | 1898 | 950 |
| 1890 | 1,260 | 1899 | 900 |
| 1891 | 250 | 1900 | ..... |
| 1892 | 400 | 1901 | 500 |
| 1893 | 200 | 1902 | 5,200 |
| 1894 | 325 | 1903 | 9,374 |
| 1895 | ..... | 1904 | 19,109 |
| 1896 | ..... | 1905 | 15,228 |
| 1897 | ..... | 1906 | 29,182 |

[a] Mineral Resources U. S., 1889-1906, U. S. Geol. Survey. Statistics prior to 1889 not obtainable.

Fergus County ranks fourth in the coal-producing counties of the State, and the average price per ton in that county is considerably

greater than that received in others. This higher price is due partly to the fact that coal is not readily obtained from other fields, but chiefly because local conditions are not conducive to cheap mining.

## CHARACTER OF THE COAL.

### PHYSICAL CHARACTER.

The coal of the Lewistown field has certain physical characteristics which differentiate it in a measure from other coals of the State, with the exception of that from the Great Falls field, to the west. The coal is persistently banded in appearance, with alternating layers of bright and dull luster, the latter predominating. In general, therefore, the coal is dull or grayish black in color. The bright bands are thin, ranging from a mere film to one-fourth inch in thickness. The dull bands owe their appearance chiefly to the presence of mineral charcoal. Even in these bands, which at first sight appear to be entirely lusterless, closer examination shows that very minute lenses of bright coal are present. Sulphur in the form of iron pyrites ($FeS_2$) is more or less abundant, occurring usually in the form of small nodules or lenses, although it is present also as a thin incrustation between layers or along joint planes.

The coal in the Spring Creek and neighboring mines has near the bottom of the bed several thin partings which at first glance appear to be similar to the bright bands previously mentioned. This material will not burn readily, however, and is thrown aside as waste. It is termed "black jack" by the miners. A sample obtained at the Spring Creek mine and analyzed at the laboratory of the fuel-testing plant at Pittsburg carried 31.84 per cent of ash. In several localities, notably in the Mace mine on Warm Spring Creek, a dull, lusterless variety of coal, resembling cannel, was noted. It occurs in the Mace mine as lenses of considerable extent in the bed, the largest being 200 feet in length.

### CHEMICAL CHARACTER.

Chemical analyses of the coal show that it is to be classed as medium-grade bituminous. That there is a considerable range in quality is indicated by the heat-value determinations. A sample of coal was obtained from each working mine in the field by cutting a channel across the bed from roof to floor, exclusive of partings discarded in mining.

The results of the analyses, given in the following table, are in two sets, one showing analyses of the samples as received in the laboratory and the other on an air-dried basis. The latter more nearly represent the coal as it is used commercially.

*Analyses of coal samples from Lewistown field, Montana.*

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

| Coal district | Sage Creek. | Buffalo Creek. | | Rock Creek. | | | |
|---|---|---|---|---|---|---|---|
| Laboratory No. | 5290 | 5265 | 5267 | 5266 | 5264 | 5273 | 5274 |
| Sample as received: | | | | | | | |
| Prox. Moisture | 9.95 | 14.44 | 17.03 | 15.72 | 16.86 | 13.90 | 9.18 |
| Prox. Volatile matter | 24.87 | 28.80 | 27.34 | 29.64 | 30.23 | 26.25 | 29.69 |
| Prox. Fixed carbon | 44.22 | 45.65 | 43.83 | 43.81 | 45.60 | 41.84 | 43.31 |
| Prox. Ash | 20.96 | 11.11 | 11.80 | 10.83 | 7.31 | 18.01 | 17.82 |
| Ult. Sulphur | 5.51 | 4.08 | 4.14 | 2.81 | 3.03 | 6.05 | 9.39 |
| Ult. Hydrogen | ..... | ..... | 4.98 | ..... | 5.62 | ..... | ..... |
| Ult. Carbon | ..... | ..... | 51.73 | ..... | 58.27 | ..... | ..... |
| Ult. Nitrogen | ..... | ..... | .62 | ..... | .67 | ..... | ..... |
| Ult. Oxygen | ..... | ..... | 26.73 | ..... | 25.10 | ..... | ..... |
| Calories | 4,937 | ..... | 4,941 | ..... | 5,726 | 5,381 | 5,371 |
| British thermal units | 8,887 | ..... | 8,894 | ..... | 10,307 | 9,686 | 9,668 |
| Loss of moisture on air drying | 3.00 | 7.30 | 9.00 | 6.50 | 8.20 | 6.10 | 1.90 |
| Air-dried sample: | | | | | | | |
| Prox. Moisture | 7.16 | 7.70 | 8.82 | 9.86 | 9.43 | 8.31 | 7.42 |
| Prox. Volatile matter | 25.64 | 31.07 | 30.04 | 31.70 | 32.93 | 27.95 | 30.27 |
| Prox. Fixed carbon | 45.59 | 49.25 | 48.17 | 46.86 | 49.68 | 44.56 | 44.15 |
| Prox. Ash | 21.61 | 11.98 | 12.97 | 11.58 | 7.96 | 19.18 | 18.16 |
| Ult. Sulphur | 5.68 | 4.40 | 4.55 | 3.01 | 3.30 | 6.43 | 9.57 |
| Ult. Hydrogen | ..... | ..... | 4.37 | ..... | 5.13 | ..... | ..... |
| Ult. Carbon | ..... | ..... | 56.85 | ..... | 63.48 | ..... | ..... |
| Ult. Nitrogen | ..... | ..... | .68 | ..... | .73 | ..... | ..... |
| Ult. Oxygen | ..... | ..... | 20.58 | ..... | 19.40 | ..... | ..... |
| Calories | 5,090 | ..... | 5,430 | ..... | 6,237 | 5,730 | 5,475 |
| British thermal units | 9,162 | ..... | 9,774 | ..... | 11,228 | 10,315 | 9,855 |

| Coal district | Warm Spring Creek. | | McDonald Creek. | | | | |
|---|---|---|---|---|---|---|---|
| Laboratory No. | 5472 | 5475 | 5272 | 5289 | 5295 | 5294 | 5292 |
| Sample as received: | | | | | | | |
| Prox. Moisture | 2.84 | 6.89 | 15.35 | 18.88 | 11.35 | 18.56 | 14.13 |
| Prox. Volatile matter | 27.35 | 28.61 | 28.27 | 25.18 | 29.74 | 24.59 | 27.37 |
| Prox. Fixed carbon | 54.29 | 42.65 | 48.08 | 48.34 | 46.56 | 48.36 | 48.43 |
| Prox. Ash | 15.52 | 21.85 | 8.30 | 7.60 | 12.35 | 8.49 | 10.07 |
| Ult. Sulphur | 4.87 | 5.48 | 4.53 | 2.72 | 4.48 | 3.72 | 3.69 |
| Ult. Hydrogen | ..... | ..... | 5.42 | 5.19 | 5.02 | ..... | 5.06 |
| Ult. Carbon | ..... | ..... | 61.15 | 57.31 | 58.91 | ..... | 59.87 |
| Ult. Nitrogen | ..... | ..... | .71 | .66 | .82 | ..... | .74 |
| Ult. Oxygen | ..... | ..... | 19.89 | 26.52 | 18.42 | ..... | 20.57 |
| Calories | 6,512 | 5,229 | 5,897 | 5,417 | 5,841 | 5,505 | 5,794 |
| British thermal units | 11,722 | 9,412 | 10,615 | 9,751 | 10,514 | 9,909 | 10,429 |
| Loss of moisture on air drying | 1.60 | 2.80 | 8.20 | 6.40 | 3.10 | 9.60 | 7.00 |
| Air-dried sample: | | | | | | | |
| Prox. Moisture | 1.26 | 4.21 | 7.79 | 13.33 | 8.51 | 9.91 | 7.67 |
| Prox. Volatile matter | 27.80 | 29.43 | 30.80 | 26.90 | 30.69 | 27.20 | 29.43 |
| Prox. Fixed carbon | 55.17 | 43.88 | 52.37 | 51.65 | 48.05 | 53.50 | 52.07 |
| Prox. Ash | 15.77 | 22.48 | 9.04 | 8.12 | 12.75 | 9.39 | 10.83 |
| Ult. Sulphur | 4.95 | 5.64 | 4.94 | 2.91 | 4.62 | 4.12 | 3.97 |
| Ult. Hydrogen | ..... | ..... | 4.91 | 4.79 | 4.83 | ..... | 4.60 |
| Ult. Carbon | ..... | ..... | 66.61 | 61.23 | 60.79 | ..... | 64.38 |
| Ult. Nitrogen | ..... | ..... | .77 | .70 | .85 | ..... | .79 |
| Ult. Oxygen | ..... | ..... | 13.73 | 22.25 | 16.16 | ..... | 15.43 |
| Calories | 6,618 | 5,379 | 6,424 | 5,787 | 6,028 | 6,090 | 6,230 |
| British thermal units | 11,912 | 9,683 | 11,563 | 10,417 | 10,850 | 10,961 | 11,214 |

*Analyses of coal samples from Lewistown field, Montana*—Continued.

| Coal district | McDonald Creek. | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Laboratory No. | 5295 | 5293 | 5291 | 5343 | 5471 | 5473 | 5475 | 5476 |
| Sample as received: | | | | | | | | |
| Prox. Moisture | 12.66 | 12.31 | 12.59 | 9.84 | 8.34 | 15.65 | 7.39 | 7.98 |
| Prox. Volatile matter | 29.62 | 28.41 | 26.71 | 28.70 | 29.87 | 27.05 | 26.31 | 26.63 |
| Prox. Fixed carbon | 48.81 | 51.31 | 43.46 | 42.14 | 53.63 | 49.67 | 55.46 | 56.05 |
| Prox. Ash | 8.91 | 7.97 | 17.24 | 19.32 | 8.16 | 7.63 | 10.84 | 9.34 |
| Ult. Sulphur | 3.68 | 3.88 | 3.51 | 4.63 | 4.13 | 1.82 | 2.58 | 4.39 |
| Ult. Hydrogen | ..... | ..... | 4.84 | ..... | 5.10 | 5.13 | ..... | 4.86 |
| Ult. Carbon | ..... | ..... | 54.83 | ..... | 66.23 | 56.70 | ..... | 64.85 |
| Ult. Nitrogen | ..... | ..... | .76 | ..... | .76 | .70 | ..... | .76 |
| Ult. Oxygen | ..... | ..... | 18.82 | ..... | 15.62 | 28.02 | ..... | 15.80 |
| Calories | 6,061 | 6,194 | 5,220 | 5,283 | 6,540 | 5,303 | 6,035 | 6,394 |
| British thermal units | 10,910 | 11,149 | 9,396 | 9,509 | 11,772 | 9,545 | 10,863 | 11,509 |
| Loss of moisture on air drying | 6.00 | 6.40 | 5.30 | 3.50 | 3.70 | 9.70 | 2.80 | 3.40 |
| Air-dried sample: | | | | | | | | |
| Prox. Moisture | 7.09 | 6.31 | 7.70 | 6.57 | 4.82 | 6.59 | 4.72 | 4.74 |
| Prox. Volatile matter | 31.51 | 30.35 | 28.20 | 29.74 | 31.02 | 29.95 | 27.07 | 27.57 |
| Prox. Fixed carbon | 51.92 | 54.82 | 45.89 | 43.67 | 55.69 | 55.01 | 57.06 | 58.02 |
| Prox. Ash | 9.48 | 8.52 | 18.21 | 20.02 | 8.47 | 8.45 | 11.15 | 9.67 |
| Ult. Sulphur | 3.91 | 4.15 | 3.70 | 4.80 | 4.29 | 2.02 | 2.65 | 4.54 |
| Ult. Hydrogen | ..... | ..... | 4.49 | ..... | 4.87 | 4.48 | ..... | 4.64 |
| Ult. Carbon | ..... | ..... | 57.90 | ..... | 68.78 | 62.79 | ..... | 67.13 |
| Ult. Nitrogen | ..... | ..... | .80 | ..... | .79 | .78 | ..... | .79 |
| Ult. Oxygen | ..... | ..... | 14.90 | ..... | 12.80 | 21.48 | ..... | 13.23 |
| Calories | 6,447 | 6,617 | 5,512 | 5,475 | 6,791 | 5,873 | 6,209 | 6,619 |
| British thermal units | 11,606 | 11,911 | 9,922 | 9,854 | 12,224 | 10,570 | 11,176 | 11,914 |

Comparison of the foregoing analyses shows that there is a considerable variation in the samples, especially in moisture and ash content, the range of the former being from 2.84 to 18.88 per cent, and of the latter from 7.31 to 21.85 per cent. Sulphur is relatively high, the average being 4.25 per cent.

## CONDITIONS OF MINING AND TRANSPORTATION.

The Spring Creek mine is the only one in the Lewistown field which has direct railroad connections, a spur having been extended from Lewistown up Big Spring Creek to the workings. The coal from other mines in the field is hauled by wagon, the greatest distance probably being from the McDonald Creek mines to Lewistown, about 12 miles. Not more than one or two men are employed in any of the mines except in that on Big Spring Creek, where about 40 are engaged, and this mine is the only one to use power. A steam and air-compressor plant are operated to pump water from the workings, and air drills are used in the entries. Only one other mine, the Brew & Parson, needs more than natural drainage, and in that mine excess water is removed by siphon. There is no trouble with gas in the field and no fans are in operation.

Practically all the mines in the district are opened directly on the dip, which is nowhere excessive, and cars are hauled from the entries by mule or more commonly pushed by hand. The abandoned New Year mine and the Nevin mine, in Warm Spring Creek basin, are opened on the strike, the coal bed dipping at a rather high angle.

The problem of timbering is in general not difficult of solution, as the roof is usually compact shale or sandstone. In a number of the small mines no timbering is needed. Timber is obtained from the various mountain uplifts bordering or within the field, or from the vicinity of the McDonald Creek divide and Rock Creek.

## FUTURE DEVELOPMENT.

The Lewistown coal field has been and seems destined to remain a region independent of other coal fields, and yet is so situated geographically that it can not well compete with other coal-producing sections of the State in their respective markets. East and north of the field there are extensive areas which seem unlikely to remain other than sparsely settled. To the south lies the Bull Mountain coal field, which is receiving an impetus in development from the construction of the transcontinental line of the Chicago, Milwaukee and St. Paul Railway. This line passes directly through the Bull Mountain field, and will furnish an outlet for the coal. The towns along the Northern Pacific in south-central Montana procure their coal from the Red Lodge, Bear Creek, Bridger, and other coal districts in the vicinity of the railroad. To the northwest is the Great Falls coal field, which controls the market in that section of the State. The Billings and Northern Railroad, which connects Billings and Great Falls, passes through Judith Gap and across the western portion of the Lewistown coal field. Although this line will do much to hasten development in the Great Falls field, especially in the Otter Creek and Sage Creek districts, it has at present no direct connection with the coals of the Lewistown field. Even if a branch line is built to Lewistown, the coals of that district can scarcely compete with those of the Sage Creek district, where they can be mined more economically principally because of greater thickness of the bed.

It seems, then, that the Lewistown coal field must continue to supply a local market only. In spite of this probability, however, there is likely to be a constant increase in the demand for the coal. The region is one well adapted to agriculture, and of late years there has been a notable increase of population. Lewistown is a thriving business center, and other towns within the field are growing rapidly. With the disappearance of the forests in the near-by mountains, an almost accomplished fact in the Little Belt, Judith, and Moccasin uplifts, and with an increasing demand for fuel from the growing population and the metal-mining districts, it seems likely that there will be a corresponding increase in the use of coal in the Lewistown