DEPARTMENT OF THE INTERIOR
FRANKLIN K. LANE, Secretary

UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, Director

BULLETIN 621—K

# GEOLOGY AND COAL RESOURCES

OF

# NORTHERN TETON COUNTY, MONTANA

BY

EUGENE STEBINGER



Contributions to economic geology, 1915, Part II
(Pages 117-156)

Published January 5, 1916



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# ILLUSTRATIONS.

# GEOLOGY AND COAL RESOURCES OF NORTHERN TETON COUNTY, MONTANA.

By EUGENE STEBINGER.

## INTRODUCTION.

The paper here presented describes the coal resources of a large area in Teton County,[1] northwestern Montana, including the Blackfeet Indian Reservation and a considerable area of the country lying to the east. The scope of the paper is limited to a consideration only of those features having a bearing on the value and quantity of the coal present. The geology of the region is briefly described, the aim being to give a general understanding of the geologic setting in which the coals occur.

Nearly all the rocks in northern Teton County belong to formations that are of the same age as others which, elsewhere in Montana, contain almost all the coal found in the State. This fact led to several generous estimates as to the extent of the coal-bearing areas likely to be found in this region. Weed[2] and Rowe[3] have published maps on which the valuable bituminous coal area of the Great Falls field is shown as extending northward entirely across Teton County to the Canadian boundary. Similarly, the presence of an extensive coal field, long actively developed at Lethridge, Alberta, 50 miles north of the boundary, gave rise to forecasts that a southward extension of that field, following the strike of the geologic formations, would be found on the line of the Great Northern Railway in northern Teton County. The result of the present work shows that although the coal-bearing formation of the Great Falls field, the Kootenai formation, is present in the area here described, the only coal in it is a bed 6 or 8 inches thick in Marias Pass, also that although the horizon of the coal mined at Lethbridge is traceable entirely across this area, it shows only thin coal beds, nowhere over 18 inches thick. Although outcrops of coal are widely distributed in all parts of the county, the total amount of coal is not large. There are coal beds between $1\frac{1}{2}$ and $3\frac{1}{2}$ feet thick in three districts, comprising only a small percentage

[1] Since the completion of this report the area in Rs. 3 and 4 W., on the east edge of the region here described, has been included in the new county Toole County, recently established.

[2] Weed, W. H., The coal fields of Montana: Eng. and Min. Jour., vol. 53, p. 521, 1892.

[3] Rowe, J. P., Montana coal and lignite deposits: Univ. Montana Bull. 37, Geol. series No. 2, pl. 2, 1906.

of the total area described, but the general scarcity of fuel in the region, together with an increasing population due to the development of extensive irrigation projects, gives considerable importance to these small areas of coal land.

The location and relative extent of the area described in this paper are shown on the index map (fig. 10). The area lies wholly in Teton County, occupying nearly all of its northern half, and contains about 3,100 square miles, of which 2,425 square miles is in the Blackfeet Indian Reservation. The international boundary between Alberta and Montana forms its northern limit, the one hundred and twelfth meridian is the boundary on the east, and the irregular line formed by Marias River and Birch Creek is the boundary on the south. On

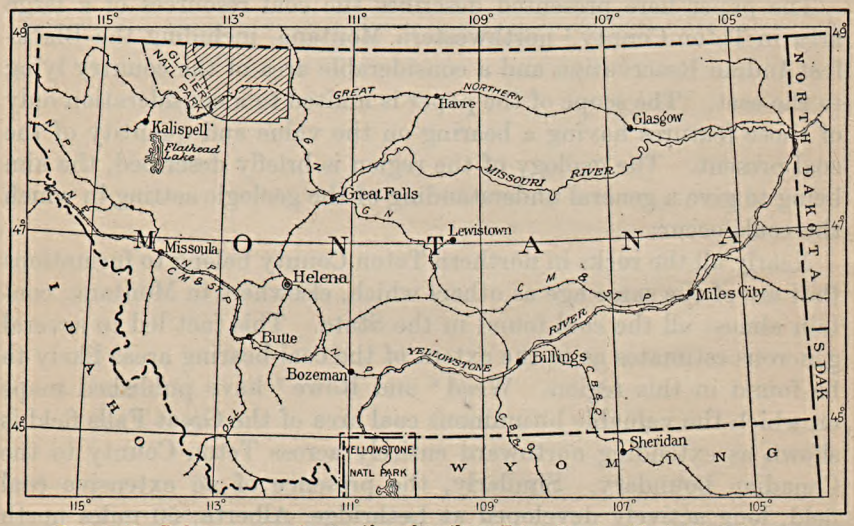



FIGURE 10.—Index map showing location of northern Teton County, Mont. (shaded area).

the west the examination was extended to the limits of the Indian reservation.

The county is a gently sloping, nearly treeless plains region that is everywhere easily accessible and offers comparatively few obstacles to railway or road construction. The main line of the Great Northern Railway crosses the region in an east-west direction, and a local line, the Montana Western Railway, extends to Valier, in the southeast corner of the area. Valier is the largest town and is the center of a thriving agricultural community, whose lands are watered by an extensive irrigation project, established under the Carey Act, with headgates on the upper part of Birch Creek. Ethridge, Cut Bank, Browning, and Glacier Park are the principal towns on the Great Northern Railway. Browning is the seat of the Indian agency for the Blackfeet Reservation. The only postal facilities off the railway

are at Babb and Family, both of which are served by stage lines running out of Browning. On the Indian reservation settlement so far has been limited almost entirely to its west half, where Indian ranches devoted almost exclusively to the raising of horses and cattle lie along the principal streams. The extensive interstream stretches remain an open range country without fences or other improvements. On the east edge of the reservation the United States Reclamation Service has under construction a system of canals whose waters will irrigate an area of about 300 square miles lying in Tps. 30 to 35 N., Rs. 5 to 7 W. This area should eventually support a large population. The canals will take water from Birch and Cut Bank creeks and all the streams lying between them. The area outside of the reservation is well settled, most of the land having been occupied during the recent movement of settlers to the plains region of Montana, after the development of dry farming.

## FIELD WORK.

Classification of the public lands with respect to their mineral value was the immediate object of the work undertaken, and therefore in addition to a regional examination of the geology necessary to an understanding of its broader features the writer made a close inspection of all the mineral-bearing tracts. The accurate location of these tracts with reference to the lines of the General Land Office surveys was also indispensable. The fact that six out of eight of the Cretaceous and Tertiary formations present are likely to be coal bearing, together with the widespread occurrence of coal in thin beds continually suggesting the possibility of the occurrence of thicker coals at a neighboring locality, made necessary a careful search for coal in all parts of the region. Because of the tendency of the soft bedrock formations to erode into badlands wherever the relief is abrupt, the exposures of the formations and coal beds on most steep slopes, and especially along the watercourses, are excellent and the presence or absence of coal in such localities could be readily determined. The extensive interstream areas, however, are generally grassed over, affording but few scattered exposures, so that it is very difficult from a surface examination to determine the mineral value of the land.

Good topographic maps were available for all of the area examined and were used in the field as base maps on which to plat the coal outcrops and other geologic data. In the Indian reservation the topography for most of the townships was sketched at the same time that the Land Office surveys were made—an innovation for work of this class, affording plats on the scale of 2 inches to the mile, made directly in the field with special reference to the land subdivisions. The only exception to this procedure was in the northwestern part of

the reservation, where the topography of the Browning and Chief Mountain quadrangles had already been sketched and was transferred to the township plats after the Land Office surveys were completed. The land corners are well marked and easily found in all parts of the region, especially on the Indian reservation, where iron pipes marking the allotments to the Indians have been placed on a large percentage of the corners. In the Valier coal field on Birch Creek the 6 miles of sinuous outcrop of the nearly horizontal coal bed was traversed with the stadia and plane table. But in the Blackfeet coal field, between Greasewood Creek and the Middle Fork of Milk River, the rocks dip steeply and the outcrop of the coal beds make nearly straight lines, all trending in the same direction. These were easily located at points where they cross the land lines, without recourse to the plane table.

The investigation was carried on by the writer, working alone, beginning in July, 1911, and continuing through a part of each of the field seasons of 1912 and 1913.

## TOPOGRAPHY.

### RELIEF.

The area described in this report lies on the west border of the Great Plains region, at the foot of the Rocky Mountains. (See Pl. XV.) The front range of the mountains rises with a wall-like abruptness from the plains without marked foothills. As seen from elevated points on the mountains, the plains appear to extend indefinitely eastward as a single surface with monotonous regularity. On closer examination, however, the part of the plains in the area here treated proves to have considerable relief, with low plateau-like areas in places, together with extensive dissected tracts along the principal streams. The total range of elevations on the general slope of the plains is about 2,500 feet. This lies between altitudes of about 6,000 feet on the plateau-like areas at the base of the mountains and 3,500 feet, the general elevation of the plains on the east edge of the area mapped. Along the valleys of the main streams in the south half of the area, such as Cut Bank and Two Medicine creeks, the relief between the valley floor and the general level of the adjacent plains ranges from 350 feet in the lower parts of the valleys through gradually increasing slopes to about 1,200 feet at their upper parts, near the front of the mountains. In the northern part of the region, however, in the valleys of the several forks of Milk River, which are much feebler streams than those above mentioned, the corresponding relief ranges only from 300 to 700 feet. In the extreme northeastern part of the area, the valley of St. Mary River, which not only carries a very

vigorous stream but also has been heavily glaciated, has a relief of 1,000 to 1,600 feet.

The topographic types that give a distinctive character to the surface features in different parts of the region are (1) high-level sloping plains or plateau-like areas, (2) low-level plains, (3) escarpments, two of which are continuous across the entire area, (4) badlands, and (5) glacial moraines of considerable extent. The high-level plains are found in the western part of the region, adjacent to the mountains, in numerous isolated tracts from a fraction of a square mile to 40 square miles or more in extent and are doubtless remnants of an older, almost perfectly formed plain. They are covered with a veneer of gravel made up of rock types found in the adjacent mountains, and have remarkably smooth surfaces with a very regular slope to the northeast, away from the mountains. Milk River Ridge and St. Marys Ridge are typical of the larger of these areas. Below these higher plains are found lower plains that are much more extensive and merge eastward into the general level of the Great Plains region. Where best developed these plains also carry a veneer of gravel and have an even slope eastward away from the mountains. The best examples of the lower plains are Carlow Flat, an extensive and very evenly graded surface crossed by the Great Northern Railway west of Cut Bank, and the equally well-developed plain lying between Cut Bank Creek and Greasewood Creek a few miles northwest of Browning.

In the eastern part of the field, extending northward from Ethridge on the Great Northern Railway, there is a very striking sandstone escarpment, locally known as "the rim." This scarp is continuous for 35 miles, reaching almost to the Canadian line at Sweet Grass. It faces eastward and ranges from 350 to 600 feet in height. It is made up of the Virgelle sandstone, lying practically horizontal, whose massive upper member forms continuous cliffs of bare rock that are impassable in most places. About 30 miles to the west is a second escarpment that is a close counterpart of the first. It trends northward and is made up of the Horsethief sandstone. It is best developed in Rim Rock Butte and Horsethief Ridge, between Cut Bank Creek and Milk River, although there are extensions of it to the south, notably at Family, on Two Medicine Creek, and southward from Fourhorns Lake, in the southern part of the Indian reservation. Both of these escarpments are due to the greater resistance to erosion offered by the sandstone compared with that offered by a soft shale which lies beneath it. Near the mountains, in a belt about 15 miles wide extending northeastward entirely across the Indian reservation, where all the rocks are much disturbed, the same two escarpment-forming sandstones appear, where steeply tilted, as persistent hogback ridges as much as 3 miles in length.

The fact that several of the formations in this region are soft and easily eroded has led to the development of extensive badland areas in many places where the relief is abrupt. On Milk River near Landslide Butte, in the northern part of the field, is a worthless area of highly dissected topography that lies along the river valley for a distance of about 7 miles and extends back on each side as much as 2 miles. A similar but more extensive area cut in rocks of the same kind lies along Two Medicine Creek, where, from the mouth of Badger Creek downstream, typical badlands are developed in a belt about 12 miles long and 1½ miles wide. There are less extensive areas of similar topography in many other places, principally along the main streams.

The surface of the region has also been modified by glaciation during several distinct stages in Pleistocene time. Bowlder clay and other drift deposited at the time of the last advance of the glaciers which invaded the area, both from the high mountains on the west and from Canada on the northeast, cover large tracts and effectually conceal the underlying Tertiary (?) and Cretaceous bedrock formation. The drift is in some places as much as 250 feet thick. In the eastern half of the region there is a bowlder-strewn belt of the northeastern continental drift that has a rough kettle and moraine topography and is continuous from the valley of Milk River, on the north edge of the region, eastward and southward for over 40 miles. In the western half of the region the upper parts of the valleys of St. Mary River and Cut Bank Creek are thickly strewn with drift of mountain glaciers that came from the west. Farther south much more extensive glaciation centering along the valley of Two Medicine Creek extended 38 miles from the mountain front, leaving considerable areas of rough moraine. The largest of these areas extends from the region between Willow and Cut Bank creeks, near Browning, eastward to Carlow Flat and Two Medicine Creek.

## DRAINAGE.

The streams on the plains of northern Teton County flow in a general northeastward direction, away from the mountains, and the principal valleys are parallel. Those that head in the mountains and therefore are clear and swift perennial streams are Birch, Badger, Two Medicine, and Cut Bank creeks and St. Mary River. Milk River and its several forks, on the other hand, do not head in the mountains, and are therefore relatively sluggish and muddy. St. Mary River is tributary to Hudson Bay, whereas the other streams form part of the Missouri River system. Except during the June rise all of the streams in the region can be forded at numerous wagon crossings. The mean annual rainfall in the eastern half of the country is somewhat under 20 inches, and that area is therefore poorly watered except by the streams coming from the west.

# GEOLOGY.

## STRATIGRAPHY.

### GENERAL FEATURES.

The geologic formations in the region here described are all sedimentary in origin and range in age from Lower Cretaceous to probably basal Tertiary. All the rocks are apparently conformable, there being no recognizable break or disturbance between any of them or any evidence that points to the existence of an important erosion interval. The sequence of the formations in the Upper Cretaceous part of the section is different from that so far described for any other locality in Montana, owing to the fact that in this region the marine invasion represented by the Claggett shale did not extend so far west as the present position of the Rocky Mountain front between latitudes 48° and 49° N. An account of these interesting relations has already been published.[1]

Two of the formations, the Colorado and Bearpaw shales, are unquestionably of marine origin and were laid down during separate epochs in which a comparatively shallow sea covered the entire region. The remaining formations are mainly of continental origin—that is, they are irregularly bedded rocks that were for the most part rapidly deposited by stream and wind action over land areas that were only slightly above sea level and thus afforded the marshes and swamps necessary for the accumulation of the vegetable matter forming the coals now found in these beds.

The succession of formations, together with the principal features of the lithology, are outlined in the following table:

[1] Stebinger, Eugene, The Montana group of northwestern Montana: U. S. Geol. Survey Prof. Paper 90, pp. 61–68, 1915.

*Formations occurring in the plains portion of northern Teton County, Mont.*

| System. | Series. | Group and formation. | Thickness in feet. | Character of the rocks. |
|---|---|---|---|---|
| Quaternary. | Recent. | Alluvium. | | Deposits of small extent found along flood plains of the larger streams. |
| | Pleistocene. | Glacial drift. | | Bowlder clay, gravel, and lake silt and clay. Contains bowlders and cobbles of granite, gneiss, quartzite, etc., transported from other regions. Deposits are of several stages not distinguished in this report. |
| Tertiary (?). | Eocene (?). | Willow Creek formation. | 720+ | Variegated clay and soft sandstone, chiefly maroon to chocolate-brown, with subordinate gray, yellow, and greenish-gray beds. Fragments of fossil bones are common. Clay in many places contains thin lenticular beds of purplish-gray limestone. Forms a red soil over large areas. Top not seen. |
| | | St. Mary River formation (coal bearing). | 980 | Alternating clay, clay shale, and soft sandstone, the sandstone is much cross-bedded and ripple-marked. Colors are gray to greenish gray, with a few red layers in the clay. Contains a few thin lenticular limestones, many fragments of dinosaur bones, and fossil shells. |
| Cretaceous. | Upper Cretaceous. | Montana group. Horsethief sandstone. | 225–375 | Gray to greenish-gray sandstone, weathering buff. Thin bedded and somewhat shaly in lower half. In upper half generally massive and concretionary, weathering in castellated forms. In places near the top contains titaniferous magnetite. Has many shell beds, mainly of oysters. |
| | | Montana group. Bearpaw shale. | 490 | Dark-gray clay shale with a few limestone concretions. Contains abundant marine shells. Forms a subdued rounded topography. |
| | | Montana group. Two Medicine formation (coal bearing). | 1950 | Gray to greenish-gray clay and soft irregular sandstone, which is most abundant in the lower 250 feet. In places thin beds of red clay and nodular limestone. Contains an abundant reptilian fauna of Judith River types, besides leaves and shells. Contains coal beds near the base and at the top. |
| | | Montana group. Virgelle sandstone. | 220 | Gray to buff coarse-grained, much cross-bedded massive sandstone, with many ferruginous concretions in upper half. In lower half slabby gray sandstone, becoming shaly toward the base. |
| | | Colorado shale. | 1,500± | Bluish-gray shale with a few limestone concretions. Contains an abundance of marine shells. Forms a subdued and rounded topography. Complete undisturbed section not present. |
| | Lower Cretaceous. | Kootenai formation. | 2,000± | Gray sandstone and shale, alternating with maroon clay shale and massive gray sandstone. Contains a conglomerate 6 to 50 feet thick near the center. Contains a few leaves and fresh-water shells. Complete undisturbed section not present. |

### NON COAL-BEARING FORMATIONS.

In addition to the glacial deposits and the two marine formations (the Colorado shale and Bearpaw shale), four of the formations, the Kootenai formation, the Horsethief and Virgelle sandstones, and the Willow Creek formation, consisting mainly of deposits of continental origin, are not coal-bearing in the region here described. All these formations may contain small fragments or pockets of coal, or even seams as much as several inches in thickness, but it is practically certain that they do not contain valuable coal beds. Fragments of coal a few inches in size are often found in exposures of glacial drift, especially in the eastern part of the area. These fragments were transported considerable distances and should not be assumed to indicate the existence of valuable beds of coal near at hand. Thin seams of coal in the Kootenai and Willow Creek formations and pockets of coal in the Virgelle and Horsethief sandstones are very unlikely to thicken with depth and do not justify extensive prospecting.

The Kootenai formation is the oldest formation in the plains portion of northern Teton County. It is exposed only in the belt of disturbed rocks lying adjacent to the mountains. In this disturbed belt folding and especially thrust faulting have so deformed the rocks that their exact sequence and thickness can not be determined, but the exposures are good and the noncoal-bearing character of the formation is fairly certain. A few miles beyond the west border of the area the Kootenai overlies a black marine shale carrying Jurassic fossils. This, together with the fact that it immediately underlies the Colorado shale, gives the formation the approximate stratigraphic position of the Kootenai of the Great Falls region, 150 miles to the southeast, which has in turn been correlated with the Kootenai formation of British Columbia and Alberta by means of the characteristic fossil plant remains, mainly leaves, found at both localities. Black carbonaceous shale, with coal beds 6 or 8 inches in thickness, is the only coaly matter present in the formation in the area here discussed. The absence of greater amounts of coal is rather surprising, in view of its extensive occurrence in the typical area to the north and also in the Great Falls region. In the fields in the vicinity of Crows Nest Pass, Alberta and British Columbia, the Kootenai contains as much as 215 feet of coal in less than 2,000 feet of strata, and in the Great Falls region the coal bed near the base of the formation is in places 14 feet thick.

The Virgelle sandstone and Horsethief sandstone contain no coal, but are of considerable importance as key rocks marking the position of valuable coal beds that lie immediately above them. In each of the three districts in the region containing valuable coals the beds

lie within 10 or 15 feet of the top of one or the other of these two sandstones, which stand out as ridges or escarpments, thus serving admirably as markers. This feature is accentuated by the fact that the upper part of each of the formations is a massive cliff-making sandstone. In the Blackfeet field prospectors should depend on following the ridges or "reefs" of the Horsethief sandstone and digging for the coal bed that lies just above it. In the Valier field and in the district on Milk River cliffs of the sandstone lying nearly horizontal are reliable markers of coal above them.

The Willow Creek formation, composed of clay shale and soft sandstone, is lithologically identical with the coal-bearing St. Mary River formation lying just below it, except that the Willow Creek rocks are characterized by a dominantly red color instead of the light-grayish tints of the St. Mary River formation. It is not coal bearing in the area described and is easily traced by means of the red soil associated with it. To the north, in central Alberta, the red color of these rocks disappears and the strata at the same position are coal bearing.

## COAL-BEARING FORMATIONS.

### TWO MEDICINE FORMATION.

The rocks here designated Two Medicine formation, about 2,000 feet thick, comprise a great mass of rudely bedded whitish to gray clay and sandy strata. The irregular bedding of these rocks suggests a hasty and unstable sedimentation, which was largely of stream character. This formation, together with the underlying Virgelle sandstone, when traced northward proves to be identical with the rocks designated Belly River series by the Canadian geologists. In western Montana, however, the Virgelle sandstone has been mapped over considerable areas as a distinct unit easily separable from the overlying softer rocks, so that the term Belly River could not be consistently used in the area here described.

The Two Medicine formation is coal bearing at three horizons—at the base of the formation, 250 feet higher, and at the top. Coaly matter is also present at many other positions in the formation in the form of beds of black carbonaceous shale 2 to 5 feet thick. The lower 200 feet of the formation is more sandy than the remainder, probably half of this part consisting of massive sandstone in irregular beds as much as 50 feet in thickness. Several of the more persistent of these sandstones can be traced for a mile or two, but in general the strata throughout the formation appear and disappear within a few hundred feet. Above the basal sandy portion the formation is made up predominantly of clay and clayey shale of whitish to greenish-gray tints interbedded with a small amount of soft gray sandstone. Beds of red clay 1 to 2 feet thick are sparingly distributed

throughout these rocks and in places produce a delicate red line in the badland exposures so characteristic of the formation.

Fossils are abundant in the Two Medicine formation and include vertebrate, plant, and mollusk remains of many species. Bone fragments of dinosaurs of Judith River types, both herbivorous and carniverous, and also of turtles can be found in almost any extensive exposure. Entire limb bones 4 to 5 feet in length belonging to the larger dinosaurs were found at several localities. The mollusks are represented mostly by brackish and fresh water forms, especially the latter. Beds made up almost exclusively of unios are present at many horizons, in some places closely associated with the dinosaur bones. A single marine invasion of brief duration while this formation was being deposited is represented by shells of the Claggett to Fox Hills near-shore fauna[1] found in sandstone about 200 feet above the base of the formation. The plant remains are mainly leaf impressions and silicified wood. The leaves are all of modern-appearing conifer and broad-leaved types. The fossil wood is distributed throughout the formation, knots and entire sections of compressed tree trunks being common.

In the eastern half of the area mapped the Two Medicine formation, lying nearly horizontal, crops out in a broad belt from 20 to 30 miles wide, making up the largest areal geologic unit in this region. In this belt of rocks the formation is well exposed in all the larger stream valleys from Birch Creek to Milk River. The lower half of the formation is exposed along 12 miles of the lower part of Birch Creek valley west of Valier. On Two Medicine Creek the entire formation can be minutely studied in practically continuous exposures that extend for over 20 miles westward from the mouth of the stream. In the vicinity of Cut Bank the lower sandy portion of the formation is completely exposed along 10 miles of the sharply trenched valley of Cut Bank Creek, and on Milk River, north of Landslide Butte, the upper 800 feet of the formation is laid bare in extensive badlands. In the belt of disturbed rocks adjacent to the mountain front many tilted sections of the formation are exposed, but the strata can not be studied advantageously because as a rule their true sequence can not be definitely ascertained.

### ST. MARY RIVER FORMATION.

The rocks included in the St. Mary River formation were first studied and described by geologists of the Canadian Survey along St. Mary River in Alberta, where they crop out for about 20 miles in the vicinity of the town of Spring Coulee. From this locality the formation is continuous southward across the international boundary into

[1] Stanton, T. W., Some variations in Upper Cretaceous stratigraphy: Washington Acad. Sci. Jour., vol. 3, p. 66, 1913.

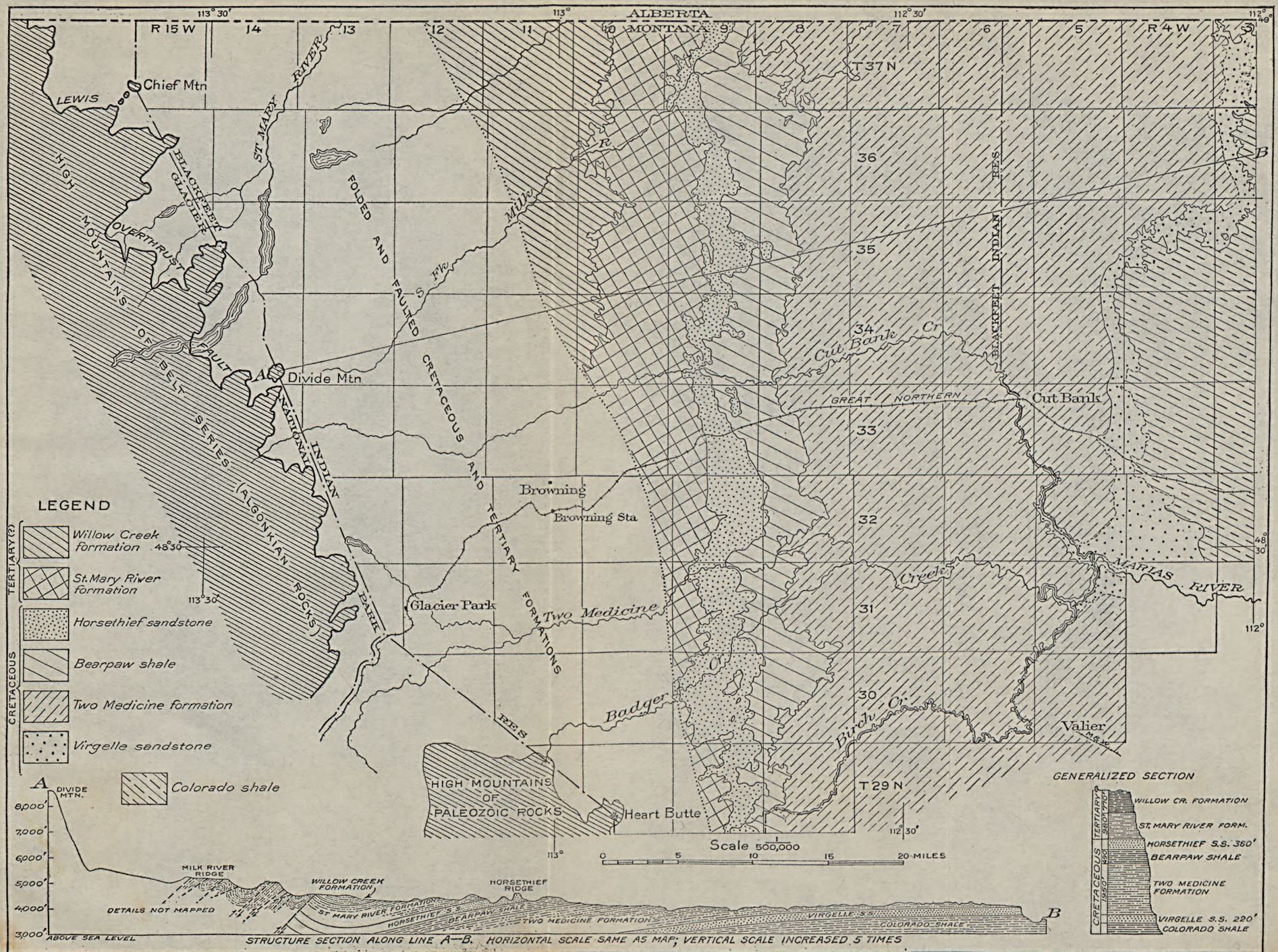
the area here described. It is composed mainly of clay and clay shale and partly consolidated sand of gray to greenish-gray color. A few buff-weathering sandstones which are not persistent are present in places. Red clay in beds a few feet thick is intercalated throughout the formation, and some lenticular beds of limestone of various tints are also present. Bone fragments of undetermined dinosaurs, usually associated with shell beds of unios, are abundant in these rocks. Coal occurs at the bottom of the formation and also at the top. On the whole the similarity to the underlying Two Medicine formation is very striking, and the two formations were doubtless laid down under similar stream conditions.

Although the St. Mary River formation is exposed at many localities in the area here described, there is no place where the complete sequence of the formation can be studied in detail. The best exposures are on the upper 7 miles of Little Rocky Coulee, where all but the lower third of the formation is laid bare in a small badland area. The base of the overlying Willow Creek formation is determinable solely by a change in color from grayish rocks to those that are dominantly red. This takes place in a 50-foot transition zone, in which red beds alternate with white to gray beds. In the disturbed belt of rocks adjacent to the mountains it is very difficult to distinguish the St. Mary River and Two Medicine formations, because their composition and fossils are closely alike. If the underlying or overlying formations associated with each are present in normal contacts, the identity of the rocks can usually be determined. Contrasted with the Two Medicine formation the St. Mary River formation is thinner and contains much less fossil wood and fewer leaves and shells.

## STRUCTURE.

Structurally the area described in this paper can be divided into two large units, differing greatly in the amount of deformation to which the rocks have been subjected. A slightly curving line shown on the geologic map (Pl. XV), extending northward from a point on Birch Creek in R. 9 W. to a point on the Canadian boundary in T. 37 N., R. 12 W., marks a sharp transition between an area on the east, in which the beds are nearly horizontal and undisturbed, and an area on the west, adjacent to the mountain front, in which the rocks have been folded and faulted to an unusual degree. The eastern area on the map is characterized by a simple arrangement of broad belts of outcrop with regular north-south trend, and the western area by a relatively complex arrangement of formation patterns.

In the horizontal rocks there is a slight, generally westward dip, varying from near zero to 5° in gentle undulating flexures with an




GEOLOGIC SKETCH MAP AND SECTIONS OF NORTHERN TETON COUNTY, MONT.

average dip of not over 2°. As a result of this average westward dip of the bedrock formations, the youngest, or, in other words, the highest stratigraphically, the Willow Creek formation, lies farthest west in these nearly horizontal rocks, whereas the oldest, the Colorado shale, lies farthest east, on the east edge of the tract. Thus, one traveling westward up any of the principal stream valleys, as, for instance, from Marias River, up Cut Bank Creek, Two Medicine Creek, or Birch Creek, would cross all the formations present, in sequence from older to younger, in a distance of 35 to 50 miles. Between the southern slopes of Milk River Ridge and the international boundary a broad, open syncline whose steeper limb is on the west, lies on the west border of the area of horizontal rocks. Its axis is between 1 and 2 miles east of the line marking the transition to the disturbed belt of rocks and closely parallels that line. Farther north in Alberta this syncline broadens into a much more extensive feature, which continues to Calgary and beyond. On the south it is practically coextensive with the Willow Creek formation and does not reach beyond Cut Bank Creek.

Minor undulations of the strata in the area of nearly horizontal rocks can be seen in detail only along the principal stream valleys. They are gentle monoclinal flexures in which the inclined beds are on the west, although in a few places reverse dips produce slight anticlinal folds in the generally westward-dipping rocks. The change in structure from the nearly horizontal rocks in the eastern half of the reservation to the steeply dipping disturbed rocks in the western half is very abrupt. Where exposures are good, especially along the major stream valleys, this change can be seen to occur within a few feet, there being no intermediate zone of gentle folding.

The disturbed belt of rocks adjacent to the mountains occupying the western third of the region here described is a small part of a structural area from 15 to 20 miles wide, lying at the base of the Rocky Mountains, which extends at least 80 miles southeastward to and beyond Sun River and a much greater distance northwestward across Alberta. Throughout this area the rocks have been intensely folded and faulted by thrust stresses that acted from the southwest. In many places the individual formations are so much crushed and broken that it is impossible to identify them with certainty. The one constant feature in this whole disturbed area is the uniform northwesterly strike of the rocks. Because of this parallelism of strike the more resistant sandstones of the several formations appear as numerous parallel strike ridges, the same formation being repeated within short distances.

## THE COAL.

### GENERAL FEATURES OF OCCURRENCE.

All the coal found in northern Teton County is of medium bituminous grade. It occurs in the Two Medicine formation and the St. Mary River formation, which have already been described. The valuable coal beds occur at five horizons in these formations, three in the Two Medicine and two in the St. Mary River.

The map and sections on Plate XVI present graphically the important coal data for the area. All the valuable occurrences of coal are shown, the outcrops of beds that could be traced being indicated by black lines. Sections of the coal at many points on these outcrops are given, besides those of numerous scattered outcrops from beds that were either too thin or too much covered to warrant mapping. The scale of the map is too small to differentiate those parts of the outcrops where coal is actually exposed from the stretches that are grassed over or otherwise covered, but in the descriptions that follow, details of the actual outcrops upon which the tracing of individual beds depends are given.

For convenience in presenting the detailed accounts of the coal the area here described is divided into several units. The subdivision is more or less arbitrary, because the small amount of mining in progress does not afford a number of districts which are separate centers of development. The coals in the area of nearly horizontal rocks in the eastern two-thirds of the area are first described, taking in turn first the Valier field, then minor coals from the Two Medicine formation, and finally the coals from the St. Mary River formation. The coals in the disturbed belt of rocks occupying the western third of the area are described separately from those in the area of nearly horizontal rocks, because the great difference in structure in the two tracts will demand very different types of mining in each. The description of the Blackfeet field, the one important area in the belt of disturbed rocks, is first presented. Then an account is given of the minor coals occurring in the disturbed belt in the Two Medicine and St. Mary River formations.

### COAL IN THE AREA OF NEARLY HORIZONTAL ROCKS.

#### VALIER FIELD.

The Valier field is about 7 miles northwest of Valier on Birch Creek. It contains at least 5 square miles of coal land, nearly all of which lies in secs. 28 to 33, T. 31 N., R. 5 W. The coal crops out along the creek in a sharply cut trenchlike valley about 200 feet deep and can be studied in detail for 2½ miles along the course of the stream. Because of the excellent exposures of the beds present, the coal was

probably known to the pioneer cattle men in this region, and it has been actively mined for at least 15 years.

The coal occurs in two beds at the base of the Two Medicine formation. The lower of these beds rests directly on the light-gray cliff-making member of the Virgelle sandstone, which is continuously exposed for many miles down Birch and Two Medicine creeks in a steep-walled box canyon that extends to Marias River. A section of the coal-bearing strata measured at locality 6,[1] a short distance southwest of the west quarter corner of sec. 28, T. 31 N., R. 5 W., is as follows:

*Section of coal-bearing rocks on Birch Creek, at locality 6 in sec. 29, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, soft gray, weathers to a buff tint. | | |
| Upper coal bed: | | |
| Coal | | 2 |
| Shale, fissile, carbonaceous | | 8 |
| Coal, clean and hard | | 4 |
| Clay, gray and compact | | 2 |
| Coal of good grade | 1 | 6 |
| Clay, gray | 10 | 0 |
| Sandstone, massive, white to gray | 12 | 0 |
| Clay, dark gray | 4 | 0 |
| Lower coal bed: | | |
| Coal, very dirty, with a few clean streaks | 1 | 4 |
| Shale, fissile and carbonaceous | 1 | 8 |
| Coal, very dirty, with a few clean fragments | 1 | 2 |
| Clay, dark gray | | 10 |
| Coal, clean and hard | | 8 |
| Shale, carbonaceous and fissile | 2 | 0 |
| Sandstone, gray and massive, main member of Virgelle sandstone | 50+ | |

The upper coal bed at this point is 2 feet 10 inches thick. The compact gray clay 2 inches thick in this bed, locally known as "bone," is a persistent parting that appears in all the exposures throughout the field. It is very regular both in thickness and appearance. The 12 feet of white to gray sandstone lying between the upper and lower coal beds is well exposed along the creek and is present as far as the coals persist. The lower bed, although it is over 7 feet thick, is everywhere too dirty to be worked, 8 inches being the greatest thickness of clean coal present.

The coal-bearing strata in this field lie nearly horizontal. In general they have a slight inclination, not exceeding 45 feet to the mile, in a direction about S. 75° W., which roughly parallels the upstream direction of Birch Creek. This dip, together with the uphill gradient of the creek, gradually carries the coal beds toward the water level of

[1] Locality numbers refer to corresponding numbers on Plate XVI.

the stream, and the upper bed passes beneath the creek in secs. 31 and 32. Thus much of the coal in secs. 30, 31, and 32 lies beneath the level of Birch Creek.

The farthest upstream exposure on Birch Creek of the upper bed is at locality 1, in the SE. ¼ sec. 31. Here the bed crops out for several hundred feet along the left bank of the creek, very close to water level. A section at this point is as follows:

*Section of coal bed at locality 1, in the SE. ¼ sec. 31, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Clay, gray. | | |
| Shale, carbonaceous and fissile, with thin layers of coal | | 10 |
| Coal, clean and hard | | 6 |
| Clay parting | | 3 |
| Coal, clean and hard | 1 | 6 |
| Clay, gray. | | |
| Thickness of bed | 3 | 1 |
| Thickness of coal | 2 | 0 |

The coal in both benches at this point seems to be of excellent quality. Even on a weathered outcrop it is hard, has a black shiny luster, and breaks out in cubic masses as much as 6 inches in size. The coal is prominently jointed in directions at right angles to each other. About 300 feet upstream this coal bed passes beneath the bed of the creek. At this point on the south side of the creek there is an excellent exposure of the rocks associated with the coal at the base of the Two Medicine formation, as follows:

*Section of coal-bearing rocks exposed on Birch Creek in the SE. ¼ sec. 31, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Top of bluff. | | |
| Interval, partly covered, but presumably of clay and shale | 30 | 0 |
| Sandstone, coarse, gray to buff, making a ledge on the slope | 25 | 0 |
| Clay, white to gray | 35 | 0 |
| Sandstone, massive, most prominent stratum on the slope, cross-bedded, gray to white | 30 | 0 |
| Clay, gray | 6 | 0 |
| Coaly shale, fissile | 3 | 0 |
| Clay, white to dark gray | 21 | 0 |
| Clay and sandy clay, grading into sandstone | 20 | 0 |
| Coaly shale, black, fissile | 3 | 0 |
| Clay, dark gray, grading into sandstone | 12 | 0 |
| Coal, upper bed | 2 | 3 |
| Water level of creek. | | |

The next exposure of the upper coal bed on Birch Creek is a little over a quarter of a mile downstream, in the NW. ¼ sec. 32, on the east side of the creek, where the bed has been mined for a number of years by A. G. Blair. The coal crops out in the steep bluffs slightly above the high-water line along the creek and has been worked in several short entries. A section of the bed at this point is as follows:

*Section of coal bed at Blair mine, in the NW. ¼ sec. 32, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, massive, gray and irregular. | | |
| Clay shale, gray | 5 | 0 |
| Coaly shale, black and fissile | 1 | 0 |
| Coal, clean and hard | | 5 |
| Clay parting, somewhat sandy | | 2 |
| Coal, with a little sandy dirt [1] | 1 | 7 |
| Clay, gray. | | |
| Thickness of bed | 3 | 2 |
| Thickness of coal | 2 | 0 |

The upper bench is in some places not more than 4 inches thick and in others as much as 12 inches. It is a shiny, black, fairly hard coal, and locally shows some whitish dirt. The lower bench, in places, is as much as 1 foot 10 inches thick, thus giving a maximum thickness of 2 feet 10 inches for this bed. The lower bench is prominently jointed and often breaks out in large blocky masses as much as 2 feet square. Immediately north of locality 2, on the opposite side of the creek, the same bed crops out for 400 to 500 feet, a short distance above water level, and at one time was mined at this point to supply coal to the Indian school at the Holy Family Mission, on the Blackfeet reservation.

About a quarter of a mile northeast of the Blair mine the creek is cutting vigorously against its right bank, making a steep cut-bank face, which again exposes the coal bed. The croppings are continuous for nearly 1,000 feet at this locality. A section of the bed near the center of this exposure gave the following:

*Section of upper coal bed at Slazak mine, in the NW. ¼ sec. 32, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Clay, dark gray, grading upward into gray sandstone. | | |
| Shale, carbonaceous, with streaks of good coal | | 10 |
| Coal, clean and hard | | 6 |
| Clay, compact, and gray bone | | 2 |
| Coal, clean and well jointed | 1 | 8 |
| Clay, dark gray. | | |
| Thickness of bed | 3 | 2 |
| Thickness of coal | 2 | 2 |

There are three short entries on the bed at this exposure where mining has been carried on by Paul Slazak for a number of years. The roof of the coal is generally a dark-gray clay, which grades upward into a soft gray sandstone. It caves badly and is irregular, being replaced at many points by sandstone, although the thickness and character of the coal itself, with the 2-inch parting near the top, remain fairly constant.

[1] Analysis 12427 on p. 138.

Near the south line of sec. 29, on the bend of the creek below the Slazak mine, the lower coal bed, here practically at water level, is seen for the first time by one traveling down the creek. It is very dirty, containing only a few streaks of clean coal, and on the whole is worthless as a fuel. Immediately below it can be seen the light-gray Virgelle sandstone, rising gradually above water level as it is followed by the eye downstream until it stands as a white cliff more than 50 feet in height at the farthest visible bend of the creek.

At locality 4, on the north side of the creek in the SW. ¼ sec. 29, the upper coal bed has been mined in a strip pit paralleling the outcrop for some distance. The section at this point is as follows:

*Section of upper bed at locality 4, on Birch Creek, in the SW. ¼ sec. 29, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Clay, soft, gray. | | |
| Coal, dirty | | 4 |
| Shale, carbonaceous and fissile | | 6 |
| Coal, of good grade | | 6 |
| Clay, compact gray bone | | 2 |
| Coal, clean and hard, with rectangular jointing | 1 | 9 |
| Thickness of bed | 3 | 3 |
| Thickness of coal | 2 | 7 |

Directly across the creek from the locality noted above there are two sharply cut coulees joining the creek at right angles from the southeast. The outcrop of the upper coal bed extends about 1,000 feet up each of these coulees in almost continuous exposure. In the western coulee there are two entries on the bed. The section of the coal is almost identical with that at locality 4.

A quarter of a mile east of locality 4, on the south side of the creek, there is a group of at least four entries extending along about 1,000 feet of outcrop of the upper bed. These entries are badly caved and have been abandoned. They were probably made during the first mining in this field. Henry Weimers was actively working one of these openings as early as 1901.

At locality 5, in the SE. ¼ sec. 29, both the upper and lower beds are exposed above the cliffs of massive Virgelle sandstone about 50 feet above creek level. The lower bed consists of 5 feet of black carbonaceous shale that weathers out in fissile papery layers. Interspersed through it are irregular streaks of clean coal as much as 4 or 5 inches thick. The section of the upper bed at this point is as follows:

*Section of upper coal bed at locality 5, in the SE. ¼ sec. 29, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, gray, platy. | | |
| Shale, coaly, with fragments of clean coal | | 11 |
| Coal, clean and hard | | 4 |
| Clay, of compact gray bone | | 2 |
| Coal, clean and prominently jointed | 1 | 11 |
| Thickness of bed | 3 | 4 |
| Thickness of coal | 2 | 3 |

The section of the coal zone on the opposite side of the creek, at locality 6, where both beds are also exposed, has already been given.

At locality 7, in the NW. ¼ sec. 28, on the east side of the creek, there is a small entry on the upper bed that was badly caved at the time it was examined. An exposure of the bed in a cut at the mouth of this entry measures as follows:

*Section of coal bed at locality 7, in the NW. ¼ sec. 28, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, coarse, gray, grading upward into yellow clay | 8 | 0 |
| Shale, carbonaceous, with coaly layers | | 6 |
| Coal, hard and shiny black | | 2 |
| Clay, compact gray bone | | 2 |
| Coal, of good grade and well jointed | 1 | 7 |
| Sand, gray. | | |
| Thickness of bed | 1 | 11 |
| Thickness of coal | 1 | 9 |

About 1,000 feet south of locality 7, on the same side of the creek and near the mouth of a small coulee entering the creek from the southeast, there is an entry about 100 feet long on the lower coal bed, which is the only entry driven on the lower coal in this field. The bed is well exposed as a thick black layer along the side of the coulee and on cursory examination might be mistaken for valuable coal. A section at the mouth of this entry is as follows:

*Section of lower coal bed at entry 1,000 feet south of locality 7, in the SW. ¼ NW. ¼ sec. 28, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, firm, gray. | | |
| Clay, gray, irregular | | 5 |
| Coal | | 3 |
| Clay, bluish gray | | 3 |
| Coal, largest bench in bed | | 8 |
| Shale, fissile, ash gray | | 6 |
| Coal | | 3 |
| Shale, fissile and coaly | 2 | 1 |
| Clay, gray | 3 | 0 |
| Sandstone, massive, gray, Virgelle sandstone | 60+ | |
| Thickness of bed | 4 | 0 |
| Thickness of coal | 1 | 2 |

In the NW. ¼ sec. 29 is a large coulee which enters Birch Creek from the west and the lower part of which consists of a narrow rock gorge in Virgelle sandstone. There are several croppings of the upper coal bed in the lower three-fourths of a mile of this coulee. At locality 8, in the SE. ¼ sec. 20, the bed measures as follows:

*Section of coal bed at locality 8, in the SE. ¼ sec. 20, T. 31 N., R. 5 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, yellowish gray, soft. | | |
| Shale, carbonaceous and fissile | | 6 |
| Coal | | 4 |
| Clay, compact gray bone | | 2 |
| Coal, clean and prominently jointed | 1 | 4 |
| Thickness of bed | 2 | 4 |
| Thickness of coal | 1 | 8 |

This is the northernmost exposure of the bed in this field. It is almost identical with the exposures all along the creek to the opposite end of the field, the thin parting with a thick bench of coal below it and a thin one above being present at every point examined. A quarter of a mile south of locality 8, on the south bank of the coulee, the sandstone forming the roof of the upper bed along the coulee has been baked throughout its lower 4 feet to a brick-red tint, the color being deepest toward the base of the sandstone. This red color was doubtless caused by the burning of the coal at this point and is noteworthy as the only evidence seen in this region of the burning of coal along the outcrop, a feature which is so common in the coal and lignite areas of eastern Montana.

Toward the north both the coal beds in the Valier field thin out and lose their identity near the south line of sec. 21. On the east side of the creek there is no trace of the upper bed with its characteristic clay parting north of the small entry at locality 7, except a small bloom in the first coulee to the northeast. Beyond this point the rocks at the horizon of the bed are concealed for about half a mile on gentle slopes on both sides of the creek by the slumping of the gravel and till of the overlying glacial drift. The beds at the coal horizon can be seen next on both sides of Birch Creek near the center of sec. 21 at the top of the box canyon cut in the Virgelle sandstone. Here they consist of 15 feet of yellow iron-stained sand, much cross-bedded, which contains lenses and thin irregular streaks of coal in great abundance. The largest of these lenticular masses seen measured 2½ feet thick by 8 feet in greatest dimension and was sharply outlined in the surrounding sand. Half a mile farther north, on the north line of sec. 21, the coaly matter in this sand is represented by a bed 2½ feet thick, of fissile carbonaceous shale with streaks of clean coal, which can be followed for about half a mile and then disappears.

At the time of the examination of the Valier field there were no data available from well borings deep enough to have reached the coal horizon in the areas on either side of Birch Creek back of the outcrop of the one workable coal bed present. Inference as to the area underlain by this coal bed must therefore be based on the extent and continuity of its outcrop. The northeastward limits of the coal area can be determined with a fair degree of accuracy where the bed thins out in that direction, but southwestward the coal is last seen passing beneath the bed of the creek in sec. 31, T. 31 N., R. 5 W., and the distance to which it extends underground in that direction is very uncertain. The bed, though thin, is very regular and persistent from the northeast extremity of its outcrop to the point where it passes beneath the creek, and it may underlie a large area to the southwest.

The coal in the one workable bed on Birch Creek seems to be very uniform in character throughout its extent. The fresh coal at a working face has a bright luster and is fairly hard. In places it shows fine streaks of whitish dirt. It is everywhere prominently jointed in two directions at right angles to each other, spaced at irregular distances of 2 feet or less. This makes the coal break out in large blocks, many of which are as much as 2 feet square and as thick as the entire lower bench of the coal bed at the point being worked. The coal withstands weathering very well and does not slack on exposure. A 20-inch cube of it which had been kept for display, was examined and found to be firm and intact after over a year's exposure to the weather. Even the weathered face of the coal on natural exposures is hard, and the coal breaks out in cubic fragments of all sizes up to 6 inches across. The coal appears to be of about the same quality in all parts of the field. Its chemical composition is shown by analysis 12427 in the following table:

*Analyses of coal samples from northern Teton County, Mont., and adjacent regions.*

[Made at the laboratory of the Bureau of Mines; A. C. Fieldner, chemist in charge.]

| | Location. | | | | Laboratory No. | Air-drying loss. | Form of analysis. | Proximate. | | | | Ultimate. | | | | | Heating value. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Quarter. | Sec. | T.N. | R.W. | | | | Moisture. | Volatile matter. | Fixed carbon. | Ash. | Sulphur. | Hydrogen. | Carbon. | Nitrogen. | Oxygen. | Calories. | British thermal units. |
| Blair mine, Valier field.. | NW. | 32 | 31 | 5 | 12427 | 1.3 | A. | 6.6 | 40.3 | 39.2 | 13.89 | 3.08 | 5.16 | 60.71 | 1.13 | 16.03 | 6,070 | 10,930 |
| | | | | | | | B. | 5.3 | 40.9 | 39.7 | 14.07 | 3.12 | 5.09 | 61.51 | 1.14 | 15.07 | 6,150 | 11,070 |
| | | | | | | | C. | ..... | 43.2 | 41.9 | 14.87 | 3.30 | 4.74 | 64.97 | 1.21 | 10.91 | 6,495 | 11,690 |
| | | | | | | | D. | ..... | 50.7 | 49.3 | ..... | 3.88 | 5.57 | 76.32 | 1.42 | 12.81 | 7,630 | 13,740 |
| Allison mine, Cut Bank Creek. | NE. | 29 | 34 | 6 | 12494 | 2.9 | A. | 7.8 | 30.2 | 34.3 | 27.7 | 1.78 | ..... | ..... | ..... | ..... | 4,835 | 8,710 |
| | | | | | | | B. | 5.1 | 31.1 | 35.2 | 28.6 | 1.83 | ..... | ..... | ..... | ..... | 4,980 | 8,970 |
| | | | | | | | C. | ..... | 32.8 | 37.1 | 30.1 | 1.93 | ..... | ..... | ..... | ..... | 5,245 | 9,450 |
| | | | | | | | D. | ..... | 46.9 | 53.1 | ..... | 2.76 | ..... | ..... | ..... | ..... | 7,505 | 13,510 |
| Stone prospect, Blackfeet field. | SE.. | 35 | 36 | 12 | 12602 | 2.3 | A. | 8.0 | 35.4 | 44.2 | 12.45 | 1.00 | 5.17 | 62.92 | 1.46 | 17.00 | 6,135 | 11,050 |
| | | | | | | | B. | 5.8 | 36.2 | 45.3 | 12.74 | 1.02 | 5.03 | 64.40 | 1.49 | 15.32 | 6,280 | 11,310 |
| | | | | | | | C. | ..... | 38.5 | 48.0 | 13.53 | 1.09 | 4.65 | 68.39 | 1.59 | 10.75 | 6,670 | 12,010 |
| | | | | | | | D. | ..... | 44.5 | 55.5 | ..... | 1.26 | 5.38 | 79.09 | 1.84 | 12.43 | 7,715 | 13,890 |
| Paisley prospect, St. Mary River. | ..... | 8 | 37 | 13 | 3934 | 1.8 | A. | 7.0 | 32.0 | 47.4 | 13.6 | .86 | ..... | ..... | ..... | ..... | 6,040 | 10,870 |
| | | | | | | | B. | 5.2 | 32.6 | 48.3 | 13.9 | .88 | ..... | ..... | ..... | ..... | 6,150 | 11,070 |
| | | | | | | | C. | ..... | 34.4 | 51.0 | 14.6 | .93 | ..... | ..... | ..... | ..... | 6,495 | 11,690 |
| | | | | | | | D. | ..... | 40.3 | 59.7 | ..... | 1.09 | ..... | ..... | ..... | ..... | 7,605 | 13,690 |
| Mine of Cottonwood Coal Co., Sand Coulee, Cascade County. | NW. | 36 | 19 | 4 E. | 4115 | 2.4 | A. | 6.0 | 28.5 | 51.4 | 14.14 | 2.38 | 4.46 | 63.61 | .91 | 14.50 | 6,195 | 11,150 |
| | | | | | | | B. | 3.7 | 29.1 | 52.7 | 14.49 | 2.44 | 4.28 | 65.18 | .93 | 12.68 | 6,350 | 11,430 |
| | | | | | | | C. | ..... | 30.3 | 54.7 | 15.04 | 2.53 | 4.03 | 67.67 | .97 | 9.76 | 6,590 | 11,870 |
| | | | | | | | D. | ..... | 35.6 | 64.4 | ..... | 2.98 | 4.75 | 79.66 | 1.14 | 11.47 | 7,760 | 13,970 |
| Galt mine, Lethbridge, Alberta, Canada. | ..... | ..... | ..... | ..... | 14882 | 2.0 | A. | 9.8 | 40.1 | 43.3 | 6.77 | .71 | 5.60 | 64.99 | 1.73 | 20.20 | 6,340 | 11,410 |
| | | | | | | | B. | 7.9 | 41.0 | 44.2 | 6.91 | .72 | 5.49 | 66.32 | 1.77 | 18.79 | 6,470 | 11,640 |
| | | | | | | | C. | ..... | 44.5 | 48.0 | 7.50 | .79 | 5.00 | 72.04 | 1.92 | 12.75 | 7,030 | 11,650 |
| | | | | | | | D. | ..... | 48.1 | 51.9 | ..... | .85 | 5.41 | 77.88 | 2.08 | 13.78 | 7,600 | 13,680 |
| City of Lethbridge mine, Lethbridge, Alberta, Canada. | ..... | ..... | ..... | ..... | 14883 | 2.8 | A. | 10.6 | 36.4 | 36.3 | 16.73 | .89 | 5.15 | 55.94 | 1.44 | 19.85 | 5,455 | 9,820 |
| | | | | | | | B. | 8.0 | 37.5 | 37.3 | 17.21 | .92 | 4.98 | 57.55 | 1.48 | 17.86 | 5,610 | 10,100 |
| | | | | | | | C. | ..... | 40.8 | 40.5 | 18.71 | 1.00 | 4.45 | 62.55 | 1.61 | 11.68 | 6,100 | 10,980 |
| | | | | | | | D. | ..... | 50.1 | 49.9 | ..... | 1.23 | 5.47 | 76.95 | 1.98 | 14.37 | 7,505 | 13,710 |

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form is not well suited for comparison, because the amount of moisture in the sample as it comes from the mine is largely a matter of variable local conditions, and consequently analyses of the same coal expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted for general comparison. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated. Analysis D represents the coal after all the moisture and ash have been theoretically removed. This is supposed to represent the true coal substance, free from the most abundant impurities. Forms C and D, which are obtained from the others by recalculation, represent theoretical conditions that do not exist.

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

It is evident from the table that coal from the Valier field compares very favorably with either of the two coals which compete with this coal in its home market, namely, that from the Great Falls field, Montana, and that from the Belly River field (Lethbridge), Alberta. The average heating value of two samples of Lethbridge coal collected by the writer and determined by the Bureau of Mines was, on the basis of air-dried coal, 10,800 British thermal units. (See analyses 14882 and 14883.) For the Great Falls coal (see analysis 4115) this value is 11,400 British thermal units, and for the Valier coal (see analysis 12427) it is 11,070 British thermal units. The ash content on the air-dried basis, is 10.3 for Lethbridge coal, 18.4 for unwashed run-of-mine coal from Great Falls, and 14.1 for Valier coal. The excess of ash in the Valier coal over that in the coal from Lethbridge is considerable, but not as great as a casual inspection of the fuel leads one to expect. This is due to the fact that the impurities in the Valier coal are whiter than those in the coal from Lethbridge, so that the Valier coal gives the impression of being a much dirtier fuel. On the whole it seems clear that coal from the Valier field

belongs to the bituminous class and compares favorably with the other bituminous coals of the same region.

## SMALL COAL BEDS IN TWO MEDICINE FORMATION.

### COAL ON TWO MEDICINE CREEK.

There are a number of exposures of either thin or very dirty coals in the badlands along the lower 10 miles of Two Medicine Creek. In going up the creek from its mouth the first of these exposures is found at locality 9, in the NE. ¼ sec. 18, T. 31 N., R. 5 W. Here 60 feet above water level of the creek, immediately above massive cliffs of Virgelle sandstone and therefore at the same horizon as the coal of the Valier field on Birch Creek, there is 1 foot 5 inches of coal. The upper 8 inches of this bed is very dirty, but the remainder seems to be fairly clean bituminous coal. The westward dip of the strata carries this bed down to creek level three-fourths of a mile upstream, in the NW. ¼ sec. 18.

Six miles farther up the creek there is a persistent bed of coal and coaly shale that can be followed for nearly 3 miles. This bed lies about 250 feet above the base of the Two Medicine formation and is approximately at the same stratigraphic position as that of more extensive outcrops of coal farther north on Cut Bank Creek. At locality 10, in the NW. ¼ sec. 3, T. 31 N., R. 6 W., the bed lies just below a 15-foot massive gray sandstone and includes 4 feet of dirty coal, which might better be described as fissile carbonaceous shale containing fragments of pure coal. A quarter of a mile west of locality 10 the bed can be seen at the level of the creek. Farther downstream, on the south side of the creek, it can be traced along several miles of outcrop but does not contain clean coal at any point.

Above locality 10 the badlands in the next 3 miles along Two Medicine Creek show many outcrops of black carbonaceous shale beds, none of which contains more than a few small lenses of coal. The largest of these beds is exposed as a prominent black outcrop that can be followed for over half a mile along the sides of the principal coulee in sec. 36, T. 32 N., R. 7 W.

### COAL ON LOWER PART OF CUT BANK CREEK.

The beds at the base of the Two Medicine formation which carry the coal in the Valier field are exposed above the bold cliffs of Virgelle sandstone along the lower 10 miles of Cut Bank Creek. A careful search was made in the clay and sandstone, but no coal was found. On the west side of the creek in sec. 5, T. 32 N., R. 5 W., the beds of this horizon contain several feet of black carbonaceous shale, which crops out at intervals across sec. 5. A mile farther downstream this carbonaceous shale is replaced by yellowish ferruginous sand and

sandy clay, similar to that found at the same stratigraphic position on the north edge of the Valier field.

About 250 feet above the base of the Two Medicine formation there is a bed of coal and coaly shale that can be traced continuously for 10 miles along the valley of Cut Bank Creek from a point near the mouth of Spring Creek, 4 miles south of the town of Cut Bank, to a point 3 miles above the mouth of Big Rocky Coulee. The bed is approximately the same as the coal of locality 10, on Two Medicine Creek. It is thus evident that coal-forming conditions in this vicinity at this stage were fairly widespread for the distance between the northernmost exposure on Big Rocky Coulee and those farther south is over 20 miles.

To the north, up the valley of Cut Bank Creek, the first outcrop noted that should probably be referred to this bed is in the NE. ¼ sec. 17, T. 32 N., R. 5 W. Here, at an altitude of 3,695 feet, in the bottom of the coulee crossing this quarter section, there are prominent croppings of black coaly shale with many small lenses of clean coal. About 1½ miles above the mouth of Spring Creek, in the S. ½ sec. 26, this coal bed is exposed for about 1,000 feet along both sides of the creek. A section of the rocks at this point is as follows:

*Section of coal-bearing rocks at locality 11, on Spring Creek, in the S. ½ sec. 26, T. 33 N., R. 6 W.*

| | Ft. | in. |
|---|---|---|
| Shale, carbonaceous, contains brackish-water shells | 30 | |
| Coal, lustrous and well jointed | 1 | 2 |
| Clay, dark gray, with fossil shells | 3 | |
| Sandstone, massive gray, persistent | 18 | |
| Clay, carbonaceous. | | |

An ash determination of an outcrop sample from the coal in this exposure gave 19.16 per cent of ash on the air-dried basis.

Two miles northeast of locality 11, in the SE ¼ sec. 24 of the same township, the bed contains 4 feet of coaly shale and can be traced in detail along the steep banks above Cut Bank Creek. Just west of the town of Cut Bank there are several exposures of the bed, but it is everywhere too dirty to be valuable as a fuel. These exposures occur (1) half a mile southwest of Cut Bank, at the top of the bluff above the creek, where the thickness is 3 feet; (2) near the top of a butte in the center of sec. 11, T. 33 N., R. 6 W., where 2 feet of dirty coal lies immediately beneath a fossil oyster bed; and (3) in a cut on the south side of the railway track in the NW. ¼ of the same section, where there is 2½ feet of coaly shale.

Between the point where the Great Northern Railway crosses Cut Bank Creek and the mouth of Big Rocky Coulee outcrops of the same dirty coal bed can be seen in every mile of the distance at altitudes which, because of the slight inclination of the strata, range

only between 3,710 and 3,750 feet. The fossil shells already noted in connection with several outcrops of the bed seem to be generally present here and aid in identifying the horizon.

At locality 12, in the NW. ¼ sec. 28, T. 34 N., R. 6 W., the bed crops out at an altitude of 3,720 feet, about 30 feet above the creek, as a dark band that can be followed for a short distance, dipping gently westward, or upstream. A section at this point, containing over 6 feet of black, coaly material is as follows:

*Section of coal bed at locality 12, in the NW. ¼ sec. 28, T. 34 N., R. 6 W.*

| | Ft. | in. |
|---|---|---|
| Shale, coaly | 2+ | |
| Coal, clean and well jointed | 1 | 2 |
| Shale, coaly | 3 | 0 |
| Sandstone, gray, massive | 20+ | |

Half a mile upstream, at locality 13, in the NE. ¼ sec. 29, the bed crops out on both sides of the creek only a few feet above water level. On the north side of the creek, close to the line between secs. 29 and 20, the bed has been opened by a short entry made by A. E. Allison, and also in a strip pit paralleling the outcrop for some distance. The coal that is being worked occurs 5 feet above the base of a 25-foot zone of carbonaceous shale lying upon the massive gray sandstone member noted at locality 12. Brackish-water shells are abundant in the carbonaceous shale. The bed of coal that is mined is the thickest of a number of coaly layers occurring throughout the shale zone. It is 1 foot 10 inches thick and on the whole is very dirty, although there are clean streaks of hard, lustrous coal in the bed. It has conspicuous joint planes and weathers out in cubic fragments. Approximate analysis of a sample cut from a fresh face of coal that was somewhat weathered is given as No. 12494 in the table on page 138.

The analysis shows that on the air-dried basis this coal contains about one-third of its weight in ash, thus forcing its heating value below 9,000 British thermal units, although the heating value of 13,510 British thermal units on the moisture and ash free basis shows that the actual fuel value of this coal is about the same as that of the coal from the Valier field. Attempts to market the fuel from this prospect at Cut Bank were unsuccessful, doubtless owing to the high ash content. An attempt was also made to use the coal on a steam plow tractor belonging to the Office of Indian Affairs, but it was given up after a single day's trial.

The slight westward dip carries the coal at the Allison prospect to creek level within a quarter of a mile upstream. One mile farther north, however, on the sharp bend of the creek in the N. ½ sec. 20, the coaly shale zone with brackish-water shells and several beds of

impure coal as much as 3 feet in thickness can be seen close to water level. The shale zone is about 35 feet thick and can be followed along the banks of the creek to, and a short distance above, the mouth of Little Rocky Coulee, where the dip of the strata finally carries it beneath the creek.

The general northward strike of the rocks carries the outcrop of the coaly shale zone containing the coal bed mined at the Allison prospect northward across the area lying between Big Rocky and Little Rocky coulees, but it is nowhere exposed in this tract because of the cover of clay and sand of the glacial drift. On Big Rocky Coulee, however, at locality 14, in sec. 17, T. 35 N., R. 6 W., a coaly shale zone that is with little doubt at the same horizon in the Two Medicine formation is again exposed and can be traced eastward about 5 miles, as far as Headlight Butte, in the adjoining township.

*Section of coaly shale zone at locality 14, in the NW. ¼ sec. 17, T. 35 N., R. 6 W.*

| | Ft. | in. |
|---|---|---|
| Clay, gray, with 2-foot oyster bed near the base | 20+ | |
| Shale, carbonaceous | | 6 |
| Clay, gray | 5 | 0 |
| Sandstone and shale, interbedded and containing coaly layers | 2 | 0 |
| Clay, gray | 10 | 0 |
| Shale, carbonaceous, fissile, with many fragments of clean coal, is sandy in places | 4 | 0 |
| Sandstone, massive, gray, and coarse grained | 6+ | |
| Bed of creek. | | |

Three miles northeast of locality 14 the same beds crop out along the sides of the coulee in the E. ½ sec. 3, T. 35 N., R. 6 W. At this point the coaly shale bed is 4 feet thick, contains brackish-water shells, and is overlain by 7 feet of gray slabby sandstone. On Headlight Butte, near the center of sec. 18, T. 35 N., R. 5 W., the same bed crops out near the top of the butte and contains 3 feet of fissile, coaly shale beneath a thick bed of massive cross-bedded sandstone.

### COAL AT TOP OF "THE RIM."

The eastward-facing escarpment locally known as "the rim," extending northward from the Great Northern Railway near Ethridge to the Canadian line, is made up of the Virgelle sandstone. The top of this sandstone escarpment was carefully examined for signs of coal, because the workable coal bed in the Valier field on Birch Creek occurs immediately above this formation in the basal beds of the Two Medicine formation. On the lower part of Cut Bank Creek no coal was found at this position. Northward from the latter locality for 20 miles, of which 12 miles lies along the top of "the rim," the basal beds of the Two Medicine formation are everywhere concealed beneath a thick cover of glacial drift. In the northern part of T. 35 N., R. 4 W., however, they are well exposed at the

upper ends of a number of coulees that have cut back into the escarpment. Exposures of thin coal in this vicinity are as follows: (1) In the NE. ¼ sec. 10, T. 35 N., R. 4 W., 3 feet above the top of the Virgelle sandstone, 4 inches of dirty coal; (2) in the center of sec. 1, T. 35 N., R. 4 W., 4 feet above the Virgelle sandstone, 6 inches of dirty coal; (3) at locality 15, in the SE. ¼ sec. 18, T. 35 N., R. 3 W., 3 feet above the Virgelle sandstone, 9 inches of dirty coal, exposed for one-third of a mile along the top of the escarpment. Northward from locality 15 to the Canadian boundary no further signs of coal were found, a thick cover of glacial drift concealing the beds of this horizon at nearly all points.

### COAL IN THE VICINITY OF LANDSLIDE BUTTE.

In the vicinity of Landslide Butte, the most prominent landmark in the eastern half of the area here described, there are outcrops of a thin coal bed in Tps. 36 and 37 N., R. 8 W., extending several miles both north and south of the butte. This coal bed lies at the top of the Two Medicine formation, immediately beneath the dark-gray Bearpaw shale, which makes the upper 300 feet of Landslide Butte. The coal is too thin to be of value but is of interest because it occurs at the same horizon in the Upper Cretaceous rocks as the valuable coal that has been extensively mined 55 miles to the north, at Lethbridge, Alberta. At Lethbridge the coal lies at the base of the dark marine clay shale called Pierre shale by Dawson.[1] This marine shale has been traced continuously along the outcrop into the area mapped in the vicinity of Landslide Butte as Bearpaw shale, so that the identity of the two formations is unquestionable. Southward from Lethbridge, where the coal is nearly 6 feet thick, coal at this horizon crops out at intervals but gradually becomes thinner until, on Milk River Ridge, 20 miles north of the international boundary line, the bed measures only 1 foot 6 inches.[1] From this locality to Landslide Butte no signs of coal have been reported, probably because for most of the distance the rocks are deeply covered with glacial drift.

On Landslide Butte, at locality 16, in the SW. ¼ sec. 32, T. 37 N., R. 8 W., the following section is exposed:

*Section of coal at top of Two Medicine formation in the SW. ¼ sec. 32, T. 37 N., R. 8 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, gray, slabby | 2+ | |
| Coal, clean and hard, breaking out in lustrous cubic masses. | | 6 |
| Coal, very dirty | | 7 |
| Coal, clean | | 1 |
| Clay, dark gray. | | |

[1] Dawson, G. M., Report on the region in the vicinity of Bow and Belly rivers: Canada Geol. Survey Rept. Progress, 1882-1884, p. 70c.

Traced down the coulee from locality 16 the outcrop of this bed is practically continuous for 2 miles along both sides of the coulee just above the steep badland slopes cut in the soft light-colored clay of the Two Medicine formation. At locality 17, in the SE. ¼ sec. 33, T. 37 N., R. 8 W., the bed is 4½ feet thick but is all very shaly and impure, containing only a few streaks of clean coal. From this exposure the outcrop of the beds at this horizon around the east slopes of Landslide Butte and to the south is much covered because of the soft nature of the overlying Bearpaw shale, and no coal was seen. In the SE. ¼ sec. 5, T. 36 N., R. 8 W., the same coal bed is exposed in the coulee running southwestward from Landslide Butte. This exposure is west of and down the dip from the main outcrop, and is brought to the surface in an elliptical outcrop near the bottom of the coulee by a slight flexure in the strata. A section on the best-exposed portion of this outcrop is as follows:

*Section of coal at locality 18, in the SE. ¼ sec. 5, T. 36 N., R. 8 W.*

| | Ft. | in. |
|---|---|---|
| Clay, gray | 2+ | |
| Coal, shaly and impure | 1 | 2 |
| Coal, clean and well jointed, lustrous | 1 | 0 |
| Coal, very dirty, practically a coaly shale | 2 | 10 |
| Sandstone, gray | 3+ | |

Several entries, one of which is at least 100 feet in length, were driven on the bed at this point but were abandoned because of the impure nature of the coal.

Five miles southwest of Landslide Butte, on the south side of the coulee, in the N. ½ sec. 32, T. 36 N., R. 8 W., the bloom of a thin coaly shale bed at this horizon can be followed for a short distance. South of this locality the beds at this horizon were examined at many points as far as Birch Creek about 50 miles distant, but at no place were any indications of coal found.

### COAL IN ST. MARY RIVER FORMATION.

Coal occurs at two horizons in the St. Mary River formation. The lower bed is at the base of the formation immediately above the Horsethief sandstone and contains coal of commercial value near the north edge of the area. The upper bed is near the top of the formation and occurs at one locality only.

The lower coal crops out at intervals along R. 9 W. entirely across the area mapped, extending from Birch Creek to the Canadian boundary. The coal is generally too thin to be of value as a commercial fuel, but its frequent occurrence over so extensive a belt of outcrop is of interest because it affords proof of widespread though transient coal-forming conditions at a stage immediately following

the deposition of the Horsethief sandstone. The following coal outcrops at this horizon were found between Birch Creek, in T. 29 N., R. 9 W., and Horsethief Ridge, near the center of T. 35 N., R. 9 W.: (1) At locality 19, in the SE. ¼ sec. 21, T. 29 N., R. 9 W., 11 inches of clean, lustrous coal above 6 inches of coaly shale, exposed for half a mile along Blacktail Creek: (2) in the SE. ¼ sec. 34, T. 30 N., R. 9 W., at locality 20, near the head of the coulee leading northeastward to Fourhorns Lake, 8 inches of coal, from which there is a strong seepage of water for a quarter of a mile on both sides of the coulee; (3) at locality 21, at the head of the box canyon at the lower end of Spring Creek (see section below); (4) 1½ miles above the mouth of Trail Coulee, making a bloom for several hundred feet on the north side of the coulee, at locality 22, in the NW. ¼ sec. 29, T. 34 N., R. 9 W., 5 feet of very dirty coal or coaly shale, containing streaks of clean coal; (5) at locality 23, in the NW. ¼ sec. 17, T. 34 N., R. 9 W., 4 feet of dirty coal, making an extensive bloom along the east bank of Cabelle Coulee, 2 miles west of Rim Rock Butte; (6) on the north side of Horsethief Ridge, just above cliffs of Horsethief sandstone, at locality 24, in the SE. ¼ sec. 14, T. 35 N., R. 9 W., 1 foot of dirty coal.

The section at locality 21 is as follows:

*Section of coal at locality 21, in the NW. ¼ sec. 32, T. 32 N., R. 9 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, with ferruginous concretions | 8 | |
| Coal, clean and lustrous | | 9 |
| Coal, very dirty and shaly | | 7 |
| Shale, dark gray | | 9 |
| Sandstone, massive and gray, massive member of Horsethief sandstone | 10+ | |

Continuing northward the next outcrops were found in the vicinity of Croff's ranch, in the southwestern part of T. 37 N., R. 9 W., where there are two exposures of coal about 3 miles apart, upon what is probably a continuous bed, averaging 2 feet thick, at the base of the St. Mary River formation. About 500 feet north of the south quarter corner of sec. 31 in this township coal crops out in a cut bank on the east side of Milk River, where the section is as follows:

*Section of coal at base of St. Mary River formation at locality 25, in sec. 31, T. 37 N., R. 9 W.*

| | Ft. | in. |
|---|---|---|
| Clay, bluish, blocky | | 6 |
| Shale, coaly | | 10 |
| Clay, bluish, blocky | 2 | |
| Coal, containing ½-inch lustrous bands, well jointed but somewhat dirty | 2 | 2 |
| Clay, bluish | | 10 |
| Sandstone, gray and slabby, upper part of Horsethief sandstone. | 12+ | |
| Water level of Milk River. | | |

In the NE. ¼ sec. 6, T. 36 N., R. 9 W., 1 mile southeast of locality 25, the same coal bed makes a bloom extending in a northwesterly direction for over 1,000 feet. The exposure is not good, however, and no measurement of the bed was made.

Northward from locality 25 there are no indications of coal on the grassy slopes at the base of the St. Mary River formation until Coal Coulee is reached, in the NW. ¼ sec. 20. Here, at locality 26, on the northeast side of the coulee, the outcrop of the coal bed can be traced for a quarter of a mile along the steep slopes until the bloom and indications of coal smut are lost on the more gentle grassy slopes. At the mouth of a short entry, badly caved at the time it was examined, the bed measures 1 foot 10 inches, without a parting. The coal was badly weathered and hence judgment as to its quality is uncertain. It very probably contains a considerable percentage of ash. About a mile southeast of locality 26, in the same land section but on the opposite side of Milk River, an isolated area of this bed occurs at the top of the escarpment made by the Horsethief sandstone. Smut from this coal is present over an area of several acres at this locality but there is no cover over the bed and the material is valueless as fuel.

Coal from the upper horizon in the St. Mary River formation is present on the North Fork of Milk River where it crosses the international boundary line. On the west bank of the stream, about 1,500 feet north of the line, coal at this horizon, which has been opened by a short prospect entry, is excellently exposed for a quarter of a mile along the river bank. A section of the rocks at this point is given below:

*Section of coal-bearing rocks near top of St. Mary River formation, at locality 27, 1,500 feet north of the north quarter corner of sec. 1, T. 37 N., R. 11 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, gray | 12 | 0 |
| Clay shale, bluish gray | 4 | 0 |
| Coal | | 10 |
| Clay shale, gray | 3 | 0 |
| Clay shale, bright green | 15 | 0 |
| Sandstone, gray | 5 | 0 |
| Water level of river. | | |

These strata dip very gently upstream, so that the coal bed is carried under the water level of the river about 1,000 feet south of the boundary. Toward the south this horizon, near the contact of St. Mary River and Willow Creek formations, can be followed for about 24 miles, almost to Cut Bank Creek, but no further indications of coal were found.

## COAL IN THE BELT OF DISTURBED ROCKS.

### BLACKFEET COAL FIELD.

The Blackfeet coal field lies in the northwestern part of the Blackfeet Indian Reservation, between Greasewood Creek and the Middle Fork of Milk River, in Rs. 11 and 12 W., and comprises an area 12 miles long and 1 mile wide. This tract is named the Blackfeet field in this report for convenience of description. Its coal has been mined only to a slight extent because of its occurrence on an Indian reservation, and very little information concerning it is available. Because of the lack of development, it is impossible to make more than a rough estimate of the amount of coal in the field, but to judge from the extent of the beds along the outcrop, it seems probable that there is at least 5 square miles of land in this field which is underlain by bituminous coal that could be mined commercially.

The coal-bearing rocks in this field are in the belt of disturbed rocks adjacent to the Rocky Mountains. They are much folded and somewhat faulted, the coal being for the most part in a narrow syncline trending northwest, lying between two anticlinal folds, which bring the Horsethief sandstone to the surface. On the west, across the entire length of the field, this structure is cut off abruptly by a reverse fault, which has carried the rocks of the Two Medicine formation against the Horsethief sandstone and thus limits the field in that direction. On the east the steeply dipping rocks of the St. Mary River formation, with the coal horizon at their base, lie in regular succession above the eastward-dipping Horsethief sandstone, but the steep dip of the strata soon carries the coal beyond minable depth, thus limiting the field on the east. Compared with the simple structure in the Valier field, with its nearly horizontal strata, the lay of the strata in the Blackfeet field is relatively complex, and successful mining of the coal will depend largely upon a knowledge of the geology of the field.

All the coal in the Blackfeet field occurs at the base of the St. Mary River formation, immediately above the Horsethief sandstone. Coal at this horizon has already been described as occurring in the area of nearly horizontal rocks at the Croff ranch and elsewhere to the south. In the Blackfeet field the Horsethief sandstone is of great importance as a marker, aiding in the location of the coal outcrop. At every point where there are natural exposures of the coal they occur at the sides of and parallel to ridges of this sandstone, which are often the only rock outcrops in sight. These ridges are from 5 to 50 feet in height, depending on the dip of the strata and the position with reference to relief and are composed of the coarse gray sandstone of the upper portion of the formation, which weathers buff, with rusty-brown ferruginous bands in places. Fossil oysters of two extinct

species, *Ostrea subtrigonalis*, and *O. glabra*, both in beds and as individuals scattered through the massive sandstone, are abundant, which is characteristic of this sandstone in this region. A detailed section on the South Fork of Milk River near the center of the field is as follows:

*Section of coal-bearing rocks at locality 31, at base of St. Mary River formation, on east flank of ridge of Horsethief sandstone, in the SE. ¼ sec. 18, T. 35 N., R. 11 W.*

| | Ft. | in. |
|---|---|---|
| Clay, greenish gray. | | |
| Coal | | 6 |
| Shale, carbonaceous | 2 | 0 |
| Sandstone, gray and platy | 1 | 0 |
| Clay, yellowish | 2 | 0 |
| Coal, clean and lustrous | 2 | 4 |
| Clay, greenish gray | | 8 |
| Sandstone, gray, platy | 9 | 0 |
| Clay, gray | | 2 |
| Coal, clean and lustrous | 1 | 10 |
| Clay, carbonaceous | 1 | 0 |
| Sandstone, massive member of Horsethief sandstone | 20+ | |

Two coal beds of importance were seen at only one other point in the field, but in general the exposures are poor and it is not improbable that two beds are everywhere present.

A low strike ridge of Horsethief sandstone crops out entirely across the SW. ¼ sec. 15, T. 34 N., R. 11 W., and can be followed northwestward for several miles. At locality 28, where the strike is N. 22° W. and the dip 62° SW., a strong coal bloom occurs on the west side of this ridge, just above the top of the Horsethief sandstone, and can be traced parallel with the ridge for about 1,500 feet northwestward. A trench dug across this coal bloom revealed 3 feet 6 inches of coal lying between a clay roof and floor. Even on the weathered outcrop the coal appeared clean and lustrous, with a fine cubic grain and no parting. It is the thickest bed of coal so far found in the field and is very probably of as good grade as that mined at the Stone ranch on the Middle Fork of Milk River. The outcrop described lies on the east limb of a syncline of the St. Mary River formation, which is paralleled on each side by a narrow anticline, bringing the Horsethief sandstone to the surface. Northwestward along these folds the next indications of coal are found about 2 miles distant, in the NE. ¼ sec. 9 of the same township. Here, above the Horsethief sandstone and dipping about 35° E., there are faint indications of coal bloom for several hundred feet parallel to the sandstone outcrops. About half a mile northwest of these exposures, at locality 29, in the SE. ¼ sec. 5, the same bed crops out along the west limb of the syncline above mentioned. The coal makes a strong bloom for 500 feet, paralleling the outcrops of the

Horsethief sandstone, which strike N. 23° W. and dip 30° NE. The bed is over 2 feet 6 inches thick, and rests on a floor of gray clay. The roof of the coal could not be reached by a shallow trench because of the thickness of the slope wash, and the full thickness of the bed at this point is therefore not known. The coal is lustrous and clean and the portion of the bed seen contains no parting. At locality 30, in the NW. ¼ sec. 4, the coal bed is again exposed, dipping eastward along the flank of the anticline on the east edge of the field. The dip of the bed parallels the slope of the ground wherever the coal is exposed at this point, and the surface is therefore covered with a thick layer of coal smut over many acres, but it is very difficult to estimate the thickness of the bed. To estimate the true thickness from the layer of weathered coal on this dip slope, the bed is probably over 2 feet thick.

Localities 29 and 30, just mentioned, are on the south slope of Milk River Ridge, which forms the divide between Milk River and Cut Bank Creek. The surface of this "ridge" is a smooth plain, covered with a veneer of gravel, which completely obscures all signs of the underlying bedrock formations. There is therefore a covered area several miles long in this part of the Blackfeet coal field, but because of the fact that coal is present at the next good exposures to the north, it is not improbable that at least a part of this covered area is coal land. On the north side of Milk River Ridge, sloping toward Milk River, a folded structure similar to that on the south side of the ridge and on the same line of strike exposes the Horsethief sandstone and the St. Mary River formation. At locality 31, a quarter of a mile south of the river, in the SE. ¼ sec. 18, T. 35 N., R. 11 W., the coal bed is well exposed along the east limb of the anticline on the east edge of the field, where it strikes N. 18° W. and dips 48° NE. The complete section of the rocks at this point has already been given (p. 149). There are two coal beds present, separated by 10 feet of sandstone and clay. Both of the coals crop out in an almost continuous bloom for 1,000 feet parallel to the ridge of Horsethief sandstone. The upper bed—that is, the one lying to the east—is 2 feet 4 inches thick, and the lower bed 1 foot 10 inches. The coal in each of the beds appears to be of the same grade. It weathers out in fine irregular fragments, which on being freshly broken show faces of clean, lustrous coal. No parting is present in either of the beds, and the material seems to be identical with that in the southern part of the field already described.

On the north side of the valley of Milk River the two parallel anticlines with an intervening syncline in the Horsethief sandstone and the St. Mary River formation, which have so far been characteristic of the coal field, still continue, except that the plane of the reverse fault on the west side of the field here cuts off a part and in

places even the crest of the west anticline. Two miles northwest of locality 31 an extended coal bloom shows in the northwest corner of sec. 7, T. 35 N., R. 11 W., at locality 32. It can be traced almost continuously for over a mile northwestward. The outcrop occurs just above the eastward-dipping Horsethief sandstone, and has a strike of N. 22° W. and a dip varying between 40° and 53° NE. At locality 32, on the south end of this outcrop, a trench across the coal bloom exposed 1 foot 6 inches of clean, lustrous coal. At the north end of this outcrop, at locality 33, a pit had been dug, exposing the coal, but was refilled. The writer was informed by a resident of the region who took part in this prospecting that the coal measured 2 feet in thickness.

Between locality 33 and the Middle Fork of Milk River the gravel of a smooth high-level plain, similar to Milk River Ridge and at the same altitude, obscures the underlying bedrock formations. Immediately north of this plain, on the slopes leading down to the Middle Fork of Milk River at the Stone ranch, the east anticline of two that extend throughout the length of the Blackfeet field exposes the Horsethief sandstone in two parallel strike ridges lying on the limbs of the fold. West of the anticline there is a syncline containing the lower part of the St. Mary River formation, exposing on its west limb the upper massive member of the Horsethief sandstone. The lower part of the Horsethief sandstone is cut off by the reverse fault, which has already been described as the boundary of the coal field on the west, and which brings the Two Medicine formation up against the younger rocks containing the coal. The folded structure thus brings the Horsethief sandstone and the coal above it to the surface in three parallel lines of outcrop, marked by low ridges of sandstone. Coal crops out along all three of these ridges.

At locality 34, about 1 mile southwest of the Stone ranch, on the west limb of the syncline above mentioned, a prospect entry driven by J. M. Stone along the strike of the coal bed, about 60 feet long in 1911, was the only opening made in the coal of the Blackfeet field up to that time. This coal has been mined by Mr. Stone for his own use for many years. The bed has no parting and ranges from 2 feet 6 inches to 2 feet 10 inches in thickness. It strikes N. 25° W. and dips 40° NE. An analysis is given on page 138 (No. 12602). The roof is a compact gray clay shale, which stands fairly well and is overlain by gray sandstone. The floor is gray clay. Fresh coal from this opening is lustrous and clean, the only impurity visible being minute flakes of iron pyrite that are abundant on smooth faces of the coal. The coal is much jointed, but the joints are irregular and closely spaced and do not stand normal to the bedding. Their attitude and also a fine irregular grain in the coal show the effects of rotational strain, or torsion incident to the folding of the rocks, and contrast strongly with

the rectangular jointing normal to the bedding which is present in the nearly horizontal coal beds in the region to the east. Highly polished slickensided surfaces, with a few concentric pressure ridges, simulating conchoidal fracture, are further evidence of the deformation undergone by the coal. Minute spherulitic markings on small fracture surfaces are probably produced in the same way. The crushed condition of this coal makes it easy to work down with the pick, but even when carefully mined in this manner it produces a large percentage of fine coal.

About three-fourths of a mile northeast of locality 34, on the opposite side of the syncline, the same coal crops out at locality 35, where it strikes N. 26° W. and dips 44° SW. Here, about 100 feet east of the southwest corner stone of section 25, T. 36 N., R. 12 W., the bloom of two coal beds lying about 10 feet apart can be traced along the outcrop, lying parallel to a prominent strike ridge of gray sandstone. Entries were driven by Mr. Stone on both of these beds where they crop out on the cut bank on the south side of the river, 1,000 feet to the north. At the time they were examined by the writer these openings were completely blocked by slumping. Mr. Stone reported that the lower bed—that is, the one lying to the east—was 10 inches thick, and the upper bed 2 feet thick. At locality 36, on the side of the anticline opposite locality 35 and a short distance south of the Stone ranch, the coal crops out with a dip of 65° NE. and a strike of N. 10° W. A shallow open cut exposes the following section:

*Section of coal bed near Stone ranch, at locality 36, in the SW. ¼ sec. 25, T. 36 N., R. 12 W.*

| | Ft. | in. |
|---|---|---|
| Sandstone, gray. | | |
| Coal, much weathered and very dirty | | 7 |
| Clay | | 1 |
| Coal, weathered and dirty | 1 | 4 |
| Clay, gray. | | |
| Thickness of bed | 2 | 0 |
| Thickness of coal | 1 | 11 |

The bed is probably the same as the upper one at locality 35. The outcrop is much obscured by soil creep, which makes it difficult to pass judgment on the quality of the coal.

It is not possible to determine the quality of the coal in a bed by examining only its surface outcrop. The prospect at the Stone ranch is the only place where fresh, unweathered coal could be obtained from the Blackfeet field, so that an estimate of the grade of the fuel is necessarily based on this single locality. It is very probable, however, that except for variations in the ash content, the coal is fairly constant in quality throughout the field, for it occurs at a single geologic horizon and has everywhere been subject to about the same amount of deformation. A sample from the Stone prospect, at

locality 34, carefully prepared according to the standards in use by the United States Geological Survey, gave analysis 12602 on page 138.

On comparing this analysis with that of coal from the Valier field it is evident that chemically the two fuels are very much alike. The deformation of the strata in the Blackfeet field has apparently raised the grade of the coal to only a very slight extent. The percentage of carbon in the fuel as given by the analysis on the moisture and ash free basis is 79 for the Blackfeet field and 76 for the Valier field. The moisture in the air-dried coal is 5.8 per cent for the former and 5.3 per cent for the latter. Oxygen on the same basis is 15.32 per cent in the Blackfeet coal and 15.07 per cent in the Valier coal. The ash content is slightly lower than in the Valier coal, being 12.73 per cent compared with 14.07 per cent.

The heating value of the coal from the two fields is also nearly the same. Air-dried coal from the Blackfeet field gave 11,310 British thermal units and that from the Valier field 11,070 British thermal units. The average of a number of samples of coal from the Lethbridge field, in Alberta, gave 11,200 British thermal units on the same basis; and from the Great Falls field 11,040 British thermal units.

The jointed and fractured nature of the coal bed in the Stone prospect has already been mentioned. This feature was observed in this locality only, but it is very probable that the coal will be found in a similar compressed and broken condition throughout the Blackfeet field. This will cause a high percentage of fine coal in the production of this field, and lumps of coal above 4 or 5 inches in greatest dimension will be unusual. The fuel, however, withstands weathering very well and does slack even after long exposure. This ability to withstand weathering, together with the jointing in the coal and its close chemical affinity to coals in Alberta and Canada long regarded as bituminous, seems to place the coal of the Blackfeet field in the bituminous class.

### MINOR OCCURRENCES OF COAL IN THE BELT OF DISTURBED ROCKS.

All the geologic formations present in the area of nearly horizontal rocks in the eastern part of the region under discussion also occur in the belt of disturbed rocks. It is thus evident that the beds at the horizons of the coal-bearing strata in the area of nearly horizontal rocks are to be found in the disturbed belt and must be considered as possibly coal bearing there. There are many scattered outcrops of coal in this belt, from the Canadian boundary to the south side of the area mapped. Outside of the Blackfeet coal field, however, every occurrence of coal found in this belt is so much disturbed by folding and faulting that even where there is coal of a thickness that might be worked, the quantity is too small or uncertain to warrant

development. Beginning at the north end of the disturbed belt, these scattered outcrops of coal will be described in the order they are passed in traveling southward across the field.

At locality 37, on the crest of the north-south ridge near the center of the SW. ¼ sec. 29, T. 37 N., R. 12 W., 1 foot 1 inch of clean, well-jointed coal shows in strata that have been much disturbed. This coal is at the top of the Two Medicine formation. About 50 feet of the overlying Bearpaw shale is exposed here, but is cut off by a fault on the west.

At locality 38, near the center of sec. 8, T. 37 N., R. 13 W., coal which crops out on the west bank of St. Mary River has been opened by a group of small workings, locally known as the Paisley mine. These openings were badly caved and inaccessible at the time of the examination, but a prospect pit sunk about 5 feet on the outcrop of the bed gave the following section. The strike is N. 20° W. and the dip 60° SW.:

*Section at Paisley prospect, on St. Mary River, in sec. 8, T. 37 N., R. 13 W.*

| | Ft. | in. |
|---|---|---|
| Clay, gray. | | |
| Coal, clean and somewhat lustrous, bedding planes only faintly shown, crushed to some extent, best coal in the bed. | | 10 |
| Coal, more dirty than upper bench, much crushed and distorted, no well-marked bedding or joint planes; crumbles to a powdered mass | 3 | 10 |
| Clay shale, dark gray. | | |

To judge from the crushed condition of the lower bench of this bed, it is not improbable that it has been thickened by shearing, being thrust upon itself. Such action on a larger scale has in many places duplicated entire formations in the disturbed belt. If this is true, the coal is apt to be very pockety and irregular in thickness. In 1906 M. R. Campbell obtained a sample of coal from this mine, the analysis of which is given as No. 3934 on page 138. The coal was not in place, and the sample consisted of lumps gathered from a mass that had fallen from the face.

About a thousand feet northwest of the Paisley prospect, on the strike of the bed, a trench 30 feet long and several feet deep was dug in an attempt to locate the extension of the bed. No coal was uncovered by this trench, and it seems safe to say that it has been cut out by faulting. However, a mile farther northwest, in the NW. ¼ sec. 8, the Horsethief sandstone, striking N. 20° W., dipping 50° SW., and containing several oyster beds, crops out as a bold strike ridge on the line of strike of the coal at the prospect. This exposure, taken in connection with a similar ridge of the same formation 2 miles to the southeast, also on the same strike line, suggests that the coal at

locality 38 belongs at the base of the St. Mary River formation, lying immediately above this sandstone.

At locality 39, in the NW. ¼ sec. 30, T. 36 N., R. 12 W., coal crops out for several hundred feet above a low ridge of Horsethief sandstone carrying several oyster beds. A trench across this outcrop exposed 14 inches of coal, striking N. 20° W., and dipping 47° SW. About 100 feet west of this outcrop the Horsethief sandstone stands on edge or is overturned, and the entire mass is much broken.

At locality 40, near the center of sec. 16, T. 35 N., R. 12 W., there is a strong coal bloom along the west side of a low ridge of Horsethief sandstone, striking N. 20° W. and dipping 60° SW. At the point where the coal is best exposed this strike ridge turns abruptly eastward and disappears in a much disturbed and broken structure. It is probable that there is a small amount of undisturbed coal here.

At the point where the Browning-Babb stage road crosses Cut Bank Creek, about 4 miles northwest of Browning, at locality 41, coal from the base of the St. Mary River formation crops out on the west side of a ridge of Horsethief sandstone containing the usual oyster shells. There are two thin coal beds at this point, the section being as follows:

*Section of coal-bearing rocks on Cut Bank Creek at locality 41, in the NW. ¼ sec. 15, T. 33 N., R. 11 W.*

| | Ft. | in. |
|---|---|---|
| Clay, gray. | | |
| Coal | 1 | 0 |
| Clay, gray | 25 | 0 |
| Coal, much weathered and apparently very dirty | 1 | 4 |
| Clay, gray | 10 | 0 |
| Sandstone, massive gray, Horsethief sandstone | 60+ | |

The lower coal bed of this section has been opened on the south bank of the creek, but the entry was so badly caved as to be inaccessible at the time of the examination. The same bed is also exposed on the north side of the creek, the thickness being about the same as that on the south. Nothing is known of the extension of this coal either north or south of the creek beyond these outcrops, because to the south the bedrock formations are thickly covered by glacial drift, and to the north they are hidden by gravel which covers the plain lying between Greasewood and Cut Bank creeks.

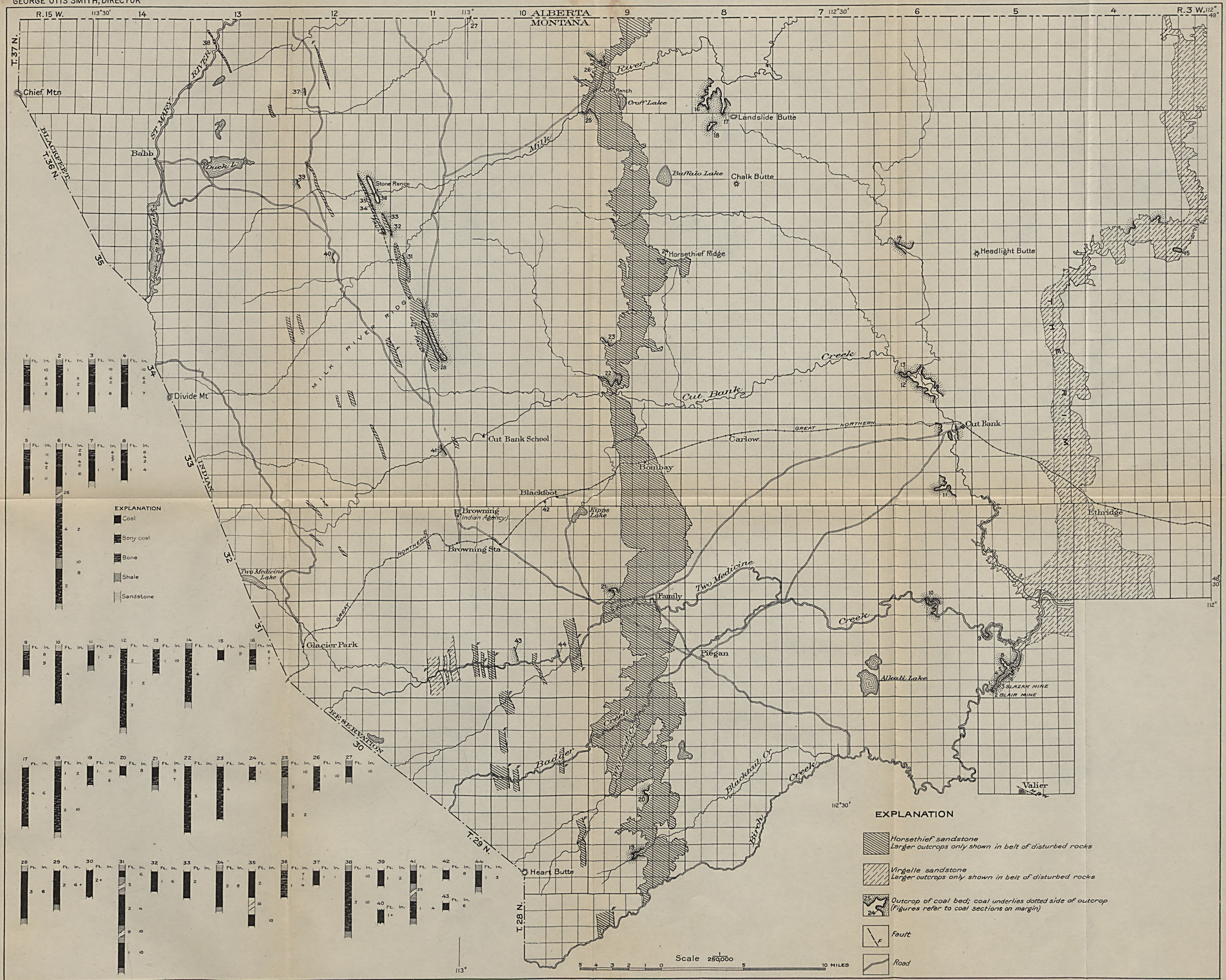
Farther south coal was found as follows: (1) At locality 42, in sec. 34, T. 33 N., R. 10 W., on the south side of the right of way of the Great Northern Railway, just within the boundary of the disturbed belt, 8 inches of coal in gray shale, dipping 10° NE. (2) On Two Medicine Creek, at locality 43, in the NW. ¼ sec. 20, T. 31 N., R. 10 W., 6 inches of lustrous coal in the Two Medicine formation in an 8-foot bed of fissile carbonaceous shale containing fossil shells, striking N. 15° W. and dipping 35° SW. (3) At locality 44, in the NW. ¼ sec.

23, T. 31 N., R. 10 W., coal crops out for 300 feet on the north side of Two Medicine Creek, striking N. 17° W. and dipping 60° SW. A trench dug across this outcrop gave the following section:

*Section of coal bed at locality 44, in the NW. ¼ sec. 23, T. 31 N., R. 10 W., on north side of Two Medicine Creek.*

| | Ft. | in. |
|---|---|---|
| Shale, carbonaceous, grading into coal below. | | |
| Coal, lustrous, but much crushed, having a foliated appearance | 1 | 3 |
| Clay, gray. | | |

The coal in this section is very irregular both in thickness and in quality. A few hundred feet north of the point where the section was measured the entire bed seemed to be little better than a coaly shale.




EXPLANATION

- Coal
- Bony coal
- Bone
- Shale
- Sandstone

EXPLANATION

- Horsethief sandstone — Larger outcrops only shown in belt of disturbed rocks
- Virgelle sandstone — Larger outcrops only shown in belt of disturbed rocks
- Outcrop of coal bed; coal underlies dotted side of outcrop (Figures refer to coal sections on margin)
- Fault
- Road

Base from U.S.G.S. topographic atlas sheets, General Land Office plats, and author's field sheets

# MAP SHOWING COAL RESOURCES AND SECTIONS OF THE COAL BEDS OF NORTHERN TETON COUNTY, MONTANA

By Eugene Stebinger

1915

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY