LIGNITE IN THE VICINITY OF PLENTYWOOD AND SCOBEY, SHERIDAN COUNTY, MONTANA.

By C. M. Bauer.

INTRODUCTION.

This paper presents the results of an examination of an area in northeastern Montana along the north border of the Fort Peck Indian Reservation, made principally for the purpose of ascertaining the amount and character of the lignite. This investigation was made partly to supplement the information previously obtained relative to the lignite in the northeastern part of the Fort Peck Indian Reservation and partly to classify the land. A geologic reconnaissance of the Fort Peck field had been made by C. D. Smith[1] in 1908, before the land in the northern part of the reservation was surveyed. In 1911, subsequent to the land survey, the reservation was reexamined in detail by the writer. At this time some additional information regarding the lignite was obtained, but owing to the general cover of glacial drift in the northern part of the reservation, exposures of the lignite-bearing rocks are few, and there are extensive areas in this region in which very little additional knowledge regarding the lignite was gained. North of the reservation, along Big Muddy Creek, however, exposures of the lignite-bearing rocks are more numerous, and, chiefly in order to throw light upon the geology within the reservation itself, the writer, assisted by E. T. Hodge, gave this area special attention during the field season of 1912. This work has shown that in this area, and presumably also in the northern part of the reservation, the lignite is commonly weathered and the beds are in general thin. The lignite will probably, therefore, command only a local market, though owing to the scarcity of other fuel in this region it is economically important.

The area here described consists of three parts. The western part is made up of a little more than two townships on Poplar River, near Scobey, Mont., and the eastern part consists of six entire townships as well as parts of two others along Big Muddy Creek, in the vicinity of Plentywood, Mont. The intervening area was examined merely in

[1] Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont.: U. S. Geol. Survey Bull. 381, 1910.

a reconnaissance way owing to the fact that the land was unsurveyed. The results of this examination are included in the general discussion of the district, but detailed mapping was limited to the two areas defined above. The areas in Montana described in this bulletin are shown in figure 9.

FIELD METHODS.

The methods used in mapping in different parts of the field were varied to meet the conditions. The Land Office plats of the eastern and western portions of this field are comparatively recent and appear to be accurate and satisfactory; they were therefore used as a base for the geologic mapping. In the area around Scobey rock

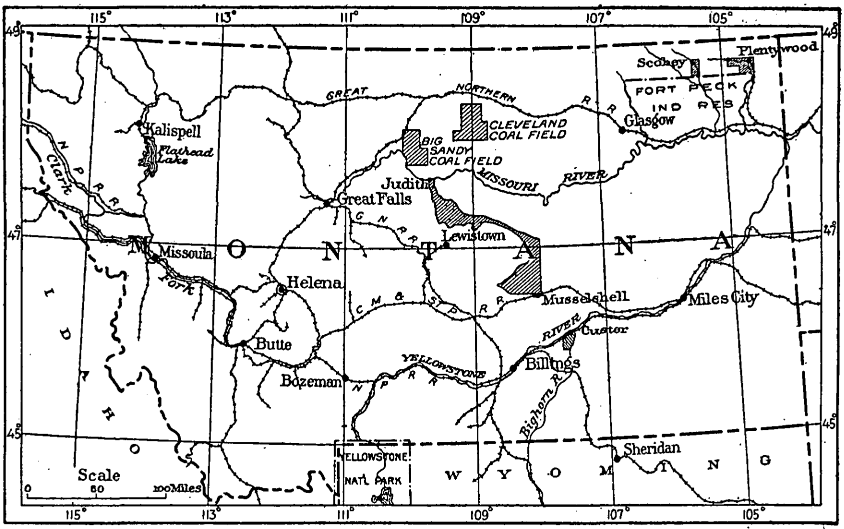


FIGURE 9.—Map showing coal fields of Montana described in this bulletin.

exposures are in general widely separated, and the mapping here consisted chiefly in locating these isolated outcrops. Whenever possible, the method followed was triangulation from land corners, using a plane table and telescopic alidade. In the vicinity of Redstone and Plentywood, in the eastern part of the field, however, outcrops are more nearly continuous, and in this area locations were made by stadia traverse, the altitude of each lignite prospect being determined by vertical angles. Springs, houses, and roads were also carefully located in both districts. The examination of the area between the surveyed portions at either end of the field was in the nature of a reconnaissance, the results of which are included in the general discussion.

SURFACE FEATURES.

RELIEF.

This field is a part of the Great Plains region and is in the main a rolling prairie with broad, gentle slopes. The western portion is drained by Poplar River and the eastern by Big Muddy Creek, and between the two lies a high divide many miles in width. The broad and nearly flat valley of Poplar River traverses the field from north to south in R. 48 E. (Pl. XV, p. 308). In R. 52 E. the somewhat narrower valley of Big Muddy Creek enters the area from the north and extends across it to the southeast corner of the field, where it turns southward to form the east boundary of the Fort Peck Indian Reservation. For a distance of about 6 miles in T. 34 N., R. 55 E., this stream flows through a valley which is much narrower than that in the other portion of its course. This constricted portion seems to represent a more recent valley into which the river was diverted by the partial filling of its old valley with glacial material. The old valley is plainly discernible near Antelope, where a branch of the Great Northern Railway follows it for several miles.

The maximum relief in the region is about 750 feet. For instance, the valley of Big Muddy Creek near the reservation boundary has an elevation above sea level of approximately 2,000 feet, and the land on the divide directly to the west reaches an elevation of about 2,750 feet. However, local differences in altitude are not great, and even in the rough country bordering Big Muddy Creek the height of the bluffs is commonly less than 150 feet.

The summits of all the highest hills and ridges are approximately at the same altitude and are covered with quartzite gravel. The concordance of these hilltops suggests the existence of an old river plain at the close of the first stage in the development of the present topography. The areas known to be covered by this gravel in the districts mapped are shown in Plates XV and XVI (pp. 308 and 314). A second stage in the development is represented by the general level of the country, which has an altitude of about 150 feet above the flood plains of the present streams. The development of this second peneplain, presumably by erosion, was not complete when the country was covered by an ice sheet. The general effect of the glaciation has been to round off the hills and partly fill the valleys. The plain thus formed extends throughout the field and gives a prairie aspect to most of the topography. A third stage in the erosion is shown in the present flood plains of Poplar River and Big Muddy Creek, which are about a mile wide.

DRAINAGE.

The direction of the present drainage is southeastward. Poplar River rises in the Canadian province of Saskatchewan and flows southeast to Missouri River, emptying into that stream at Poplar. Big Muddy Creek also rises in Saskatchewan and flows in a southerly direction as far as T. 35 N., where it is joined from the west by Eagle Creek. For 15 miles beyond this place it trends eastward and then bends and flows southward 50 miles to join Missouri River. The course of Big Muddy Creek is extremely sinuous, though the current is fairly rapid. Along both of these streams lie flats from half a mile to 2 miles in width, the development of which is due partly to the filling in of glacial débris and partly to the normal meandering and aggrading of the streams. The presence of the glacial material is shown in several wells in the valley of Big Muddy Creek in the vicinity of Redstone, which penetrate glacial drift and alluvium to a depth of 30 feet. In this material the channel of the Big Muddy is eroded to a depth of 18 to 25 feet, whereas Poplar River flows in a channel only 10 to 15 feet deep. These flats contain many water holes representing cut-off meanders.

The country is fairly well watered by springs, although the average annual rainfall is only 13.5 inches. Most of the spring water contains some "alkali" but not enough to prevent its use as a domestic supply. Many of the springs issue from the outcrops of lignite beds, probably because the joints in the lignite form channels for the ground water, whereas the rocks immediately below the beds are relatively impervious.

Although the annual precipitation in this part of Montana is only about 13.5 inches, more than half of this amount falls in light rains between the beginning of April and the end of July or during the growing season, when it is most needed for crops. The average annual snowfall is about 40 inches, but the snow is normally light and dry, and the winds generally carry most of it into ravines, leaving the ranges bare and accessible for grazing throughout most of the winter.[1]

CULTURE.

A branch of the Great Northern Railway, which extends as far as Plentywood, renders the eastern part of the field easily accessible. The western part can be reached at present by stage from Poplar, Mont. The principal town in the western section is Scobey, which is located on Poplar River, in T. 35 N., R. 48 E. Redstone, Plentywood, and Antelope are thriving towns in the eastern part of the field.

[1] Summary of the climatological data for the United States by sections; Climatological section No. 30, northeastern Montana, U. S. Dept. Agr. Weather Bureau.

Most of the area has been filed on by settlers as agricultural land. A few quarter sections have been allotted to Indians but are not occupied by them, these lands being leased by farmers and stockmen for grazing or for the natural hay which they produce. The land is arable almost everywhere except along the outcrops of the stratified rocks, where the soil is thin or absent. However, these outcrops are few and are confined for the most part to the roughest portions of the field, particularly along Big Muddy Creek. The bottom land along Big Muddy Creek and Poplar River supports a considerable growth of natural hay which can be cropped every year, but on the uplands the wild hay can be profitably cut only every third year. The principal crops of the region are flax, oats, barley, and potatoes, some spring wheat, and some corn for fodder only. Millet has been raised with success, as has also timothy hay. Likewise most garden vegetables except celery have been raised successfully. These crops are cultivated without irrigation, although in a few places on the flats of Poplar River and Big Muddy Creek irrigation has been applied to the land with mediocre success.

There is very little timber land in the region. Thickets of quaking aspen, cottonwood, box elder, and ash grow in a few of the larger coulees, but the trees are not sufficiently numerous to be utilized even for fence posts. There are also a few willows along the principal streams, but the trees are too widely scattered to be of value.

GEOLOGY.

STRATIGRAPHY.

OCCURRENCE OF THE ROCKS.

The oldest sedimentary rocks exposed in this field are in the valley of Poplar River at a lignite mine in sec. 3, T. 33 N., R. 48 E., and in sec. 26, T. 35 N., R. 48 E. These rocks probably belong to the Lance formation. The formation is lignite bearing in part and is commonly characterized by its somber color. Stratigraphically above these rocks lie the lignite-bearing strata of the Fort Union formation. These strata are predominantly light colored, but in many regions where these formations are well exposed the colors and other lithologic characters of the one formation blend into those of the other so that the line of demarcation is uncertain.

In the area here described, moreover, exposures are generally poor, and it is impossible to determine the exact line of separation between the formations. No fossils were found by which the age of the rocks could be determined, hence the basis on which the approximate boundary line is drawn (Pl. XV, p. 308) is the information obtained in the Fort Peck Reservation by C. D. Smith [1] in 1908, and by the

[1] Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont.: U. S. Geol. Survey Bull. 381, 1910.

writer in 1911. On the reservation the Lance strata are predominantly somber colored, and those of the Fort Union, which also contain a greater number of lignite beds, are light colored. A lignite bed located near the horizon at which the lithology changes was assumed to represent the base of the Fort Union and was mapped as such. However, for 10 miles south of the reservation boundary, exposures near the contact are scanty and the separation was made largely on the basis of the color of outcropping beds.

Owing, therefore, to the absence of a sharp lithologic boundary between the formations, and to the lack of exposures near the critical horizon in this field and also in the northern part of the reservation, the accurate mapping of the Lance-Fort Union boundary is impossible. In drawing the line shown on the map the known outcrops of somber-colored beds were considered to belong to the Lance and those of yellow beds to the Fort Union. A bed of lignite 16 to 22 feet thick, which outcrops on Coal Creek near the international boundary, is thought to be the same as a bed 18 feet thick reported by G. M. Dawson[1] from Porcupine Creek on the international boundary a few miles west of the one hundred and sixth meridian. This is regarded as probably identical with the bed mapped as the base of the Fort Union and its horizon was projected as accurately as possible into the Scobey district. In mapping the inferred outcrop of this horizon it was of course necessary to take into account the topography and also the low eastward dip of the strata (less than 10 feet to the mile).

TERTIARY (?) SYSTEM.

LANCE FORMATION.

In the field here described about 175 feet of strata, consisting of somber-colored shale and cross-bedded sandstone with local lenses of impure lignite, are referred to the Lance formation. The base of the formation is not exposed, but on the adjoining reservation it has a total thickness of 200 to 300 feet. Its separation from the overlying Fort Union formation is based on its stratigraphic position and lithologic character. In these particulars it agrees with the Lance formation as recognized in other areas in eastern Montana and in North Dakota, where it is further characterized by a dinosaur fauna which has not been found in the Fort Union. Formerly the Survey considered the evidence of the age of the Lance so conflicting that it was ascribed to the Cretaceous or Tertiary, but recently the close correlation of the Lance flora with that of well-determined Tertiary formations of the Gulf coast, considered together with the mountain-making movements that are supposed to have immediately preceded the deposition of the strata, has led the Survey to assign the formation to the Tertiary (?) system.

[1] Dawson, G. M., The lignite Tertiary formation: Canada Geol. Survey Rept. for 1879-1880, p. 29a, 1881.

TERTIARY SYSTEM.

FORT UNION FORMATION.

The Fort Union formation, of Eocene age, is the uppermost consolidated formation in this field. It consists of light-colored sandstone, shale, and clay, with numerous beds of lignite, and rests with apparent conformity on the underlying Lance formation. The best exposures of these rocks are in the bluffs along Big Muddy Creek. Masses of sandstone are exposed more commonly than shale or clay, because in the weathering of a hill the sandstone is most resistant, producing irregular projecting ledges, above and below which the hill slopes are generally grass covered.

The following section, compiled from measured sections in three localities in the Plentywood district, illustrates the character of the Fort Union formation in this field:

Section of the Fort Union formation compiled from three localities.

Section in NW. ¼ sec. 28, T. 34 N., R. 55 E.

	Ft.	in.
Sandstone (top eroded)	60+	
Shale, sandy	10	
Sandstone, friable	8	
Shale, carbonaceous	3	4
Lignite		6
Shale	24	9
Sandstone, friable	2	6
Sandstone, hard		10
Sandstone, argillaceous	7	
Shale, sandy	31	
Sandstone, hard		10
Shale, gray	5	
Shale, carbonaceous	4	4
Shale, sandy	34	
Shale, drab	5	
Shale, carbonaceous		4
Shale, brown	4	
Sandstone, light gray	13	11
Lignite (Richardson bed)	2+	

Section in SW. ¼ sec. 29, T. 35 N., R. 55 E.

	Ft.	in.
Lignite (Richardson bed).		
Shale, sandy	12+	
Sandstone	15	
Sandstone (forming ledge)	4	
Sandstone, cross-bedded	48	
Shale	4	10
Sandstone, white, containing streaks of white clay	16	8
Shale, carbonaceous		4
Shale, gray	10+	

Section in SW. ¼ sec. 6, T. 35 N., R. 52 E.

	Ft.	in.
Interval of shale and sandstone, covered in part	80±	
Sandstone, hard	1	6
Sandstone, friable	26	
Shale, carbonaceous		4
Shale, gray	12	
Sandstone	11	6
Clay, drab	1	
Lignite	1	4
Shale, brown	4	5
Sandstone	1	2
Lignite		8
Shale, carbonaceous	1	6
Shale, sandy	11	6
Shale, drab	5	10
Shale, carbonaceous		6
Lignite	1	8
Sandstone	2	3
Lignite (Redstone bed)	2	8+
Total lignite	8	10+
Total	494±	

A complete section of the Fort Union formation in this field would probably measure more than 1,000 feet.[1]

A white clay bed [2] of economic importance occurs in this formation in the vicinity of Redstone and Plentywood. It is a fair-grade clay, suitable for the manufacture of brick, draintile, and stoneware.

In some places red-baked rock known locally as scoria or clinker is found, the old Redstone post office in sec. 16, T. 35 N., R. 52 E., having derived its name from the presence of this clinker in the neighboring bluffs. The clinker is caused by the burning of a lignite bed along its outcrop. The fire may have been started in various ways. It is generally ascribed to lightning, prairie fires, the agency of man, or spontaneous combustion caused by rapid oxidation in weathering. The heat generated may become so intense locally as to cause flowage in the overlying strata, but as the burning progresses under greater cover the fire commonly dies out, owing to lack of air.

TERTIARY OR QUATERNARY SYSTEM.

QUARTZITE GRAVEL.

Certain high hills and ridges, as shown on the maps (Pls. XV and XVI, pp. 308 and 314) are capped by quartzite gravel ranging from a few inches to 14 feet in thickness. This gravel is commonly stratified and was probably deposited by streams. In a few places it is

[1] Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: U. S. Geol. Survey Bull. 471, p. 326, 1912.

[2] Bauer, C. M., Clay in northeastern Montana: U. S. Geol. Survey Bull. 540, pp. 369–372, 1914.

consolidated but nowhere, so far as is known, in the area here described. However, in the Fort Peck Reservation, on the high bluff south of Cottonwood Creek, in the SE. ¼ sec. 33, T. 32 N., R. 46 E., the formation consists of consolidated sand and gravel cemented with lime. The lower part is about 8 feet thick and consists of sorted quartzite pebbles cemented with lime, resembling concrete filler for sidewalks. The upper part is a massive white calcareous sandstone having a maximum observed thickness of 4 feet. Some of the pebbles in the lower part are 2 inches in diameter, though most of them are less than 1 inch. In the area under discussion over 90 per cent of the pebbles are red or brown quartzite, though a few pebbles of argillite were noted. All are well rounded and very few are larger than 3 inches in diameter. Many of the pebbles are coated with lime. Where the deposit is best preserved it contains a considerable amount of interstitial yellow sand. As the deposit is lithologically different from the glacial drift, and furthermore is limited in extent to the tops of the highest hills, whereas the glacial drift is scattered generally and in many places overlies it, it is probably pre-Pleistocene. Although no fossils were found in this gravel, a similar deposit containing fossils in the vicinity of the Cypress Hills is described by R. G. McConnell.[1] McConnell gave the age of the beds as Miocene, but more complete identification of the fossils by E. D. Cope [2] reveals the age of the beds as Oligocene or Lower Miocene.

QUATERNARY SYSTEM.

GLACIAL DRIFT.

The stratified rocks are covered generally with glacial material consisting of sand and clay intermingled with bowlders of granite, limestone, basalt, sandstone, and many other rocks. The drift is usually unstratified, and its known thickness in this area ranges from a few inches to 40 feet, being commonly greatest in the valleys. In general it is thinner around Plentywood than in the vicinity of Scobey, but along the railroad, in T. 34 N., R. 55 E., near Antelope, it is probably even thicker than 40 feet. On the west side of Poplar Creek, in sec. 18, T. 34 N., R. 48 E., a well was dug through 40 feet of glacial material containing a few blocks of lignite 1 foot in diameter as well as fragments of granite and limestone.

[1] McConnell, R. G., On the Cypress Hills, Wood Mountain, and adjacent country: Canada Geol. Survey Ann. Rept., new ser., vol. 1, 1886.

[2] Cope, E. D., On Vertebrata from the Tertiary and Cretaceous rocks of the Northwest Territory: Canada Geol. Survey Contr. Canadian Paleontology, vol. 3, pt. 1, 1891.

STRUCTURE OF THE STRATIFIED ROCKS.

In the vicinity of Scobey the lignite-bearing rocks lie nearly flat, but owing to the scarcity of outcrops little knowledge of the exact dip can be obtained. However, from the attitude of the beds to the south it is assumed that they have an easterly dip of about 10 feet to the mile. Along Big Muddy Creek definite information of the structure was obtained by determining the altitudes of the lignite beds at many points. In T. 35 N., R. 52 E., altitudes determined on the Redstone lignite bed indicate a southeastward dip of about 15 feet to the mile, and in T. 34 N., R. 55 E., they indicate a dip of about 16 feet to the mile in the same direction. Minor undulations in the strata alter this dip locally, but these measurements illustrate the general attitude of the beds.

THE LIGNITE.

PHYSICAL AND CHEMICAL CHARACTERS.

The lignite is dark brown in color when fresh and its luster is dull to waxy. The texture is commonly dense, though in places it is woody. In some specimens even the structure of fairly large pieces of wood, generally flattened, is preserved, this being most common in the case of the harder parts such as knots. A pronounced characteristic of lignite is its tendency to slack on exposure to the air, due to the fact that it contains much water, which evaporates on exposure, causing shrinkage and the development of an irregular network of cracks along which the lignite separates into pieces. If the lignite is covered after being taken out of the mine so that the drying proceeds slowly disintegration is materially retarded.

Two samples of lignite from this field were submitted to the United States Bureau of Mines for analysis. Both samples seemed to have been slightly weathered, though they were taken from the deepest mines in the area. Sample No. 14614 was taken from the Richardson mine at location 65 in sec. 21, T. 34 N., R. 55 E., about 90 feet below the surface and about 200 feet north of the opening. This sample included the lignite of the lower bench, which is 5 feet 2 inches thick, as shown in section No. 65 in Plate XVII (p. 314). Sample No. 14670 was taken from the Pierce mine at location 52 in sec. 10, T. 35 N., R. 55 E., about 45 feet below the surface and 250 feet northwest of the opening of the main entry. Only the lower part of the bed was sampled at this place and included 3 feet 9 inches of lignite, as shown in section No. 52 in Plate XVII. For purposes of comparison, three representative analyses (Nos. 10724, 12533, and 11045) of lignite from neighboring fields are also given in the accompanying table (p. 304).

The method followed in taking these samples "involves selecting a representative face of the bed to be sampled; cleaning the face, making a cut across it from roof to floor, and rejecting or including impurities according as these are included or excluded in mining operations; reducing the gross sample, by crushing and quartering, to about 4 pounds; and immediately sealing the sample in an air-tight container for shipment to the laboratory." [1]

The four analyses given below for each sample are not different determinations but are merely four forms of one analysis. Form A is the analysis of the lignite exactly as it comes from the mine. Owing to the fact, however, that the original moisture content of a sample is largely a matter of accident and depends partly on the amount of water in the mine from which it came, it is best for comparative purposes to use form B, which is the analysis of the sample air dried under uniform conditions. Form C is the theoretical analysis of the sample after all moisture has been eliminated. Form D is also computed and is the analysis of the sample after all moisture and ash have been theoretically removed.

[1] Bur. Mines Bull. 22, 1913.

Analyses of lignite samples from Scobey-Plentywood and adjacent lignite fields, Mont.

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

Laboratory No.	Name of mine and location.	Collector.	Location.				No. on Plate XVI.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.	Heating value.	
			Quarter.	Sec.	T.	R.				Moisture.	Volatile matter.[a]	Fixed carbon.	Ash.	Sulphur.	Calories.	British thermal units.
14670	Pierce mine, 2½ miles northeast of Plentywood, Mont.	C. M. Bauer....	SE....	10	35 N...	55 E...	52	5.9	A	34.3	29.6	28.0	8.1	0.66	3,755	6,760
									B	30.2	31.4	29.8	8.6	.70	3,990	7,180
									C	....	45.0	42.7	12.3	1.00	5,715	10,290
									D	....	51.3	48.7	....	1.14	6,520	11,730
14614	Richardson mine, 3 miles west of Antelope, Mont.	.....do..........	NW...	21	34 N...	55 E...	65	5.4	A	29.1	29.7	33.8	7.4	.31	4,165	7,500
									B	25.1	31.3	35.8	7.8	.33	4,405	7,930
									C	....	41.9	47.7	10.4	.44	5,880	10,580
									D	....	46.7	53.3	....	.49	6,565	11,820
10724	Bruegger mine, 3 miles north of Culbertson, Mont.	A. L. Beekly....	SW...	8	28 N...	56 E...	....	23.6	A	32.6	27.4	30.9	9.1	1.28	3,730	6,710
									B	11.8	35.9	40.4	11.9	1.68	4,880	8,790
									C	....	40.7	45.8	13.5	1.90	5,535	9,960
									D	....	47.1	52.9	....	2.20	6,400	11,520
12533	Mine of the United States Reclamation Service, 2½ miles northeast of Williston, N. Dak.	F. A. Herald....	....	7	154 N.	100 W.	....	33.2	A	43.9	24.9	25.4	5.8	.49	3,300	5,940
									B	16.0	37.2	38.1	8.7	.73	4,940	8,890
									C	....	44.3	45.3	10.4	.87	5,875	10,580
									D	....	49.5	50.5	....	.97	6,555	11,800
11045	Snyder mine, 6½ miles north of Glendive, Mont.	J. H. Hance.....	NW...	27	17 N...	55 E...	....	23.4	A	32.1	25.6	34.2	8.1	1.36	3,950	7,110
									B	11.4	33.3	44.7	10.6	1.77	5,155	9,280
									C	....	37.7	50.4	11.9	2.00	5,815	10,470
									D	....	42.7	57.3	....	2.27	6,605	11,890

[a] Volatile matter determined by the modified official method. See Bur. Mines Bull. 22, p. 29, 1913.

The samples taken in this field were both slightly weathered, whereas those from the neighboring areas were fresh. Weathered lignite gives up relatively little of its moisture on air drying, whereas fresh lignite generally loses two-thirds or more. This is well shown in the accompanying table. The weathered samples from this field yielded less than 6 per cent of moisture on air drying, but the fresh samples from the other areas yielded 23 to 33 per cent. It is evident that the amount of moisture retained by a weathered sample after the air-drying process must decidedly impair its heating value on the air-dried basis. Thus, the samples from this field yielded 7,180 and 7,930 British thermal units, whereas the fresh samples of representative lignite from the three other localities all gave over 8,700 (form B). On the other hand, the ash in the Plentywood lignite is slightly lower, and the sulphur, especially in the sample from the Richardson mine, is decidedly lower. Furthermore, it is evident that if the ash and moisture be disregarded, and only the lignite substance be considered, the Plentywood lignite compares very favorably with that from the other localities (form D). This suggests that if entirely unweathered lignite could be found and mined in the Scobey-Plentywood field it would probably be equal in every respect to the product of the neighboring fields with which it would come into competition. It is believed, however, that all the lignite mined in the field at the present time is slightly weathered and is for this reason somewhat inferior to that mined in many near-by localities.

DISTRIBUTION.

Thin beds of lignite outcrop in many places along Poplar River, but in the western district considered in this report the beds are generally too thin to be of value at the present time. Owing to the lack of good exposures, it is not known how many beds of lignite occur near Scobey. The locations of the various outcrops that were discovered, however, are shown on the map (Pl. XV, p. 308), and the thickness and character of these beds are discussed under the description of the township in which each is found.

In the eastern part of the field along Big Muddy Creek the exposures are better, and a number of lignite beds are known (Pl. XVI, p. 314). All the surveyed land in the vicinity of Plentywood is underlain at a depth of less than 500 feet by lignite beds 3 feet or more in thickness. These beds outcrop in many localities and are utilized locally for fuel. A detailed description of the topography, geology, and lignite resources of each township mapped follows.

DESCRIPTION BY TOWNSHIPS.

AREA NEAR SCOBEY.

35 N., R. 48 E.—Poplar River flows southward through the central part of T. 35 N., R. 48 E. (Pl. XV, p. 308). The lignite-bearing rocks probably belong both to the Lance and the Fort Union formations, but no fossils were found. Exposures are few, as the stratified rocks are generally covered by glacial drift. In the SW. ¼ sec. 17 about 35 feet of bowlder clay is exposed. In the SE. ¼ SE. ¼ sec. 32 there is a kamelike deposit of glacial drift of which the following is the section:

Section of glacial drift in the SE. ¼ SE. ¼ sec. 32, T. 35 N., R. 48 E.

	Feet.
Gravel, unstratified, 90 per cent quartzite pebbles	4
Sand and gravel, stratified	3
Bowlder clay, unstratified, containing sand and gravel (the lower part consolidated)	8
Shale, dark gray.	
	15

Thin beds of lignite outcrop in secs. 1, 11, 24, and 26. A lignite bed was also reported on unsurveyed land about one-half mile west of the southwest corner of sec. 7. At this place (location 1, Pl. XV)[1] a bed of lignite 1 foot 4 inches in thickness outcrops in a large spring. At location 2, in the SW. ¼ sec. 1, a bed of lignite is exposed, the base of which is concealed by the water of a spring. Above the water level 2 feet 1 inch of lignite is exposed, and this portion of the bed has been stripped for local use. At location 3 two thin beds outcrop. The lower bed contains 1 foot 6 inches of weathered lignite, and the upper bed, which is about 20 feet higher stratigraphically, contains about 8 inches of lignite. At location 4, in the W. ½ sec. 24, a bed contains about 1 foot 6 inches of lignite. Several thin beds occur lower down in the stratigraphic section, one of which outcrops in the SE. ¼ sec. 24 at location 5, where it carries less than 6 inches of lignite. In sec. 26 a thin bed of lignite included in about 40 feet of somber-colored sandstone and sandy shale is exposed. This bed, however, contains only about 10 inches of lignite. The following stratigraphic section was measured in the SE. ¼ SW. ¼ sec. 26:

[1] Locations of points at which lignite sections were measured are shown by numbers on the maps (Pls. XV and XVI); and the sections, numbered correspondingly, are either shown in Pl. XVII or are given in the text

Section at location 6, in the SE. ¼ SW. ¼ sec. 26, T. 35 N., R. 48 E.

	Ft.	in.
Glacial drift (containing limestone and igneous bowlders)	5+	
Shale, yellow, sandy	2+	
Shale, dark gray (containing gypsum)	2	8
Shale, gray, sandy	18	
Shale, brown	1	6
Shale, gray	3	
Lignite		10
Shale, gray	12+	
Total	45+	
Lignite		10

T. 34 N., R. 48 E.—The surface features of T. 34 N., R. 48 E. are very similar to those of the township immediately to the north. Poplar River flows through the central portion of the township in a valley about 2 miles wide. The lignite-bearing rocks are exposed only at a few places and no fossils were found in them. From the general character of these strata it is believed that they probably belong both to the Lance and the Fort Union formations. The boundary shown on the map (Pl. XV) indicates approximately the areal extent of each formation. So far as could be determined from the outcrops the strata lie flat. The hills in the western part of the township are covered with small quartzite pebbles, the significance of which has been discussed above. The area was at one time covered by the continental ice sheet and therefore is now generally covered with glacial drift. The drift contains bowlders and fragments of limestone, quartzite, sandstone, lignite, basalt, granite, and schist. In the broad valley of the creek which traverses sec. 18 the drift is 40 feet thick, as shown in a well, and contains bowlders of lignite, some as large as 1 foot in diameter. Measurements of lignite beds were very difficult to obtain owing to the thick cover of glacial drift.

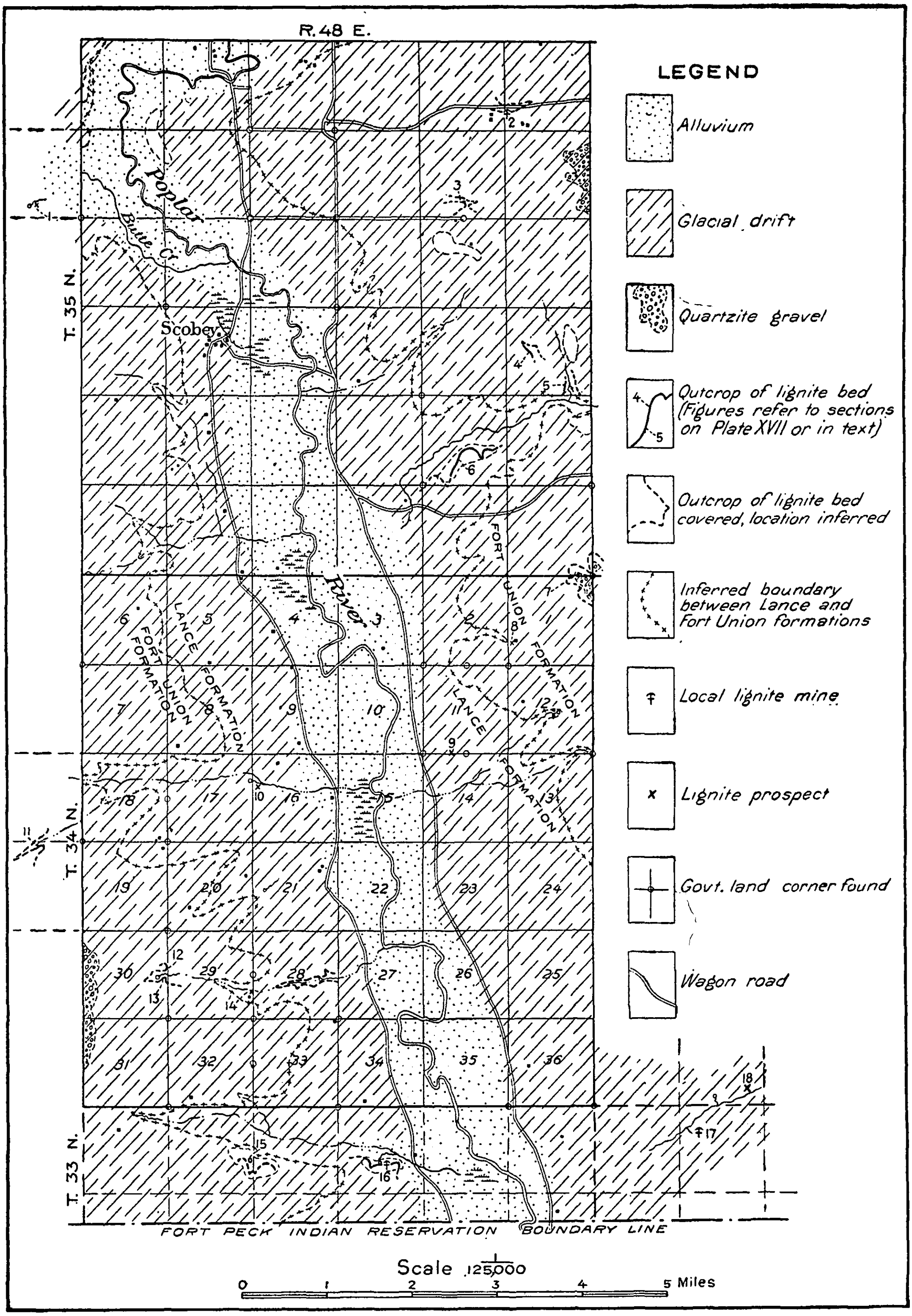
A thin bed of lignite outcrops in the NE. ¼ sec. 1 at location 7, where it carries 1 foot 2 inches of lignite. At location 8, in the SW. ¼ sec. 1, a bed of lignite about 3 feet thick was reported in a well at a depth of about 30 feet. Section No. 9 (Pl. XVII, p. 314) shows a bed of lignite as it is exposed in the SE. ¼ SW. ¼ sec. 11. The bed at this place contains 2 feet of much weathered lignite. At location 10, in the NW. ¼ sec. 16, a bed of lignite less than 10 inches thick is exposed, the outcrop being marked for a considerable distance by springs and seeps. Section No. 11 was measured about one-half mile west of the west border of this township, or near the north quarter corner of sec. 24, T. 34 N., R. 47 E. This section and sections Nos. 12 and 13, which are believed to be on the same bed, show an average thickness of 3 feet Sections Nos. 11 and 13 are shown in Plate XVII. The thickness of the lignite at location 12 is the same as that at location 13, though the bed rests on carbonaceous shale at location 12.

T. 33 N., R. 48 E. (fractional).—The area comprised in fractional T. 33 N., R. 48 E. is an unsurveyed strip of land between T. 34 N., R. 48 E., on the north and the Fort Peck Indian Reservation on the south and includes about 9 or 10 square miles. This area lies mostly in the valleys of Poplar River and a small tributary. It is for the most part rolling and grass covered but is broken into badland bluffs along the smaller streams. The lignite-bearing rocks probably belong to both the Lance and Fort Union formations, the inferred boundary between which is shown in Plate XV. The strata have a slight easterly dip. Exposures of the stratified rocks are few, owing to the general cover of glacial drift. Lignite beds and other adjacent strata outcrop in secs. 3 and 5. Section No. 15 (Pl. XVII, p. 314), which was measured on a hill in sec. 5, shows 3 feet of lignite, but the bottom of the bed was not reached owing to the presence of water from a spring. This bed is higher than the one measured in sec. 3 and is believed to be in the Fort Union formation. Section No. 16 was measured in sec. 3, at a strip pit from which considerable lignite has been taken within the last few years. At the pit the bed ranges in thickness from 1 foot 8 inches to 2 feet 6 inches, which suggests that it is elsewhere variable and probably belongs to the Lance formation.

Tps. 33–34 N., R. 49 E.—In T. 33 N., R. 49 E., only secs. 5 and 6 were examined and in T. 34 N. only a part of sec. 32. The lignite-bearing formation is believed to be Lance. It outcrops mainly in a coulee just north of the reservation line, most of the area being covered with glacial drift. Section No. 17 (Pl. XVII) was measured at a strip pit on the south side of the coulee, where the bed contains about 5½ feet of lignite. The pit is operated by farmers who live in the immediate vicinity. The lignite, which is poor in quality, has not been carefully mined, and a great deal of bone has been excavated with it for use as fuel. Section No. 18 (Pl. XVII) was measured on a bed 15 feet higher stratigraphically than the one at the strip pit. This bed is associated with sandstone and carries 2 feet 4 inches of fair lignite.

AREA NEAR PLENTYWOOD.

T. 35 N., R. 52 E.—Big Muddy Creek flows southeastward across the north-central part of T. 35 N., R. 52 E. Eagle Creek, a tributary of the Big Muddy, flows into the township in the SW. ¼ sec. 6, leaves it in the NE. ¼ sec. 6, enters it again near the north quarter corner of sec. 5, and empties into the Big Muddy near the center of this section. The township in general is very rough, having a relief of about 400 feet The interstream ridges in the southwestern part have about the same altitude, and their broad, flat tops suggest a former continuous plain. The remnants of this plain are now well covered with glacial drift, but in most of the stream valleys in the central and northwestern



MAP OF AREA NEAR SCOBEY, SHERIDAN COUNTY, MONT.

By C. M. Bauer.

portions of the township outcrops of the stratified rocks are abundant. The strata consist of shale, clay, and sandstone, as shown in the section given below. The dip of the beds southward is about 15 feet to the mile as shown by altitudes determined by plane-table traverse on the Redstone lignite bed.

Section at location 19, in the SW. ¼ SW. ¼ sec. 6, T. 35 N., R. 52 E.

	Ft.	in.
Shale and sandstone, partly concealed	60+	
Sandstone, hard	1	6
Sandstone, light yellow, friable	26	
Shale, brown, carbonaceous		4
Shale, gray	12	
Sandstone, argillaceous	11	6
Clay, gray		10
Shale, brown		2
Lignite, weathered	1	4
Shale, gray	4	
Shale, gray, finely laminated		5
Sandstone, yellow, friable	1	2
Lignite		8
Shale, carbonaceous	1	6
Shale, gray, sandy	11	6
Shale, black, carbonaceous		10
Shale, gray, sandy	5	
Shale, brown		6
Lignite	1	8
Shale, dark gray		3
Sandstone	1	9
Shale, brown		3
Lignite (Redstone)	2	8+
Talus	10	
Water in Eagle Creek.		
	155	10+

This section, however, does not include the highest strata outcropping in the township, which are generally concealed by glacial drift.

At least three beds of lignite outcrop in this township. The lowest one was measured in the NW. ¼ NW. ¼ sec. 8, at location 22, where 1 foot 7 inches of lignite is exposed. About 50 feet stratigraphically above this bed is the Redstone bed, which is mined at several localities. This bed was measured at locations 19, 20, 21, 25, 26, and 29, and the sections at these points are shown graphically in Plate XVII. The bed ranges in thickness from about 3 feet to nearly 5½ feet. In the NW. ¼ NW. ¼ sec. 8, at location 21, this bed is mined by a combination of stripping and drifting. The lignite at this place is very good in quality. The bed is also mined in sec. 16 at the Bergh mine (location 25), where it attains its maximum observed thickness, 5 feet 5 inches. At location 23, a well in the bottom of a coulee, 3 feet of lignite is reported. This bed is probably the Redstone bed. Lignite is reported in a well at location 24, but the stratigraphic position of the bed could not be determined. Sections Nos. 27 and 28 were measured on a bed about 80 feet above the Redstone lignite. This bed is probably the same as that measured at locations 30, 31, 33, and 35, but as the outcrops are isolated this correlation is not certain. The sections as given in Plate XVII show the bed to range in thickness from a little over 1 foot to more than 4 feet. Section No. 32, measured in sec. 35, is on a bed which may be the same but contains only 1 foot 4 inches of impure lignite.

T. 35 N., R. 53 E.—Big Muddy Creek flows through the central part of T. 35 N., R. 53 E. It meanders widely over a flat which is approximately a mile in width, and the meanders are entrenched from 15 to 18 feet. About 30 feet above the alluvial flat, on the south side of the creek, lies a terrace which is generally covered with gravel and glacial drift. It is well grassed, in places cultivated, and the soil appears to be very good. This terrace includes parts of secs. 16, 17, 19, 21, 22, 24, 25, and 27. Another terrace approximately 150 feet above this one is plainly discernible in secs. 28, 29, and 30. A still higher terrace, which is about 250 to 300 feet above the Big Muddy Creek flat, is present in secs. 1, 2, 3, 4, 5, 11, 12, and 14 of this township. The highest part of this terrace lies in sec. 14, where a deposit of quartzite gravel several feet thick is exposed. All the terraces and gentle slopes are covered with glacial drift, which in some places reaches a thickness of 50 feet or more. Exposures of the underlying stratified rocks are most abundant along the north bluff of Big Muddy Creek, and in the northern part of sec. 14 badlands are developed. The weathering of certain clay and sandstone beds at this place gives a general white appearance to the exposures and the locality is known as Chalky Buttes. The beds dip about 15 feet to the mile in a southeastward direction.

There are many isolated outcrops of thin lignite beds in this township. Sections Nos. 36, 37, and 38 were measured on the same bed, which probably corresponds with the bed exposed at locations 33 and 35 in the township immediately to the west. These sections are shown graphically in Plate XVII (p. 314).

Another thin bed, which carried about 6 inches of lignite, was measured in NE. ¼ NW. ¼ sec. 27, at location 42. The thickest bed exposed in this township was measured at locations 39 and 40, where it is 3½ and 8 feet thick, respectively. Section No. 43 was probably measured on the same bed and shows a thickness of 3 feet 7 inches. These sections are shown in Plate XVII. At location 41, in the SW. ¼ NW. ¼ sec. 23, lignite is reported in a well, but the thickness of the bed is not known.

T. 35 N., R. 54 E.—In general the surface features of T. 35 N., R. 54 E., are very much like those of the township immediately to the west. The lowest terrace, which in the township to the west is about

30 feet above the creek flat, is in this township about 50 feet above it. This terrace is confined to secs. 19 and 20. The second terrace is about 175 feet above the flood plain of the creek and is well marked in secs. 25, 26, 27, 31, 34, 35, and 36. In places there are cliffs about 100 feet in height at the edge of this terrace, but in general the slopes are gentle between the second and the first terraces. The highest land in the township, which lies in secs. 8 and 9, reaches an altitude of about 300 feet above Big Muddy Creek. Outcrops of the lignite-bearing rocks occur along the small creeks in the northern part of the township and in deep gullies in secs. 26, 32, and 33 in the southern part of the township. Although the exact structure was not determined here, the strata probably dip about 16 feet to the mile to the southeast, as indicated by the dip in the township to the east.

Two beds of lignite that outcrop in this township were mapped in secs. 25, 28, 32, 33, and 34. Section No. 45 (Pl. XVII), measured in sec. 33, shows both of these beds, which are separated by 15 feet of sandstone. At this place a strip pit on the lower bed has been worked for local use. Section No. 46, in sec. 32, shows the thickness of the same beds at that place. Another bed was mapped for a short distance in sec. 25. This bed is not exposed in this township, and was mapped by inference from exposures in the township immediately to the east. An isolated outcrop of a thin bed of lignite at location 44, in the NW. ¼ NW. ¼ sec. 5, shows 1 foot 2 inches of lignite.

T. 34 N., R. 54 E.—Crazy Horse Creek flows in a northerly direction through T. 34 N., R. 54 E., its source being just outside of the southern boundary. In secs. 20, 28, 31, and 32 the valley is smooth and grass covered and outcrops of the lignite-bearing rocks are scarce, but in secs. 5, 6, 7, 8, 17, and 18 the creek flows through badlands and the rocks are well exposed. Sec. 7 is especially rough and the relief is from 300 to 400 feet. The central portion of the township is an undulating plain sloping gently toward Crazy Horse Creek. In the eastern part of the township two hills or ridges rise about 150 feet above this plain, one in secs. 2, 11, 14, and 24, and the other in secs. 29 and 30. They are very nearly of the same altitude and suggest the remnants of a higher plain which formerly extended over a considerable area. The hills are covered with quartzite gravel, which in sec. 29 is stratified and 12 feet thick. The township is generally covered with glacial drift.

The badlands in the northwestern part of the township contain several beds of carbonaceous shale but no lignite beds of value. Several isolated outcrops of lignite were found in secs. 6 and 7, but the beds were not of sufficient thickness or of good enough quality to justify mapping. At location 47, in sec. 4, however, a lignite bed over 4 feet thick outcrops (Pl. XVII) and is mined for local use. The lignite in the lower portion of the bed is of fair quality. At location 48, in sec. 5, the same bed outcrops, but a reliable measurement could not be obtained on account of erosion and slumping. Lignite is reported 25 feet below the surface in a well at location 49, in sec. 9. In the SE. ¼ NW. ¼ sec. 30, at an isolated outcrop of a thin lignite bed, 1 foot 11 inches of lignite is exposed. The upper part of the bed is weathered and covered with glacial drift, however, and it is probable that this measurement does not include the entire thickness of the bed.

T. 33 N., R. 54 E. (fractional).—Only that part of T. 33 N., R. 54 E., which lies outside of the Fort Peck Indian Reservation is described here. The area is smooth and nearly level and is generally grass covered. No outcrop of lignite-bearing rocks was found in the township. However, as the land is high, it is probable that the beds of lignite described in the townships to the north and west dip beneath this area and underlie it at a depth of less than 500 feet.

T. 35 N., R. 55 E.—The southwestern part of T. 35 N., R. 55 E., is traversed by Big Muddy Creek, which meanders on a flat about 1½ miles wide. Except for the valley of Spring Creek, a tributary of this stream, the remainder of the surface of the township is largely a rolling prairie. The lignite-bearing formation is generally concealed by glacial drift from a few inches to 40 feet thick. However, along Spring Creek, which flows through secs. 10, 15, 22, 21, and 28, there are limited exposures in which beds of lignite outcrop. Along the bluff on the south side of Big Muddy Creek a lignite bed outcrops at several places. A section was obtained in the SW. ¼ sec. 29 and is given below:

Section in the SW. ¼ SW. ¼ sec. 29, T. 35 N., R. 55 E.

	Ft.	in.
Sandstone.		
Lignite	1	1
Shale		7
Lignite (Richardson)	3	
Shale, yellow	1+	
Covered	12	
Sandstone	15+	
Sandstone, hard, calcareous	4	
Sandstone, cross-bedded, friable	48	
Shale, light gray		8
Shale, carbonaceous		2
Shale, dark gray, containing gypsum	4	
Sandstone, white, containing streaks of clay	16	8
Shale, carbonaceous		4
Shale, light gray	10+	
Water in Big Muddy Creek.		
Total	116	6+
Lignite	4	1

From the altitudes determined at several points on the Richardson bed the strata dip southeastward about 16 feet to the mile. At least two beds of lignite occur in this township at a depth of less than 200 feet. The lower exposed bed (Richardson), which was mapped along Spring Creek and in the bluffs along the Big Muddy, is represented by sections Nos. 52 to 58, inclusive. This bed ranges in thickness from 3 feet 4 inches to about 8 feet, and in general the quality is better on the south side of Big Muddy Creek than it is on the north side of that stream. The measurements of this bed, with the exception of No. 55, are shown in Plate XVII. At location 55 stripping was attempted in the summer of 1912, but only 3 feet 4 inches of badly weathered lignite was found. The bed is stripped at several places, and at location 52 it is mined by drifting. The mine at this place is owned by the Pierce brothers, who lease it to miners. A sample of lignite from this mine was obtained and its analysis is shown as No. 14670, on page 304. Several entries have been driven into the hill a distance of about 400 feet, and lignite has been taken out for a number of years and sold at the mine for $2 a ton. Owing to weathering the lignite is not of the best quality, and in the NW. ¼ NW. ¼ sec. 22 it is reported to be almost worthless. South of Big Muddy Creek the lignite appears to be less weathered. In a coulee in the SE. ¼ sec. 12, at location 51, lignite is found in a well at a depth of 18 feet and reported to be 3 feet 6 inches thick. The same bed was struck in another well in sec. 13, about 200 yards to the south.

T. 34 N., R. 55 E.—Big Muddy Creek flows southeastward through the center of T. 34 N., R. 55 E. The valley is narrower here than elsewhere and is generally bordered on either side by steep bluffs or badlands. In the vicinity of Antelope, and extending along the railroad for about 5 miles, lies a broad, gentle depression, probably representing an old valley, now nearly filled with glacial material, which suggests the former course of Big Muddy Creek. The land in this valley is excellent for farming. The part of this township that is shown on the map (Pl. XVI) as covered by glacial deposits is a gently rolling plain. The land in sec. 19, which includes the highest area in this township, is covered with quartzite gravel. Elsewhere the surface material is glacial drift, except where lignite-bearing rocks are exposed along the valley of the Big Muddy and its tributaries. A section of the stratified rocks as measured in the NW. ¼ sec. 28 is given below:

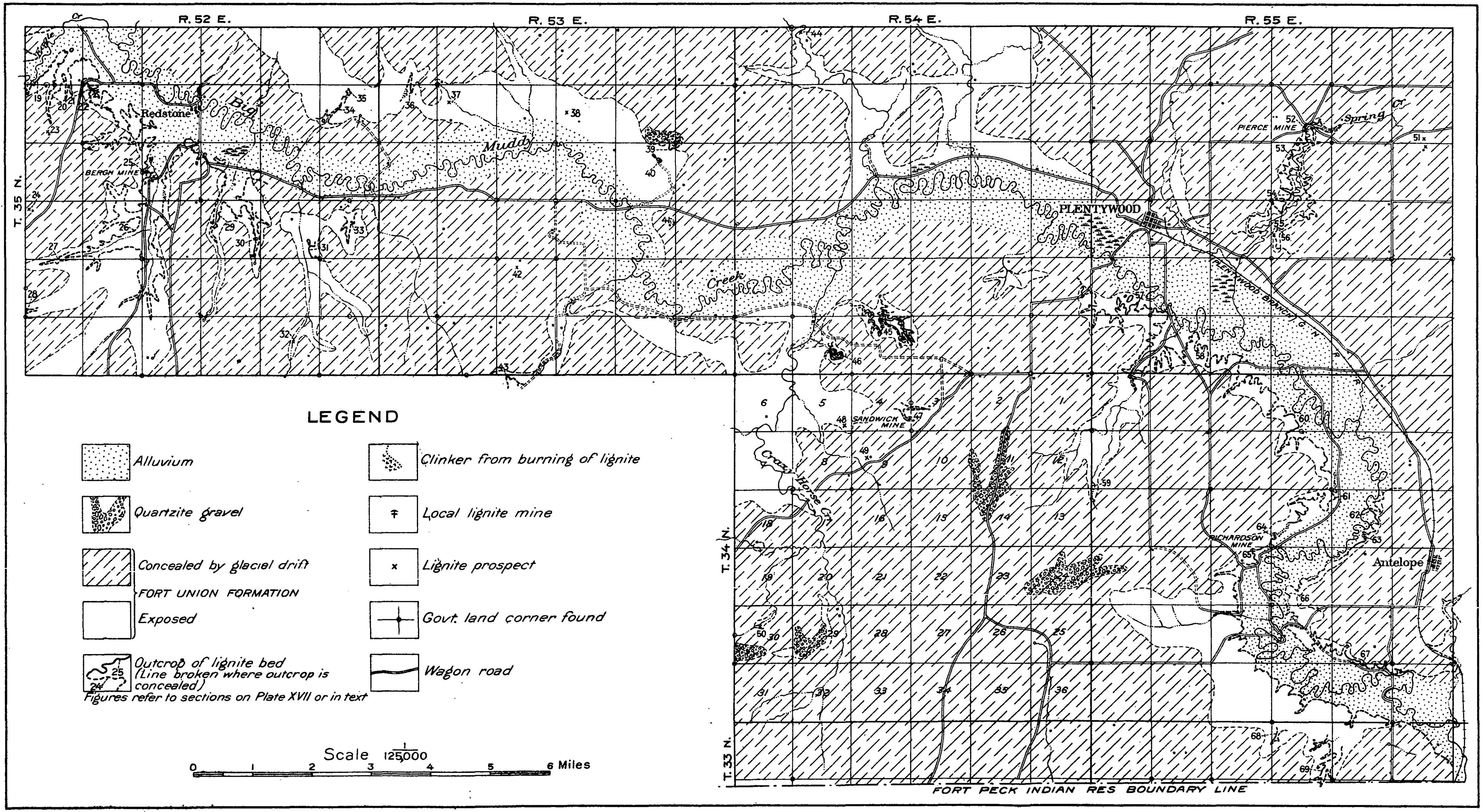
Section in the NE. ¼ NW. ¼ sec. 28, T. 34 N., R. 55 E.

	Ft.	in.
Drift.		
Sandstone, light yellow, massive	60+	
Shale, sandy, and sandstone, interbedded	10	
Sandstone, friable	8	
Shale, carbonaceous	3	4
Lignite		2
Shale, carbonaceous		5

	Ft.	in.
Bone		4
Shale, dark gray	24	4
Sandstone, buff, friable	2	6
Sandstone, hard		10
Sandstone, buff, friable	7	
Sand and shale, light, interbedded	31	
Sandstone, hard		10
Shale, light	5	
Shale, carbonaceous	4	4
Shale, gray	12	
Shale, drab	17	
Shale, gray, containing gypsum	2	6
Shale, brown, hard		10
Shale, brown, hard, containing streaks of lignite	1	6
Shale, containing streaks of limonite	5	
Shale, carbonaceous		2
Lignite		2
Shale, gray	4	
Sandstone, yellow, light	13	11
Lignite (Richardson)	2+	
	217	2+

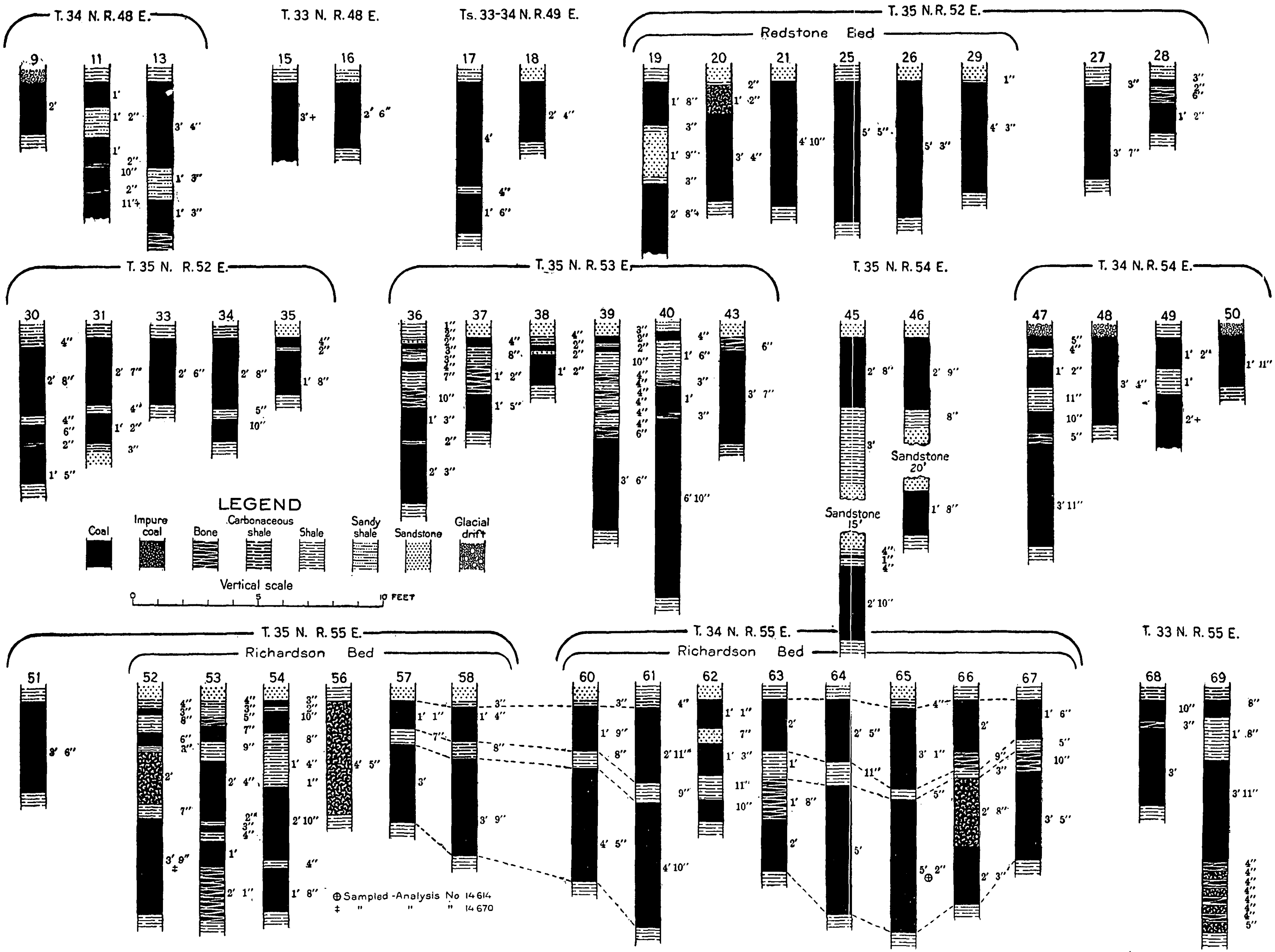
The strata dip southeastward about 16 feet to the mile as determined from altitudes on the Richardson lignite bed. Two important beds of lignite outcrop in the township, the lower one (Richardson) being represented in sections Nos. 60 to 67 inclusive and the higher by section No. 59. At location 59, in the SW. ¼ SW. ¼ sec. 7, lignite has been taken out for local use. At the time of the examination a slump had covered the bed with many feet of talus and a measurement could not be made, but the bed is reported to be over 3 feet thick. The Richardson bed can easily be traced by its clinker and also by its outcrop in many places on either bluff along Big Muddy Creek. About one-fourth mile south of location 66 the red baked clay and shale caused by the burning of the bed measured 17 feet. On the west side of Big Muddy Creek, a short distance north of the Richardson mine, the clinker is 40 feet or more in thickness. This lignite bed is in general thicker and of better quality on the west side of Big Muddy Creek than on the east. It is thickest in the vicinity of the Richardson mine in the northern part of sec. 21, where it carries over 8 feet of lignite. This mine, opened in 1909, is at present operated by Fred Richardson and M. J. Morris. The main entry is about 400 feet long and runs northwestward from the opening. Side entries have been started. A sample of lignite was procured from this mine (location 65) and its analysis is given as No. 14614 on page 14. At location 63, in the SE. ¼ SE. ¼ sec. 14, a strip pit is operated by farmers in the vicinity.

T. 33 N., R. 55 E. (fractional).—Only that part of T. 33 N., R. 55 E. which lies north of the Fort Peck Indian Reservation is described



MAP OF AREA NEAR PLENTYWOOD, SHERIDAN COUNTY, MONTANA

By C. M. Bauer



SECTIONS OF LIGNITE BEDS IN THE SCOBEY-PLENTYWOOD FIELD, SHERIDAN COUNTY, MONT.

here. The land in general is high, sloping in the eastern part of the township to Big Muddy Creek. The lignite-bearing rocks outcrop in secs. 2, 3, and 4. No determinations of the dip of the beds were made in this township, but the structure is believed to be similar to that in the township to the north. Sections 68 and 69 were measured on a bed of lignite which has been mined for local use at the localities indicated by the respective numbers. However, very little lignite has been removed. The sections of the bed at these places are shown in Plate XVII. This township is believed to be underlain by the lignite bed which outcrops along Big Muddy Creek in the township to the north, as well as other lignite beds which outcrop along Big Muddy Creek farther west.

DEVELOPMENT AND USE OF THE LIGNITE.

The value of the lignite in this field is enhanced by the shortage of wood and also by the lack of transportation facilities for importing coal. Fuel is difficult to obtain and, as the winter season is long and severe, thin beds of lignite are prospected and worked, in many places even where they are weathered and impure.

In the vicinity of Scobey any bed is considered workable by the residents that is a foot or more thick and is near enough to the surface for the overburden to be stripped off by shovels or by a horse scraper. Strip pits have been worked in the SW. ¼ SW. ¼ sec. 1, T. 35 N., R. 48 E., and in the NW. ¼ SE. ¼ sec. 3, T. 33 N., R. 48 E., and in the NW. ¼ sec. 5, T. 33 N., R. 49 E., for local use.

In the eastern part of the field lignite is mined by stripping and drifting at a number of places, as indicated on the map (Pl. XVI) and mentioned under the township descriptions. The most important mines in this area are the Bergh mine (location 25), near Redstone, in the NW. ¼ SW. ¼ sec. 16, T. 35 N., R. 52 E.; the Pierce mine (location 52), in the NW. ¼ SE. ¼ sec. 10, T. 35 N., R. 55 E.; and the Richardson mine (location 65), in the NW. ¼ NE. ¼ sec. 21, T. 34 N., R. 55 E. Although the drifts at these places have been driven a considerable distance, no unweathered lignite has yet been obtained. The lignite sells for $2 a ton at the mine.

The use of the lignite in this field is largely confined at present to domestic heating and cooking. Lignite has been used with success in traction engines for plowing and threshing, but owing to its property of slacking it can not be stocked very long or shipped very far. Its future development will depend largely on the application of briquetting[1] or similar methods of preserving the lignite for use in manufacturing.

[1] Wright, C. L., Briquetting tests of lignite: Bur. Mines Bull. 14, 1912.

GEOLOGY AND COAL RESOURCES OF THE AREA SOUTHWEST OF CUSTER, YELLOWSTONE AND BIGHORN COUNTIES, MONTANA.

By G. Sherburne Rogers.

INTRODUCTION.

The area described in this paper is located on the west side of Bighorn River, Mont., in the angle formed by its junction with the Yellowstone (fig. 9, p. 294). The coal-bearing strata outcrop on Pine Ridge in the form of a comparatively small outlier on the western edge of the great coal field which covers most of eastern Montana. Only the northwestern part of the area known to be underlain by coal-bearing strata was examined, further work being prevented by the beginning of cold and stormy weather. The coal in this district is a fairly high grade subbituminous coal and compares favorably with the commercial varieties now sold in neighboring markets. Inasmuch as little is known of this isolated coal field the results of the writer's examination are set forth in this paper, although only about one-third of the area believed to be coal bearing was investigated.

The district here described comprises parts of Bighorn and Yellowstone counties, which are located in the south-central part of the State. It covers an area of 125 square miles, only 6¼ square miles of which, however, is underlain by coal. As shown on the map, the area examined comprises those portions of Tps. 3, 4, and 5 N., Rs. 33 and 34 E., lying south of Yellowstone and west of Bighorn rivers, together with portions of Tps. 2, 3, and 4 N., R. 32 E., and of T. 2 N., R. 33 E.

The Northern Pacific Railway traverses the northern portion of the field, following the valley of Yellowstone River. Custer, located on the railroad in sec. 1, T. 4 N., R. 33 E., is the principal town and is the chief market center for the country within a radius of about 20 miles. Waco is a smaller settlement about 8 miles farther west. The most important wagon road in the field is the old Yellowstone Trail, which follows the railroad from Billings to Custer, and there, owing to the difficulty of crossing Bighorn River and the generally rough country to the east, crosses the Yellowstone and traverses the comparatively flat land on the north side. The road to Hardin, a thriving town situated on the Chicago, Burlington & Quincy Railroad at the point where it crosses Bighorn River, about 30 miles to the south, runs southeast from Custer, striking the valley of the Bighorn near the mouth of Mission Creek. (See map, Pl. XVIII, p. 326.) Besides these two principal roads many secondary trails lead through the area, the best of which are approximately located on the map.

In the examination of this area, which was made in October, 1913,[1] the writer was ably assisted by Messrs. Wallace Lee, R. C. Moore, and A. H. Sloan. This party had been previously engaged in the detailed examination of a large area lying east of Bighorn River for the purpose of classifying the public domain. Although no public land remains in the district described in this paper, the same exact field methods were used. That is, after carefully prospecting the district for coal, the outcrops of all beds thicker than 18 inches were meandered by stadia and plane-table methods, the traverse being tied to land corners. The angle at which the beds dip was determined by means of a careful line of elevation carried throughout the traverse. The coal was examined at short distances and the measurements recorded. In the area not underlain by coal, however, no traverse was made, and the positions of roads and creeks shown on the map (Pl. XVIII) are taken for the most part from the plats of the General Land Office.

The General Land Office surveys of most of the townships in this district are recent. They appear to be accurate and satisfactory, and the cornerstones are generally well marked.

TOPOGRAPHY.[2]

The dominant topographic feature in the district lying in the western angle of Bighorn and Yellowstone rivers is Pine Ridge, the northeastern extremity of which lies within the area described in this paper. From the foot of this high and abrupt ridge the land slopes more gently to another relatively steep escarpment which limits the flat bottom land along the two rivers. (See Pl. XVIII.)

Yellowstone and Bighorn rivers meet at a rather acute angle, and Pine Ridge constitutes the high divide between them, the present shape and position of the ridge being controlled partly by the geology. The top of the ridge is remarkably level and rises only slightly to the south, maintaining an average height of about 1,100 feet above the rivers. Because of the level character of its crest and its thick covering of gravel, it is believed to represent an old river terrace. In other words, at some time in the past the river beds must have been about 1,100 feet higher than at present, and the rivers, in mean-

[1] Although this work was done in 1913 the unavoidable delay in publishing the volume for 1912 has made it possible to include this paper in that volume.

[2] The Fort Custer topographic sheet of the U. S. Geol. Survey, published in 1894, shows the southern portion of the district described in this paper.

dering, deposited the gravel which now covers Pine Ridge. The ridge itself rises about 400 feet above the immediately surrounding country, and its level crest is in this district commonly less than 200 feet wide. Its slopes are everywhere steep, and are broken into characteristic rounded hills. The foot of the ridge approximately coincides with the outcrop of the coal bed south of the large fault shown on the map (Pl. XVIII), the northern end of the ridge being located in sec. 6, T. 3 N., R. 33 E. Owing to the steepness of the slopes, the narrowness of the ridge, and its heavy covering of gravel, this land is valuable chiefly for grazing. Numerous springs on the east slope and a somewhat smaller number on the west serve to make the land available for either summer or winter range. As the name Pine Ridge implies, its slopes are covered by a fairly thick growth of pine, suitable for mine timbers and other rough lumber.

East of the main ridge the land slopes gently toward the Bighorn and is for the most part fairly smooth. This area includes the greater part of Tps. 3 and 4 N., R. 33 E., and although there is a drop of about 500 feet in a distance of 5 miles or less much of the land is sufficiently level for dry farming. In the extreme eastern part of these townships, and extending also into R. 34 E., the land is almost perfectly flat and thinly gravel covered; hence, it seems to represent the first terrace above the present river bottoms. The east and north boundary of this flat area as approximately indicated on the map is formed by a steep and fairly regular escarpment about 200 feet high. It is particularly well marked along the Bighorn and also along the Yellowstone as far west as Sand Creek. At the foot of this slope lies the flood plain of the rivers, ranging in width from half a mile to 2 miles. This bottom land is level and fertile and is now practically all under cultivation.

The district east of Pine Ridge is drained chiefly by Mission and Sorrel Horse creeks and a large creek south of Sorrel Horse Creek. These streams are intermittent, but along their courses springs are fairly common and on Sorrel Horse strong enough, except in the heat of summer, to give rise to a flowing stream.

The creeks have excavated valleys somewhat narrow in proportion to their length and have to only a slight extent dissected the gentle slope to the east of the ridge. A striking feature of this drainage, especially near the headwaters at Pine Ridge, is the abundance of almost parallel valleys. Thus, for distances of 2 or 3 miles the streams flow within a mile of each other, and at the foot of the ridge many of the smaller coulees flow for a mile or more within 1,000 feet of each other. This seems to be due to the steep gradient near their sources and to the abundance of gravel which, being homogeneous in character, has not interfered with the natural course of the streams as determined by the uniform easterly slope.

In contrast to the gentle valley slopes of Mission and Sorrel Horse creeks are the steep gorges of Sand Creek and the other northward-flowing streams that drain the northern end of Pine Ridge. Owing to the proximity of the river, which causes a drop of about 700 feet in a distance of 4 miles or less, the coulees are narrow and steep. The area at the north end of the ridge is therefore strikingly different from that on the gently graded east slope and is dissected into almost impassable badlands. The lower terrace is also practically obliterated in this district, so that the escarpment shown on the map here marks merely the limit of the bottom land rather than a well-developed terrace.

The small area lying west of Pine Ridge is drained by Reid Creek, a large northward-flowing stream, which has bisected the northern end of the ridge and which flows just west of the border of the district.

GEOLOGY.[1]

STRATIGRAPHY.

The Lance formation outcrops throughout this district, except in about a square mile in the southeast corner, where Pierre shale is exposed. Quaternary gravel in many places overlies and partly conceals the older formations. (See columnar section, Pl. XVIII, p. 326.)

CRETACEOUS SYSTEM.

PIERRE SHALE.

Although an important formation in the area to the south, the Pierre shale is practically negligible in this district. It is concealed by the flood plain of Bighorn River, and the upper boundary shown on the map is inferred from the boundary exposed on the opposite side of the river. The Pierre is composed almost entirely of dark greenish-gray shale containing abundant limestone concretions. The fossils inclosed by these concretions indicate that the formation is of marine origin.

TERTIARY (?) SYSTEM.

LANCE FORMATION.

The Lance formation in this area may be divided into two parts, namely, a coal-bearing member, which comprises the upper 250 feet, and a lower portion about 900 feet thick. This distinction is made partly on lithologic grounds and partly because of the slight difference in the fossils found in the two divisions.

Lower part of the Lance formation.—The total thickness of the lower part of the Lance formation was not accurately measured in the field, but the figure given, 900 feet, is a close estimate. This portion of the

[1] A more complete description of the geology of this general region will be found in a forthcoming bulletin by the writer on the geology of the Tullock Creek coal field, Rosebud County, Mont.

formation, as shown on the map, outcrops over most of the area described in this report. No detailed stratigraphic section was made, but the following facts were observed: The strata consist entirely of sandstone and shale, and contain no coal. The sandstone for the most part is soft and yellow, occurring in beds from 1 to 50 feet thick. Through these beds, however, are scattered numerous lenses of hard gray sandstone, which on weathering tend to stand out prominently, forming cap rocks, which are common in the area underlain by these strata. These cap rocks in certain localities are very persistent and in conjunction with the soft yellow sandstone form prominent escarpments, which locally are impassable for considerable distances. In general, however, the sandstone beds are lenticular and can be traced only 2 or 3 miles, and in many places a sandstone 30 or 40 feet thick disappears within 300 feet. The shale which alternates with the sandstone beds ranges in color from yellowish gray to greenish yellow, the latter tint being more common and characteristic of this portion of the Lance formation. In the upper 300 feet of the section, or the portion immediately underlying the coal-bearing member, the shale markedly predominates over the sandstone, whereas in the lower 600 feet the amount of each is about equal. No fossils were collected in the district considered in this report, but numerous invertebrates found in these strata just east of Bighorn River constitute a typical Lance fauna.

Coal-bearing (upper) member of the Lance formation.—The coal-bearing member of the Lance formation resembles the lower portion of the Lance in a general way, but certain differences are apparent on close examination. Although the sandstone is lithologically similar to that in the lower portion, it commonly occurs in beds less than 20 feet thick. These beds, however, are much more persistent than the thicker ones which are common in the lower portion of the formation. The shale is for the most part yellowish gray to brownish, the greenish tint being uncommon. Many bands of carbonaceous shale are present in the member, most of which contain at least a few inches of coal or bone. The base of the member is marked by a coal bed, which ranges in thickness from 1½ to 4 feet. Although none of the carbonaceous bands above this horizon contain more than a foot of coal in this area, as many as eight coal beds thicker than 18 inches have been observed in the district east of Bighorn River. These strata may therefore be distinguished in the field from those of the lower portion of the Lance by the presence of carbonaceous beds, by the generally yellowish-brown color of the shale, and by the greater regularity of the sandstone. Furthermore, fossils are less numerous in the coal-bearing member than in the lower part of the Lance, and collections made east of Bighorn River contain a fauna slightly different from that which is typical of the Lance formation. The total thickness of the coal-bearing member is not present in this district, the maximum observed being about 250 feet.

QUATERNARY SYSTEM.

The oldest unconsolidated deposit in this district is the gravel on Pine Ridge, which is about 1,100 feet above the present rivers. It is believed to be Quaternary in age because of its close resemblance to later undoubted Quaternary gravel deposits. The great amount of erosion which has taken place since its deposition, however, indicates that it is either early Quaternary or possibly late Tertiary. It is made up for the most part of pebbles from half an inch to 3 inches in diameter, although pebbles 6 or 8 inches in diameter are not rare. There is also an interstitial filling of fine gravel and sand. The thickness of the gravel is difficult to estimate, owing to the fact that it constantly slumps down, never forming cut banks. The thickness of 40 feet given in the columnar section (Pl. XVIII, p. 326) probably represents a maximum, and the average thickness is probably less than 30 feet. As mentioned above, the gravel has exercised a distinct influence on the topography and drainage and is constantly being carried down and reworked by the streams which have their sources in Pine Ridge. Probably more than half of the gravel is composed of quartzite, chert, and other siliceous rocks, but a very wide range of igneous rocks also enters into its composition, and all the main types, from rhyolite to pyroxenite, have been observed by the writer.

The next well-defined Quaternary deposit is the gravel of the lower terrace, which lies at a height of about 200 feet above the river. This gravel is most apparent on the slope and at the foot of this terrace, having been almost entirely removed from its flat top. It is apparently similar in every way to the gravel on Pine Ridge. As it lies close to the railroad it may at some time become valuable for concrete work, for which it would be adapted after screening. The supply is practicably inexhaustible.

The most recent deposit in the district is the alluvium of which the present bottom land is formed. It is a rather clayey loam, and its fertility makes it valuable for agriculture.

STRUCTURE.

In a general way the area described in this paper is situated near the boundary between the Great Plains district, in which the strata characteristically lie almost flat, and a piedmont district in which the strata have been somewhat disturbed by more or less distant upheavals. Thus this area lies at the extreme northern edge of the so-called Bighorn uplift, the center of which is about 70 miles to the south. The strata dip gently to the north and east at angles averaging about 1°.

The dip is monoclinal in general character, but appears to be interrupted in places by minor rolls, one of which crosses the southern part of this area. Thus at the most southerly point in the area examined the dip is slightly to the south (2 feet in 1,000), whereas elsewhere in the field it is about 1° to the north or northeast. The axis of this gentle anticline passes through sec. 36, T. 3 N., R. 32 E., and north of this point for at least 8 miles the dip is uniformly to the north and northeast.

The dips shown on the map (Pl. XVIII) are computed from numerous elevations determined on the coal bed, and as they are all low are given in feet in 1,000 feet rather than in degrees.[1] The dip is too low to measure with a clinometer except locally, and accurate data are therefore not available in the non coal-bearing area. It is believed from observations made on the east side of Bighorn River that the general dip throughout this area is in a direction about N. 20° E., but that it decreases north and east of Pine Ridge until the strata along the rivers lie almost flat.

Faults are not uncommon in the district, and it is probable that those shown on the map are only a small proportion of those which actually exist. Owing to poor exposures and to the lack of key strata in the lower part of the Lance, it is impossible to detect faults without very careful work, and none are mapped except in the coal-bearing area. All the faults found are approximately parallel to the strike except the one in secs. 19 and 30, T. 3 N., R. 33 E. This fault was mapped inferentially on the evidence of the elevations, which show a drop of about 75 feet to the east, but although its position could not be actually seen it is believed that it is located within close limits. The small fault in sec. 6, T. 3 N., R. 33 E., is clearly visible, however, as is also that in sec. 13, T. 3 N., R. 32 E. Each of these faults has a displacement of 30 feet. The fault in sec. 7, T. 3 N., R. 33 E., has a total displacement of 76 feet downthrown to the south, but no trace of it could be found on the west side of the divide. The largest fault is that which repeats the coal outcrop at the north end of the ridge. Its position was determined with reasonable accuracy at a number of points in the coulees which it crosses, the displacement ranging from 130 feet on the west to 100 feet on the east. These two faults apparently inclose a block, which is tilted slightly to the east as would be expected if the faults die out to the west. The small fault in sec. 1, T. 3 N., R. 32 E., has a downthrow of 29 feet to the south.

[1] A dip of 17.5 feet in 1,000 feet is equivalent to a dip of 1°.

All these faults are normal, with fault planes inclining probably less than 45° from the vertical. As has been shown, some of them are step faults and others are block faults. Several other small breaks with displacements of less than 10 feet were observed, mostly at the northern end of the ridge, and it is probable that the simple monoclinal dip described above is broken in many places by similar small faults.

THE COAL.

OCCURRENCE AND CHARACTER.

The one coal bed thicker than 18 inches in the area examined lies at the base of the coal-bearing member of the Lance formation. Above this bed therefore are the yellow shale and generally thin sandstone beds of this member, and beneath it are the greenish shale and the sandstone of the lower part of the Lance. The generally shaly character of the strata that incloses it is shown in the sections given below. The measured sections of the bed itself, shown graphically on Plate XVIII, are numbered to correspond with the locations at which the sections were measured, as shown on the map. In every section of the bed measured a parting of a peculiar sandy carbonaceous material was found, ranging in thickness from three-fourths of an inch to 1¼ inches; in nearly every section this parting is located from 1 to 10 inches below the top of the coal bed.[1] The most notable exception is in section No. 10, where the presence of a lenticular upper bench has caused the parting to assume a position below the middle of the coal. The bed can generally be easily recognized by the characteristic appearance, thickness, and position of this parting.

[1] Rogers, G. S., Occurrence and genesis of a persistent parting in a coal bed of the Lance formation: Am. Jour. Sci., 4th ser., vol. 37, p. 299, 1914.

Stratigraphic sections measured across the coal bed.

SE. ¼ sec. 7, T. 3 N., R. 33 E.

	Ft.	in.
Shale, yellow	10	
Shale, brown, carbonaceous	3	
Shale, yellow	4	
Shale, brown, carbonaceous, with some bone	3	
Shale, yellow	8	
Sandstone, yellow, soft	6	
Shale, gray	10	
Shale, yellow	6	
Coal (section No. 6, Pl. XVIII)	3	2
Shale, carbonaceous	1	
Shale, greenish gray	20	
	74	2

SW. ¼ sec. 31, T. 4 N., R. 33 E.

	Ft.	in.
Shale, yellowish gray	10	
Coal (section No. 14, Pl. XVIII)	1	10
Shale, carbonaceous	1	
Shale, greenish yellow	12	
Sandstone, yellow, soft	29	
	53	10

SW. ¼ sec. 32, T. 4 N., R. 33 E.

	Ft.	in.
Sandstone, yellow, soft	25	
Shale, yellow	20	
Shale, brown, carbonaceous, with some bone	2	
Shale, gray	7	
Bone	1	
Shale, brown, carbonaceous	2	
Coal (section No. 11, Pl. XVIII)	2	1
Shale, brown, carbonaceous	1	
	60	1

Center W. ½ sec. 12, T. 3 N., R. 32 E.

	Feet.
Sandstone, yellow, soft	4
Shale, yellow, sandy	8
Coal (section No. 19, Pl. XVIII)	3
Shale, carbonaceous	2
Shale, yellowish green	5
	22

The thickness and character of the coal bed are shown in the graphic sections on Plate XVIII. These sections show the bed to be thicker than 18 inches everywhere except in the center of the northern part of the ridge and to consist for the most part of clean coal not badly broken by partings. These sections show the actual measurements of the bed, but on figure 10 are shown the isopachous lines [1] or thickness contours, which are a device for showing at a glance the estimated thickness of the bed at any point. In drawing these contours the measured sections of the bed were first evaluated in terms of solid coal without partings, according to the method of the land-classification board of the United States Geological Survey. This is done on the broad assumption that in mining the cost of removing a parting is generally about equal to the profit on a similar thickness of coal, so that to obtain the thickness of coal which may profitably be mined an inch of coal should be disregarded for every inch of parting. Thus, 24 inches of coal separated in the center by 3 inches of shale is considered to be equivalent in value to 21 inches of solid coal. All the measured sections have been thus treated, and the results are given in figure 10. By grading between these sections the points were established at which the coal is thought to be 18, 24, and 30 inches thick, and so on, and lines were then drawn

[1] An isopachous line, in the sense here used, is an imaginary line connecting the points at which the coal bed is of equal thickness.

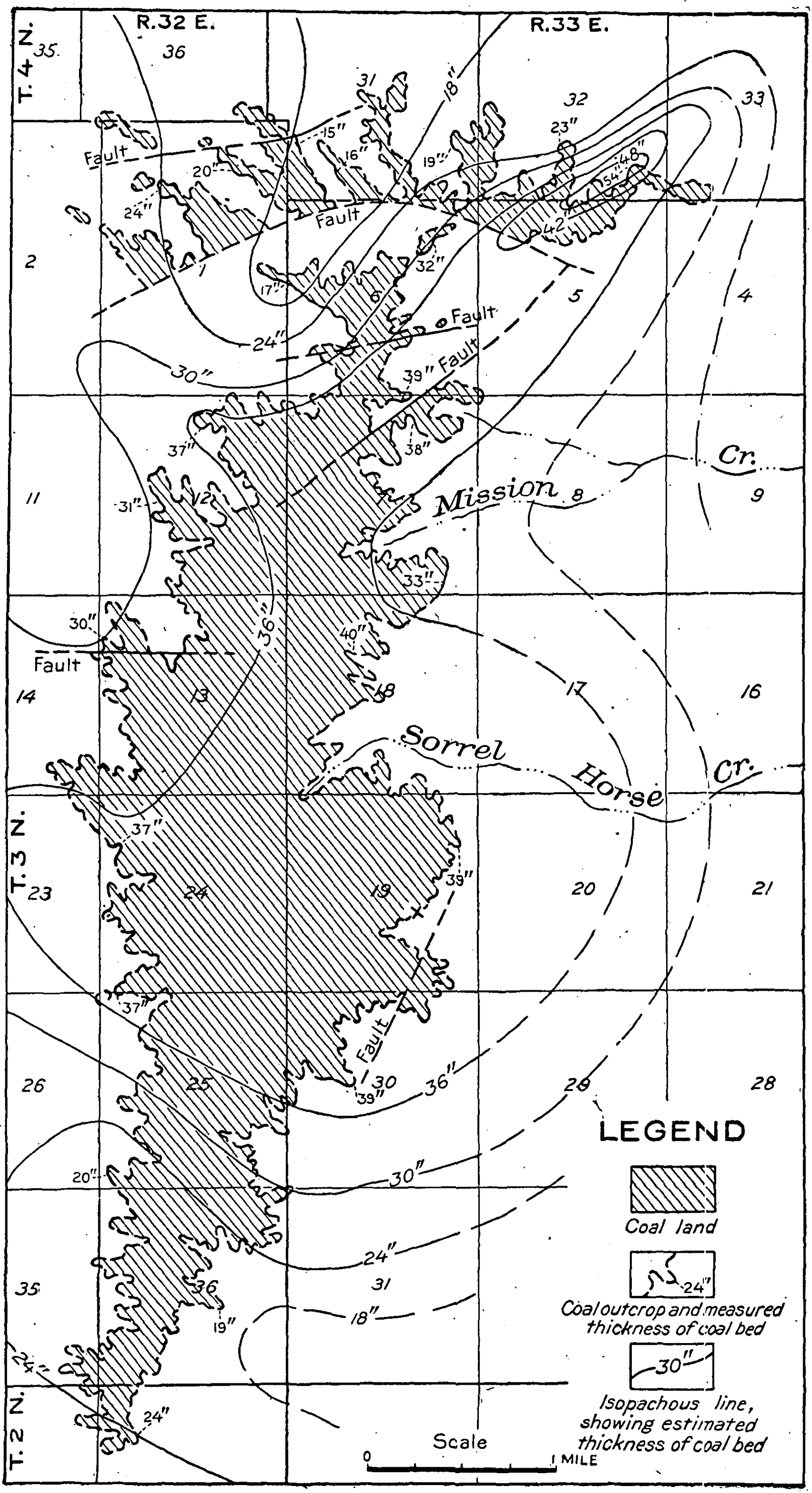


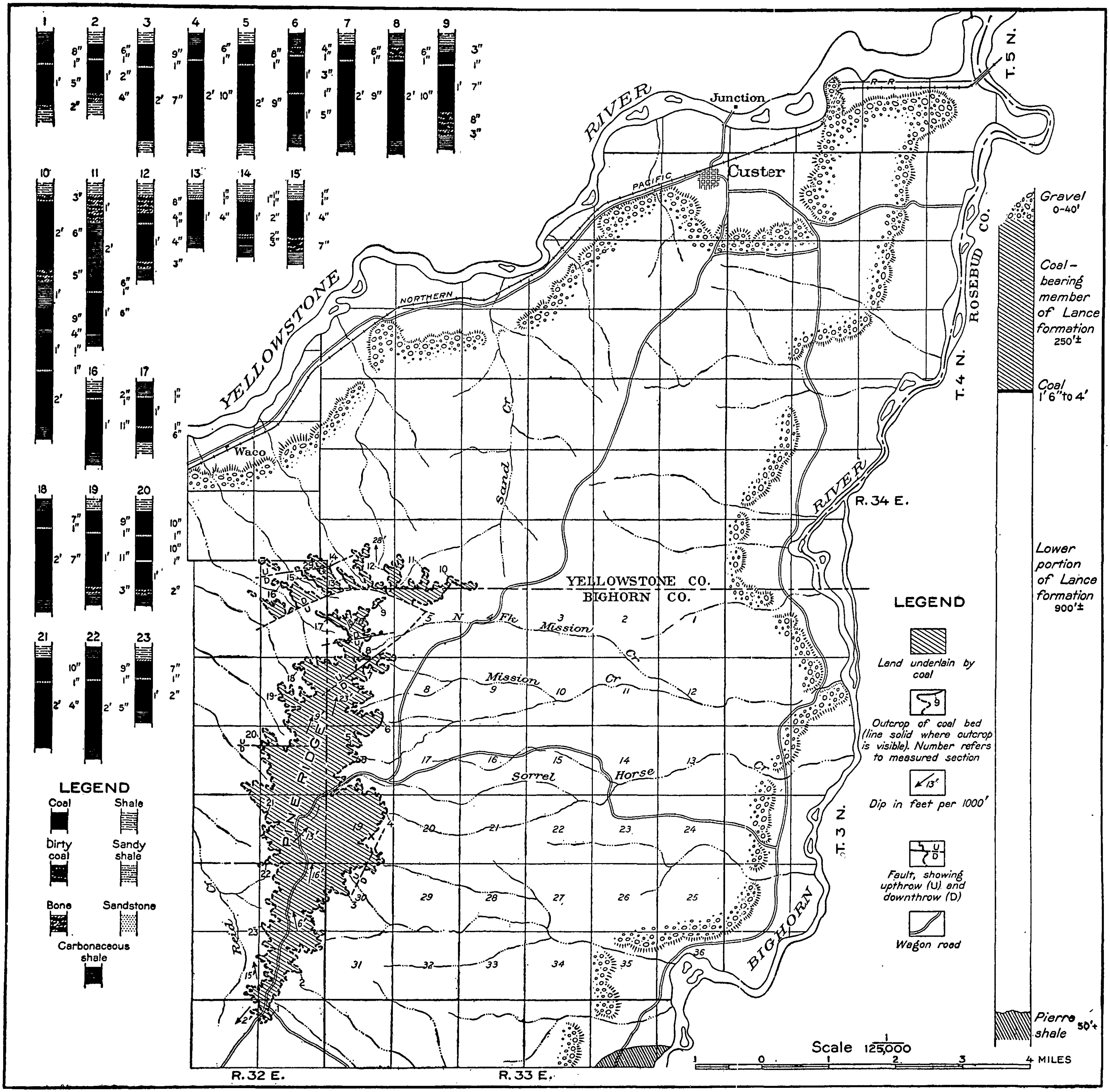
FIGURE 10.—Map of northern part of Pine Ridge coal field, Mont., showing lines along which the coal bed is probably of equal thickness (isopachous lines).

connecting these points. Thus, at all points along the 30-inch contour the coal bed is believed to be 30 inches in thickness, calculated on the above basis, and between the 30 and 36 inch contours the bed is believed to be between 30 and 36 inches thick and to average 33 inches. For example, the south quarter corner of sec. 12, T. 3 N., R. 32 E., lies almost halfway between these contours, so that although the coal is concealed at that point it may be inferred that it is 32 or 33 inches thick. The value of these contours depends of course upon the number and relative positions of the measured sections upon which they are based, and as in the area under consideration many sections have been measured at favorable locations, it is believed that the contours are reliable and fairly accurate.

These contours show that the bed is thickest in sec. 32, T. 4 N., R. 33 E., but that most of the central portion of the ridge is underlain by coal between 36 and 39 inches in thickness. The bed is thinnest in a long embayment from the north, where, in sec. 31, T. 4 N., R. 33 E., it is less than 18 inches thick. In the southern part of the area the bed is also thin but appears to become somewhat thicker farther south.

Thickness contours roughly define the limits of the ancient swamp in which the coal was deposited. Inasmuch as the contours in this area are concentric in character and appear to close within a short distance beyond its borders, it may be inferred that the center of the swamp was not far distant. Owing to the small size of the area examined the data gathered are hardly sufficient for any statement as to the thickness of the coal to the west or south, but if the center of the swamp was located within this district it is reasonable to suppose that the coal is thinner in those directions. On the other hand it must be remembered that other swamps, semi-independent in character, may have existed contemporaneously, and hence that, although the coal bed decreases in thickness for a few miles, it may farther on become thicker. Furthermore, it is possible that the overlying carbonaceous zones, which in this field are of no value, may at a distance of a few miles carry several feet of coal. It is evident, therefore, that no reliable generalizations can be made before the adjacent areas are examined.

The strata above the base of the coal-bearing member in this area do not contain any coal beds more than a foot thick. At locality 10 an upper bench of the main coal bed is exposed, and this is represented in other localities by a carbonaceous streak a few feet above the horizon of the sandy parting. About 30 feet above the principal bed are two fairly constant carbonaceous beds (see section measured in the SE. ¼ sec. 7, T. 3 N., R. 33 E., on p. 324), but neither of these beds contains more than 6 inches of coal. A detailed section of one of them is as follows:



MAP OF AREA SOUTHWEST OF CUSTER, YELLOWSTONE AND BIGHORN COUNTIES, MONT., INCLUDING PART OF PINE RIDGE COAL FIELD, AND SECTIONS OF THE COAL.

By G. Sherburne Rogers.

Section of coal bed in NW. ¼ sec. 13, T. 3 N., R. 32 E.

	Ft.	in.
Shale, carbonaceous		11
Coal		2
Shale, gray		4
Coal		3
Clay, white		1½
Bone		10
Shale, yellow.		
	2	7½

Above this bed occur several lenticular carbonaceous streaks, containing at certain places a few inches of coal but nowhere attaining economic importance.

QUALITY OF THE COAL.

The coal of this field is of good subbituminous grade. It has no visible woody structure and is black in streak as well as in color. It has a bright vitreous luster and weathers in the platy manner characteristic of subbituminous coal. It is brittle when fresh, and most of it is clean and fairly pure.

In this area no opportunity was afforded the writer of observing the behavior of perfectly fresh coal when exposed to the air, but from facts observed east of Bighorn River it seems probable that it would check within a month or so and would partly fall to pieces if too roughly handled. The checking that takes place within the first few months after the coal is mined does not, however, entirely penetrate it, but rather tends to form a protective coating around a core of unchecked material beneath. If proper precautions are observed in moving it, therefore, this coal should form a fairly satisfactory fuel. It is possibly somewhat "light" for a good forced-draft steam coal, but it might be successfully used in stationary engines and as domestic fuel. If it ever commands a distant market, however, it is probable that closed cars will be needed for shipment.

This coal in physical appearance and in inferred stocking qualities is superior to that mined near Sheridan, Wyo. It resembles closely the Roundup and other coal mined in the Bull Mountains, about 50 miles northwest of this area. It is probably somewhat inferior, however, to the Red Lodge and Bear Creek coal, which is extensively mined about 80 miles southwest of this field.

As no development work has been done in this area there was no chance of obtaining a sample of fresh coal for analysis. At a point about 20 miles northeast of Pine Ridge, however, a sample was obtained by blasting 8 feet back under a heavy sandstone bed. The coal in that district appears to be somewhat lower in quality than that in this area, and the calorific value of the sample was furthermore undoubtedly impaired by its slightly weathered condition. This sample in the air-dried condition yielded 9,376 British thermal units, and taking the above facts into consideration it is probable that perfectly fresh coal (air dried) in this area would give over 10,500 British thermal units, nearly the heat value of the average Bull Mountain coal.

QUANTITY OF THE COAL.

On figure 10 the thickness contours of this coal bed are shown, and the principle of their construction has been described above. As the outcrop of the bed is a rather sinuous line entirely surrounding the coal area, and as 23 accurate measurements of the coal were made along the outcrop, it is believed that these thickness contours are located with considerable accuracy, and that they form the best basis for computing the tonnage. The area of the coal land between each two of these contours was separately determined, and the thickness of the coal in each area was assumed to be the average between the two inclosing contour lines. On this basis it is estimated that there is a total of 20,869,760 tons of coal in this field, of which at least 60 per cent is recoverable.

OUTLOOK FOR DEVELOPMENT.

At the present time practically no development work has been done. In the SE. ¼ sec. 19, T. 3 N., R. 33 E., the coal has been opened, but work was stopped after driving the entry about 5 feet.

On figure 10 is shown the thickness of the coal bed at all localities in the coal-bearing area. The bed reaches a maximum of 54 inches in sec. 32, T. 4 N., R. 33 E., and this locality has the added advantage of being nearest to the railroad (Pl. XVIII). On the other hand, there is not a great body of coal in that district, and the cover averages less than 40 feet, so that the coal is probably more weathered than in the area to the south. Furthermore, faults seem to be more common, and the thickness of the coal is more variable. For a mine of any size, therefore, the area at the head of Mission and Sorrel Horse creeks would probably be the most favorable. As the dip to the northeast is fairly constant, the entry should be driven from the east side of the ridge in order to take advantage of the natural drainage and to lessen the cost of hauling out the loaded cars. Springs are common along the coal bed, and it is probable that the water would be a constant source of trouble in an entry driven from the west or down the dip. In the area south of Sorrel Horse Creek the coal is somewhat thinner, and owing to the northerly dip the bed is within 60 feet of the top of the ridge.

As stated above, the coal in this bed seems to be superior in quality to that mined near Sheridan, Wyo., and to be nearly equal to the Bull Mountain coal. It is probably inferior, however, to the Red Lodge and Bear Creek coal, which sells in Custer for less than $3 a ton. At the present time it would be impossible to mine it in competition with these coals, owing to the long haul to the railroad, and its commercial importance is therefore dependent largely on better transportation facilities.

COAL DISCOVERED IN A RECONNAISSANCE SURVEY BETWEEN MUSSELSHELL AND JUDITH, MONTANA.

By C. F. Bowen.

INTRODUCTION.

As coal-bearing formations were known to be exposed in the central part of Montana, between Missouri and Yellowstone rivers, an examination of this area was undertaken in 1912 in order to obtain definite information regarding the quantity of the coal and the extent of the beds. This examination has shown that the coal is confined to the area north of the Judith Mountains, that the beds are thin and few in number, and that the coal is of low grade. The field is therefore not of commercial importance.

The area lies in the central part of Montana and ranges from less than 1 mile to about 30 miles in width. It extends from Musselshell, on Musselshell River, northwestward to Judith, at the mouth of Judith River on the Missouri, a distance of about 125 miles. This area is about 1,400 square miles in extent. Its geographic location is shown on the index map (fig. 9, p. 294).

The purpose of this report is to give a brief account of the stratigraphy and coal resources of the formations in the area above described. A more detailed report on the stratigraphy and age of the formations is in preparation and will be published later. The field work on which this report is based was done during the period from June 25 to August 5, 1912, and was in the nature of a careful reconnaissance survey.

The mapping was done by Harvey Bassler and the writer. The residents of the region were courteous and hospitable and furnished much information that was of value in carrying on the work, for which the writer here expresses his acknowledgments.

In 1853 Hayden did his first work in the upper Missouri region. Following him, Cope, C. A. White, Peale, Marsh, and others studied the section along Missouri River but did not attempt detailed mapping of the individual formations. In recent years more detailed work has been done in this and adjacent areas by Stanton and Hatcher,[1] W. R. Calvert,[2] and C. T. Lupton.[3]

As a rule the township boundaries in this area are well established. The subdivisions of the townships, however, are for the most part unsatisfactory, except where the original surveys are comparatively recent or where resurveys have been made.

The United States Geological Survey is preparing a map of the United States on the scale of about 16 miles to the inch, and part of this map was enlarged to a scale of 4 miles to the inch and used as a base for geologic mapping. The land lines and the drainage on this map are fairly accurate. The slight discrepancies which occur are so small that they do not appreciably affect the accuracy of the map on the scale on which it is here published, and therefore no adjustments were made.

Horizontal control for geologic mapping was furnished by the land survey. A main stadia traverse was carried throughout the area and was tied to land corners generally not less than once in each township. A Johnson plane table and telescopic alidade were used in running the traverse. Side traverses, which were tied to the main traverse and to land corners, were made by horse pacing and by triangulation, a 15-inch plane table and open-sight alidade being used for the work. By these methods the structure was platted and the boundaries of the formations of the Montana group were mapped, but no attempt was made to map or study the formations above and below the Montana. The map thus prepared is reproduced here as Plate XIX. On it the formation boundaries are represented by solid lines where they are located with considerable accuracy and by broken lines where their location is only approximate.

Although the country is very sparsely settled, satisfactory wagon roads connect the post offices and the large stock ranches and furnish a ready route of travel throughout the field.

The Chicago, Milwaukee & St. Paul Railway passes through the southeast corner of the area. A branch of this road built several years ago from Harlowton north to Lewistown has been extended north to Hilger and is now under construction to Roy. The construction of a branch line from Lewistown east to Winnett is also contemplated.

TOPOGRAPHY.

The area lies wholly within the plains region, although it is not far removed from several important mountain masses which have influenced its topography, drainage, and structure. Broadly considered,

[1] Stanton, T. W., and Hatcher, J. B., The geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, 1905.

[2] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, 1909.

[3] Lupton, C. T., The eastern part of the Bull Mountain coal field, Mont.: U. S. Geol. Survey Bull. 431, pp. 163-189, 1911.

the topography is that of an uneven plain more or less dissected by streams, but locally there is a considerable development of badland forms, which occur where the Eagle sandstone or Judith River formation is exposed at the surface in a comparatively flat-lying attitude, as in the area between Willow and Flat Willow creeks, or near the larger drainage lines, as along Judith River.

The drainage belongs to the Missouri River system, and the streams enter that river either directly or indirectly by way of Musselshell River. The principal streams tributary to Musselshell River are Willow, Flat Willow, McDonald, and Boxelder creeks. These streams rise in the Big Snowy and Judith mountains and flow eastward across the plains to the Musselshell, which enters the Missouri a few miles east of the eastern boundary of the area represented on Plate XIX (p. 336). The northwestern part of the area is drained by Judith River and Dog Creek, which rise in the mountains and flow northward to Missouri River.

GEOLOGY.

STRATIGRAPHY.

Rocks ranging in age from Carboniferous to Tertiary are exposed in the area lying between the crests of the Big Snowy and Judith mountains on the west and Musselshell River on the east. As no detailed study was made of any formations except those of the Montana group, this discussion is confined primarily to these rocks and only brief mention is made of the immediately subjacent and superjacent formations. The formations of the Montana group and their stratigraphic relation in north-central Montana were described by Stanton and Hatcher[1] in 1905. Their grouping of the formations is followed in this paper. Dr. Peale,[2] in a paper on the stratigraphic position and age of the Judith River formation, dissents, however, from Stanton and Hatcher's conclusions. The succession, thickness, and character of these formations as determined by the writer in this field are presented in the following table:

[1] Stanton, T. W., and Hatcher, J. B., op. cit.

[2] Peale, A. C., The stratigraphic position and age of the Judith River formation: Jour. Geology, vol. 20, pp. 530-549, 640-652, 738-757, 1912.

Generalized section of the sedimentary rocks discussed in this report.

System.	Group.	Formation.	Thickness.	Characteristics.
			Feet.	
Tertiary (?).		Lance formation.	700-800	Alternating gray sandstone and clay shale, with thin beds of coal near the top.[a]
Cretaceous.	Montana.	Bearpaw shale.	1,100±	Marine shale, dark gray to black in upper part but with greenish tinge in lower part in southern portion of the field. The shale contains numerous calcareous concretions which yield *Baculites ovatus, Baculites compressus, Scaphites nodosus, Inoceramus barabini,* and other forms characteristic of the Pierre shale.
		Judith River formation.	250-500	Alternating beds of sandstone, clay, and shale including carbonaceous members, mainly of brackish or fresh water origin. In the northern part of the area a more or less persistent coal bed occurs near the top of the formation and is in most places overlain by a bed of marl or breccia, containing *Ostrea subtrigonalis* in great numbers. The formation also contains bones of vertebrates, fragments of leaves and stems, and much silicified wood.
		Claggett formation.	200±	Alternating sandstone and shale, becoming chiefly sandstone at top. Marine fossils occur in these sandstones along Missouri and Judith rivers but have not yet been found in the southern part of the area. The common forms are *Tancredia americana, Cardium speciosum, Mactra formosa, Mactra alta,* and other species formerly considered characteristic of the Fox Hills sandstone.
			500±	Marine shale which is not easily distinguished either lithologically or paleontologically from the Bearpaw shale. The most common fossils are *Baculites ovatus, Baculites compressus, Gervillia borealis, Inoceramus barabini,* and *Leda evansi.*
		Eagle sandstone.	200-300	In the northern part of the field the Eagle consists of an upper division of gray thin-bedded sandstone with some shaly members, a middle division of dark-colored shale containing thin beds of carbonaceous shale and coal, and a lower division, about 120 feet thick, of white to buff massive to heavy-bedded sandstone. In the southern part of the field the carbonaceous shale is replaced by thin-bedded shaly sandstone and the basal sandstone is dirty gray to brownish in color. Fossils are rare, but a few marine invertebrates have been found.
	Colorado shale.		(b)	In its upper part the Colorado is a black marine shale with alternating thin beds of sandy shale and sandstone. At one locality examined a calcareous fossiliferous sandstone occurs in the upper part of the formation. Baculites sp., *Dosinia orbiculata, Gyrodes conradi, Inoceramus deformis, Inoceramus labiatus, Scaphites ventricosus,* and other forms were collected from this formation.

a Lupton, C. T., loc. cit.

b Not measured.

The width of outcrop and the surface distribution of the formations which are controlled by structure and erosion are shown on the map (Pl. XIX). Where the structure is monoclinal and the dips steep, as along the north side of the field east of Black Butte, the width of outcrop of the entire Montana group may be less than 1 mile. In such places the Eagle sandstone and Judith River formation, because of their greater resistance to erosion, form hogback ridges whose crests are marked by sandstone ledges, whereas the soft shales of the Claggett and Bearpaw formations occupy valleys. In proportion as the dip decreases the width of outcrop of the formations increases, and where the slope of the surface accords with the dip the width of outcrop of a given formation may be many miles across. These conditions are illustrated by the width of outcrop of the Judith River formation northwest of Roy. In such places the Judith River strata are commonly eroded into badland forms so that the formation is well exposed and easily traced. In some places, as at Hilger, the formations occupy synclinal depressions between mountain uplifts; this structure gives rise to a wide outcrop of the formation occupying the central part of the synclinal depression, though the dips near the mountains may be comparatively steep.

For the most part the formations are well exposed throughout the field. Because of this condition they can be followed almost continuously and there is no difficulty in correlating outcrops. The chief exceptions to the above statements occur at the crossing of stream valleys and along the base of the Judith and North Moccasin mountains. Near these mountains the formations are more or less obscured by bench gravels, so that the outcrops may be separated by considerable distances, and there is in places considerable discordance in dip and strike between two successive exposures. These conditions render the exact position of the beds beneath the covered area more or less uncertain, but there is commonly little doubt as to the formation to which an outcrop belongs.

STRUCTURE.

The dominant structure in the eastern part of the area is a broad symmetrical anticline on which are superimposed several smaller folds, thus producing the type of fold known as an anticlinorium. The axis of the major fold trends northwest and pitches to the southeast. In the southeastern part of the field the strata dip away from the axis of the anticline at angles ranging from 20° to 70°, the steeper dips occurring nearest the axis of the fold, but as the mountains are approached the dips decrease in amount, and around the north base of the Judith and North Moccasin mountains they do not exceed 45° and the anticline loses its distinctive character.

The minor folds which complicate the major anticline are also open symmetrical folds whose axes pitch to the southeast and trend roughly northwest-southeast, although they are somewhat sinuous in character. The dips on opposite limbs of these folds as a rule range from 2° to 6°.

A dome structure has been produced by the uplift of Black Butte and the North Moccasin Mountains. So far as examined the beds dip steeply away from these uplifts except at the southeast side of Black Butte, where the strata dip steeply toward the butte, probably as the result of faulting.

Out on the plains north of the Judith and North Moccasin mountains the strata dip at a low angle to the north or northeast.

Faults are not important structural features except in the area along Judith River north of the northern boundary of T. 20 N. Two minor faults cut the beds on the north side of the Judith Mountains, and, as already pointed out, there may be a small fault at the southeast side of Black Butte. Between Fullerton and Missouri River three prominent faults, striking a little west of north, cross the valley of Judith River. At the first and second faults north of Fullerton the beds dip steeply to the north near the fault plane, but a short distance away they are nearly flat. At the fault nearest Missouri River the dip is to the south, or in the opposite direction to that at the faults farther south, and there is evidence of some minor faults, the details of which were not worked out. The northernmost fault exhibits the maximum throw observed at any of these displacements, and at that place the white massive sandstone at the base of the Eagle sandstone is brought into contact with the sandstone beds constituting the upper part of the Claggett formation. If the thickness of that part of the Eagle above the white massive sandstone be considered as 150 feet and that of the lower or shale portion of the Claggett as 500 feet, the throw would be about 650 feet.

These same lines of disturbance were seen on the east side of Dog Creek in T. 21 N., R. 19 E., where the structure seems more complicated than on Judith River. The maximum disturbance, however, is probably shown along Missouri River between Armells Creek and Dog Creek. In speaking of this area Hayden says:[1]

> It presents perhaps the most rugged scenery on the Missouri River, the denudation and erosion having been much greater than at the Bad Lands of White River. But the most remarkable feature of this basin is the wonderful disturbance of the strata. So much are the beds disturbed and blended together by forces acting from beneath that it seems almost hopeless to obtain a section showing with perfect accuracy the order of superposition of the different strata.

THE COAL.

In the northwest part of the field the Eagle sandstone and the Judith River formation contain some coal which is locally valuable, but no important coal beds occur southeast of Black Butte. For convenience of description, the coal beds of the Eagle and Judith River formations will be described separately.

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[1] Hayden, F. V., Notes explanatory of a map and section illustrating the geological structure of the country bordering on the Missouri River from the mouth of the Platte River to Fort Benton: Philadelphia Acad. Nat. Sci. Proc., vol. 9, pp. 115–116, 1858.

COAL IN THE EAGLE SANDSTONE.

The easternmost indications of coal in the Eagle sandstone were found near the northern side of sec. 12, T. 17 N., R. 23 E. At this place there is a bed of carbonaceous shale about 1 foot thick. Near the northwest corner of the same township a bed that is probably the same is about 2 feet thick and contains 3 inches of coal at the top and 6 inches at the bottom, with carbonaceous sandstone and shale between. On the southeast side of Black Butte, at locality 1,[1] a bed of coal 2 feet thick is exposed. It seems to be of local occurrence, as no other exposures could be found in this vicinity.

In the NE. ¼ sec. 8, T. 18 N., R. 18 E., a carbonaceous bed containing about 4 inches of bony lignite at the top is exposed at an old surface pit. Coal is also reported as being mined from the Eagle sandstone near Deerfield, but this locality was not visited.

Between Fullerton and Judith the Eagle sandstone is exposed by faulting at several places, and at each place it contains some coal of subbituminous quality. At locality 5 there is 13 inches of good coal, and at locality 2 (see section in Pl. XIX) the coal is 26 inches thick. At locality 3, sec. 13, T. 22 N., R. 16 E., there is 4 feet 7 inches of coal in two benches, separated by 1 foot 3 inches of bone and clay, as shown in section No. 3 (Pl. XIX). At locality 4, sec. 11, in the same township, 36 inches of coal is exposed. Some coal was also observed in exposures of the Eagle sandstone on Dog Creek near the northwest corner of T. 22 N., R. 17 E.

From the sections given above it seems probable that the Eagle sandstone may contain coal of commercial value in the northern part of the field. As the formation is exposed only in the vicinity of faults, a careful survey on a scale large enough to show all the details of structure is necessary before the probable extent of the coal can be determined.

COAL IN THE JUDITH RIVER FORMATION.

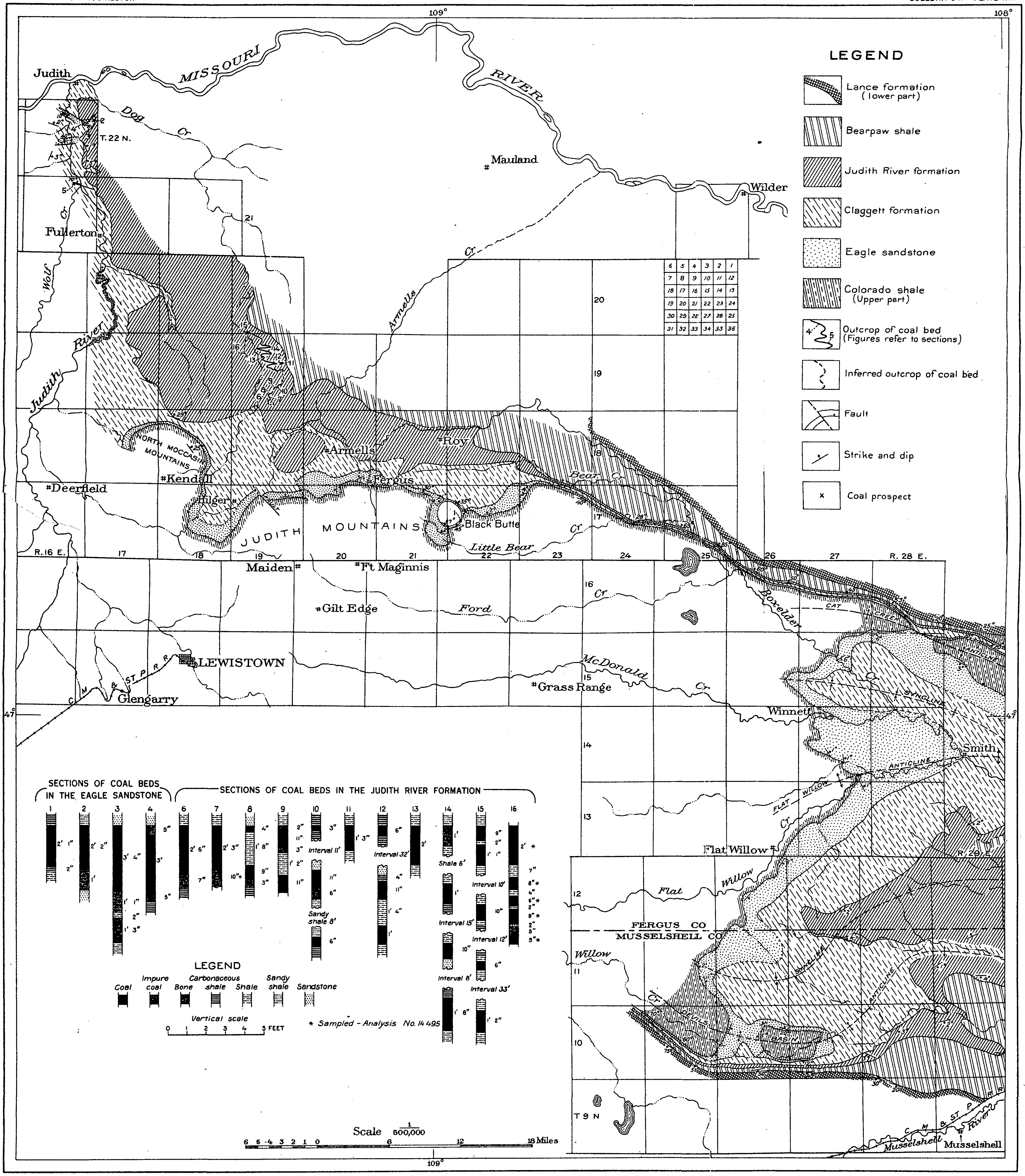
The Judith River formation contains beds of carbonaceous shale throughout the field, but no coal was found south of the southern boundary of T. 19 N.; north of that township line some coal occurs in the Judith River formation, but its full extent is not known. The region in which the Judith River is believed to be coal bearing is the triangular area between Armells and Dog creeks and Missouri River. Coal beds occur near the top of the formation and are said to have a maximum thickness of 7 feet, but in the area described in this report the beds are thin, ranging for the most part from a few inches up to 30 inches in thickness. Sections Nos. 6 to 16 (Pl. XIX) were measured on coal beds in the Judith River formation.

[1] These numbers refer to the locations and the coal sections shown in Pl. XIX.

In T. 19 N., R. 19 E., where a detailed search for coal was made, a zone of clay and carbonaceous shale is exposed containing one or more thin beds of coal, one of which locally attains a thickness of 4 feet. Immediately above these coal beds lies a thick indurated stratum made up almost wholly of invertebrate shells inclosed in a sandy matrix, which serves as an excellent marker in tracing the coal. This *Ostrea subtrigonalis* marl or breccia, as it is commonly called from its abundant content of the shells of that species, was regarded by Stanton and Hatcher as the top of the Judith River formation. The outcrop of the principal coal bed across the township is shown on the map (Pl. XIX), and sections Nos. 6 to 16 on the same plate represent the thickness and character of the beds at the localities indicated. These sections show that the principal bed commonly ranges from 1 foot to 2½ feet in thickness, but that at locality 16 the total thickness is 6 feet. At this locality, however, the bed contains four partings in its lower portion, leaving but 2 feet of unbroken coal at the top of the section. At this place there is a short entry on the bed and a small amount of coal is mined for local use, chiefly as fuel for traction engines. The property is owned and operated by Mr. Stone and is therefore called the Stone prospect.

At the Stone prospect the coal shows the following physical properties: Color black, streak black to brown, fracture conchoidal, a tendency to prismatic jointing, a bedded structure, and a lack of prominent woody characteristics. When exposed to the atmosphere the coal slacks readily and breaks up into small irregular fragments.

A sample of the coal was taken from the face of the entry and sent to the Pittsburgh laboratory of the Bureau of Mines for analysis. In collecting the sample the face of the bed was first freed from all foreign matter and the bed was then trenched across from top to bottom, but the shale partings and bone were excluded from the sample. A section of the bed at the point of sampling is represented by section No. 16 in Plate XIX. The total thickness of the bed at that place is 6 feet, but the sample, which included only the coal, represents a thickness of 4 feet 4 inches. The bed is dry and the face from which the sample was taken was fresh. The results of the analysis are as follows:



GEOLOGIC MAP OF AREA EXAMINED BETWEEN MUSSELSHELL AND JUDITH, MONTANA

By C. F. Bowen

ENGRAVED AND PRINTED BY THE U.S.GEOLOGICAL SURVEY

Analysis of coal from the Stone prospect, sec. 7, T. 19 N., R. 19 E.

[Made at the Pittsburgh laboratory of the Bureau of Mines, A. C. Fieldner, chemist in charge. Laboratory No. 14495. Air-drying loss, 11.1 per cent.]

	As received.	Air dried.	Moisture free.	Moisture and ash free.
Moisture	23.1	13.5		
Volatile matter [a]	33.5	37.7	43.5	52.2
Fixed carbon	30.6	34.4	39.8	47.8
Ash	12.8	14.4	16.7	
Sulphur	1.08	1.22	1.4	1.68
Calories	4,305	4,845	5,600	6,720
British thermal units	7,750	8,720	10,080	12,090

[a] Determined by the modified method, the use of which generally results in a higher percentage of fixed carbon than when determined by the official method.

This analysis shows that the coal is high in moisture and ash and low in calorific value. From its physical and chemical properties, and the fact that it slacks readily when exposed to the atmosphere, the coal is regarded as low-grade subbituminous, which is distinguished from lignite chiefly by its black color.

The coal in the Eagle sandstone may prove to be of importance in localities near Missouri River, where, because of the lack of timber and the distance from the railroad, conditions may favor its development for local use.

The coal in the Judith River formation in this area is not of sufficient importance to justify development on a large scale. Farther north, however, on lower Dog Creek and Missouri River, the beds attain a greater thickness and will no doubt prove valuable, for local consumption at least, in a country where timber and other forms of fuel are practically absent.

THE CLEVELAND COAL FIELD, BLAINE COUNTY, MONTANA.

By C. F. Bowen.

INTRODUCTION.

The writer made an examination in the fall of 1912 of land lying east of the Bearpaw Mountains, Montana, for the purpose of determining whether or not coal is present here, and if so the character of the coal and the thickness of the beds. Only a small area was found to be underlain by coal and the beds are thin and apparently lenticular in character. The coal has little prospective importance except for settlers in the immediate vicinity.

This area, called the Cleveland coal field from the chief town within its borders, comprises an area of about 423 square miles included in Tps. 28 to 31 N., Rs. 20 to 22 E. (in part), and T. 28 N., R. 19 E. of the Montana principal meridian. The northern end of the district is about 6 miles south of Milk River, and the area lies for the most part between the Fort Belknap Indian Reservation on the east and the Bearpaw Mountains on the west. Its relation to other well-known places in Montana is shown in figure 9 (p. 294).

The geologic mapping was done by the writer assisted by Harvey Bassler. The writer wishes to acknowledge the hospitality and hearty cooperation of the residents of the district.

As land classification, which is based on land surveys, was the prime object of the investigation, the Land Office plats were made the bases for geologic mapping. All locations were made with reference to corners established by the land survey. The mapping was done on a plane table, on a scale of 2 inches to the mile. Telescopic alidade and stadia were used in mapping coal beds and open-sight alidade and pacing in meandering geologic boundaries.

The igneous rocks of the Bearpaw Mountains have been briefly described by Weed and Pirsson,[1] and the glacial geology of the region has been discussed by Calhoun.[2] In 1908 and 1909 L. J. Pepperberg[3]

[1] Weed, W. H., and Pirsson, L. V., The Bearpaw Mountains, Mont.: Am. Jour. Sci., 4th ser., vol. 1, pp. 283-301, 351-362, 1896; vol. 2, pp. 136-148, 188-189, 1896.

[2] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, 1906.

[3] Pepperberg, L. J., The Milk River coal field, Mont.: U. S. Geol. Survey Bull. 381, pp. 82-108, 1910; The southern extension of the Milk River coal field, Chouteau County, Mont.: U. S. Geol. Survey Bull. 471, p. 359, 1912.

studied the coal resources of the Milk River field, which adjoins the Cleveland field on the north and exhibits conditions similar to those reported here.

EXPLANATION OF MAP.

The geologic map accompanying this report (Pl. XX, p. 350) was compiled from the plane-table sheets prepared during the field examination and from the General Land Office plats. It shows the distribution and attitude of the geologic formations as interpreted from a study of their widely separated exposures, the outcrops of the principal coal beds, the locations of points at which coal sections were measured, and also the principal roads and streams of the district. In interpreting the geologic map it must be remembered that the greater part of the area is covered by glacial drift, which obscures the outcrops of the rock formations. For this reason the positions of the geologic boundaries are in part hypothetical. The formation boundaries are indicated by broken lines where there is more or less certainty regarding their location and are omitted entirely where their location is largely hypothetical.

GEOGRAPHY.

All parts of the field except the mountain area are readily accessible by wagon roads from the town of Chinook, on the north side of Milk River on the Great Northern Railway.

As the area lies in the western part of the Great Plains province, its surface partakes more or less of the character of a plain, but in this part of the State the surface is broken by several isolated mountain ranges, one of which, the Bearpaw Mountains, lies partly in this area and extends westward for a distance of about 40 miles. In the field three rather distinct types of topography are represented. These are: (1) The mountainous type; (2) the foothills type, lying between the mountains and the lowlands; and (3) the plains type, which varies from a gently rolling, grass-grown, drift-covered plain, still undissected and containing numerous undrained depressions, to a somewhat well dissected and drained surface in which numerous steep, narrow gorges, locally termed coulees, have been eroded. In the northeastern part of the field this topography approaches the badland type, which is typically developed immediately south of the district along Missouri River and its tributaries.

The area is drained by tributaries of Milk and Missouri rivers. The principal streams are Snake, Boxelder, and Peoples creeks on the north and Suction Creek on the south. These streams rise in the Bearpaw Mountains and, with the exception of Boxelder Creek, are perennial within the area surveyed, though some of them may become intermittent farther out on the plains

GEOLOGY.

STRATIGRAPHY.

CHARACTER OF THE ROCKS.

The sedimentary rocks represented in this field range in age from Mississippian to Recent, the latter consisting of the alluvial deposits along stream valleys. Because the coal resources were the primary object of the examination, the field study was confined to the coal-bearing formations, and these are here discussed in more detail than are the other formations present. The table given below shows the stratigraphic succession, character, and thickness of the formations of the district.

Generalized section of the sedimentary formations of the Cleveland coal field.

System.	Series.	Group and formation.		Character.
Quaternary.	Recent.	Alluvium.		Deposits found along the streams; of small extent in this area.
		Bench gravel.		A mixture of gravel and finer material derived from the near-by mountains. The pebbles are mostly igneous rock and are not well rounded or waterworn.
	Pleistocene.	Glacial drift.		Ground and terminal moraines containing numerous bowlders of granite, gneiss, and some quartzite not found in place in this part of the State.
Cretaceous.	Upper Cretaceous.	Montana group.	Bearpaw shale.	Dark-colored marine shale, containing calcareous concretions in which are found *Baculites ovatus*, *B. compressus*, *Scaphites nodosus*, and other Pierre forms; thickness exposed in this field 200± feet.
			Judith River formation.	Brown to light-yellow sandstone alternating with ash-colored clay yielding fresh and brackish water invertebrates and also remains of vertebrates; contains some coal. Thickness 500± feet.
			Claggett formation.	Like the Bearpaw both lithologically and paleontologically. Thickness 350–500 feet.
			Eagle sandstone.	Massive and cross-bedded yellow to brown sandstone, in places containing many large brown concretions; when well exposed forms prominent ledges; in few places contains fossils. Thickness 250–300 feet.
		Colorado shale.		Dark marine shale with intercalated sandy beds in upper part; numerous large calcareous concretions in places near top of formation; yields some invertebrate fossils and locally an abundance of fish scales.
	Lower Cretaceous (?).	Kootenai (?) formation.		Alternating beds of shale and sandstone underlying the Colorado shale and overlying rocks known to be of Jurassic age; no fossils found.
Jurassic.	Upper Jurassic.	Ellis formation.		Dark-gray fine-grained limestone, richly fossiliferous.
Carboniferous.	Mississippian.	Madison (?) limestone.		Gray crystalline limestone, containing numerous fossils; not certainly found in place.

CARBONIFEROUS SYSTEM.

MADISON (?) LIMESTONE.

Stratigraphically the lowest formation exposed in the field is a gray crystalline limestone, which is very different lithologically from any other rocks in the region and which outcrops at the extreme eastern end of the Bearpaw Mountains. Fossils collected from this limestone in secs. 1 and 12, T. 28 N., R. 20 E., have been identified by George H. Girty as Carboniferous forms and tentatively referred by him to the Madison limestone. The specimens obtained from sec. 12 were found in loose fragments along one of the branches of Suction Creek and had evidently been brought down from some higher elevation. The fossils from sec. 1 were obtained at the top of one of the mountain ridges in connection with a collection from the Ellis formation. At the time of making the collection it was not recognized that two formations were involved and the collector is not now sure whether or not all of the specimens were obtained from rock in place. Whether the fossils were actually found in place or not, they demonstrate the existence of Carboniferous rocks in the region, as the Bearpaw Mountains were not overridden by the continental ice sheet, and therefore the fossils could not have been brought to their present position from some extraneous locality except by the agency of man, a contingency which does not seem probable.

Previous to the discovery of these fossils sedimentary rocks older than the Colorado shale had not been recognized in the Bearpaw Mountains, and despite the slight uncertainty as to location and exact age which attaches to them the find is an important one. It may be confidently stated that careful stratigraphic work in the older formations involved in the Bearpaw uplift will differentiate the rocks of Carboniferous age, but at present nothing can be said of their distribution or thickness.

JURASSIC SYSTEM.

ELLIS FORMATION.

The Ellis formation is best exposed on a tributary of Suction Creek, sec. 1, T. 28 N., R. 20 E., 2 or 3 miles above Henry Martin's ranch in sec. 7. At this place there is 200 feet of dark-gray to lead-gray, fine-grained, richly fossiliferous limestone, which is overlain by an apparently conformable succession of alternating beds of calcareous sandstone, sandy shale, and shale having a thickness (if not repeated by faulting) of about 1,300 feet. Fossils were obtained from the limestone and one of the lower beds of calcareous sandstone and submitted to Mr. Stanton, who refers the beds to the Ellis formation. The 1,300 feet of sandstone and shale overlying the fossiliferous limestone are here provisionally referred to the Kootenai, although future work may show them to belong to the Ellis formation. On the west in this locality the Ellis formation is cut off by a sharp fault along which it abuts against younger rocks. How widespread the Ellis formation may be in the Bearpaw Mountains has not been determined, but rocks of similar character were seen at several localities in the eastern end of the range.

CRETACEOUS (?) SYSTEM.

KOOTENAI (?) FORMATION.

The only direct evidence of the presence of the Kootenai, or some other formation occupying the same stratigraphic position, is the existence of a great thickness of dark-gray shales and gray sandstone lying between the undoubted Ellis formation and the Colorado shale. No fossils have been obtained from these beds, so that it is impossible to correlate them on a paleontologic basis. Lithologically the rocks are not similar to the red or maroon-colored members so characteristic of the upper part of the Kootenai in the Lewistown and Great Falls fields, so that if these beds do represent the Kootenai or a part of it they probably correspond to the lower unvariegated portion, although the thickness shown here seems to be much greater than that assigned to the Kootenai by Fisher[1] and Calvert[2] in the fields farther south. Like the Ellis formation, the distribution of these rocks, whatever their age, is undetermined; they were observed at the same localities as the Ellis, which they overlie with apparent conformity.

CRETACEOUS SYSTEM.

COLORADO SHALE.

Above the Kootenai (?) formation lies the Colorado shale, the oldest formation in the field positively identified as Cretaceous. This formation is so well developed on the flanks and in the foothills of the Bearpaw Mountains that the term Bearpaw, if it were not preoccupied, would be an appropriate designation. The term Colorado shale is applied to what in other States is known as the Colorado group, embracing the Benton shale and Niobrara limestone.

The formation is more or less fossiliferous. In some localities a sandstone member 400 feet below the top of the formation contains an abundance of fish scales and some invertebrates. Fossils collected from it have been identified as of Colorado age by Mr. T. W. Stanton.

The Colorado shale is a black to lead-gray clay shale, containing in its upper part, at least locally, many large calcareous concretions. These concretions weather yellowish brown and carry numerous veins of calcite, which give a septarian-like character to the entire mass.

[1] Fisher, C. A., Geology of the Great Falls coal field, Mont.: U. S. Geol. Survey Bull. 356, p. 30, 1909.
[2] Calvert, W. R., Geology of the Lewistown coal field, Mont.: U. S. Geol. Survey Bull. 390, p. 27. 1909.

This part of the formation resembles very closely the shales of the Claggett formation. Below the concretionary member the formation contains numerous thin sandstone bands alternating with the black shale. Some of these sandstone members are fossiliferous, the most abundant remains being fish scales.

The thickness of the entire formation was not determined. A thickness of about 525 feet is exposed around Eagle Butte, in sec. 6, T. 29 N., R. 21 E., but it is probable that only a part of the formation is exposed. Near Henry Martin's ranch, in sec. 7, T. 28 N., R. 21 E., a thickness of more than 1,400 feet of black shale overlies the rocks described above as the Kootenai (?) formation. Whether this is the true stratigraphic thickness of the Colorado or whether the formation is repeated by faulting is not known.

The Colorado shale is extensively developed around the east end of the Bearpaw Mountains, and is by far the most widespread of the pre-Montana rocks. Perhaps the type locality for the formation in this field is the undifferentiated area lying south and southeast of Cleveland.

The Colorado shale exhibits apparently conformable relations both at top and bottom. It is sharply delimited from the overlying Eagle sandstone by the striking lithologic difference between the two formations. The change to the underlying formation is not well shown in the localities where the two were studied, but it seems to be less abrupt lithologically than is the change to the overlying formation.

EAGLE SANDSTONE.

Above the Colorado shale in apparent conformity lies the Eagle sandstone, so named by Weed[1] from its development at the mouth of Eagle Creek on Missouri River, about 40 miles below Fort Benton. This sandstone, according to Stanton and Hatcher,[2] represents the lower part of the Montana group. All the fossils collected from it by the writer have been reported by Stanton to be of Montana age.

In this field the formation consists of buff to gray, massive to heavy-bedded sandstone, which is locally cross-bedded and becomes more thinly bedded toward the top. Large reddish-brown sandstone concretions are locally very numerous and form conspicuous bowlders which strew the surface of the weathered outcrop. Where not covered by drift the sandstone forms prominent ledges, which constitute a striking topographic feature.

Few places in this area afford favorable opportunities for measuring the thickness of the formation, but in the NE. ¼ sec. 18, T. 29 N., R. 21 E., both upper and lower boundaries are well shown in a clean-cut exposure; the thickness at this locality is 310 feet.

[1] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton folio (No. 55), 1899.

[2] Stanton, T. W., and Hatcher, J. B., The geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, pp. 63, 66, 1905.

The Eagle is well exposed only locally in this district. As a rule the outcrop is concealed beneath drift or gravels or is interrupted by igneous intrusions, so that the actual surface distribution of the formation is difficult to determine. In a general way it occupies a narrow zone encircling the Bearpaw Mountains in the region where the foothills merge into the plains.

The Eagle is the lowest formation of the Montana group and is conformable with both subjacent and superjacent formations. It forms a striking lithologic contrast to them, however, and is easily distinguishable in the field.

CLAGGETT FORMATION.

Above the Eagle sandstone lies a formation consisting chiefly of dark marine shale which Stanton and Hatcher[1] designated the Claggett formation and correlated with the lower part of the Pierre shale. This formation contains *Baculites ovatus*, *Baculites compressus*, *Inoceramus barabini*, *Gervillia borealis*, and other forms characteristic of the Pierre shale.

The Claggett in this area consists of dark lead-gray shale, containing numerous calcareous concretions which range up to several feet in diameter. The concretions are usually seamed with veins of calcite and as a rule contain invertebrate fossils. At the base of the formation there is a zone of sandy shale transitional to the Eagle sandstone below, and at the top there is a similar narrow transition zone. Crystals of gypsum are locally abundant in the Claggett and are conspicuous on many weathered outcrops. The shale weathers to a black gumbo soil that becomes very tenacious when wet. The formation is not well exposed in the field and no opportunity was afforded for determining accurately its thickness. Farther south, along Missouri River, it is about 500 feet thick, whereas to the north, on Milk River, Pepperberg determined it to be 350 feet thick.

Except locally, the Claggett is even less well exposed than the Eagle and its surface distribution is correspondingly more uncertain. On the accompanying map (Pl. XX, p. 350) the inferred distribution of the formation is shown, but this is of course largely hypothetical.

The Claggett overlies the Eagle sandstone conformably, and by reason of its shaly character, its dark color, and the presence of limestone concretions presents a sharp lithologic contrast to the latter. The exact line of demarcation between these formations, however, and also between the Claggett and the overlying Judith River is in some places difficult to determine, owing to the sandy transition zones mentioned above.

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[1] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds, with a chapter on the fossil plants by F. H. Knowlton: Bull. U. S. Geol. Survey 257, pp. 13, 66, 1905.

JUDITH RIVER FORMATION.

The Judith River formation, which overlies the marine Claggett, is for the most part of fresh or brackish water origin. This formation was first named by Hayden,[1] although its stratigraphic relation was at that time not understood. Stanton and Hatcher in their work on the Judith River formation[2] determined it to be a subdivision of the Montana group, and the stratigraphic equivalent of a part of the Pierre shale. This conclusion was borne out by the work of the writer in this area.

The Judith River formation comprises a series of fresh and brackish water beds, consisting of light-colored alternating sandstone and clay with some coal, the most persistent and important beds of which occur near the top of the formation. The sandstones are in places cross-bedded and ripple marked and contain ferruginous and sandy calcareous concretions, many of which are seamed with veins of amber-colored calcite and bear a general resemblance to the concretions found in the Claggett. Crystals of selenite occur to some extent in the darker-colored clay of the formation. Near the top of the formation occurs a rather persistent bed of marl composed almost entirely of shells of *Ostrea subtrigonalis*. The thickness and character of individual beds vary considerably within short horizontal distances, sandstone changing to clay, and coal to carbonaceous shale, and vice versa. It is therefore impossible to select any key rocks which can be used to correlate sections measured at separate localities. The best reference stratum is the Ostrea-bearing marl or breccia bed near the top of the formation. The following detailed sections measured at various localities serve to show the character and variability of the beds:

Section of Judith River formation one-half mile north of Kerr mine on Sixmile Coulee, sec. 30, T. 32 N., R. 20 E.

	Ft.	in.
Concretionary band		6
Clay shale	10	
Shale, brown, carbonaceous	2	
Shale, gray, sandy	1	6
Concretionary band		4
Shale, sandy	1	6
Shale, brown, carbonaceous	2	
Coal, bony, and bone	1	
Coal, good	2	
Shale, carbonaceous	2	
Shale, gray, sandy	5	
Shale, carbonaceous	1	

[1] Hayden, F. V., Geology of the Missouri Valley: U. S. Geol. Survey of Wyoming and portions of contiguous Territories; Preliminary (second) Rept. Progress, p. 97, 1872.

[2] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds, with a chapter on fossil plants by F. H. Knowlton: Bull. U. S. Geol. Survey 257, p. 63, 1905.

	Ft.	in.
Shale, somewhat sandy	2	
Sand, gray, with 6-inch concretionary band	4	
Clay shale, gray	10	
Shale, brown, carbonaceous		5
Coal, bony		7
Shale, carbonaceous	1	2
Clay shale, drab	5	6
Ironstone, concretionary band		3
Shale, gray	3	
Coal		5
Bone		9
Shale, carbonaceous		5
Coal		11
Bone		2
Coal		2
Bone		4
Shale, carbonaceous		11
Clay, dark gray	1	8
Clay, carbonaceous		8
Sandstone, gray		5
Clay with iron concretions	1	
Clay, gray, sandy	3	
Bone and bony coal		6
Shale, carbonaceous	2	8
Coal, bony		9
Bone		2
Clay	1	6
Shale, carbonaceous		5
Coal		9
Coal, bony		4
Coal		6
Bone and carbonaceous shale		10
Shale	2	
Sand, argillaceous	2	
Concealed, probably sand	4	
Sand and sandstone	2	
Concealed by alluvium	10	
Concretionary layer	1	
	96	

Section of Judith River formation at Rattlesnake Butte, sec. 12, T. 28 N., R. 21 E.

	Ft.	in.
Sandstone, cross-bedded	2	
Clay shale with sandy layers	18	
Sandstone, yellow, massive, cross-bedded, with small ferruginous concretions at base	15	
Clay, in part arenaceous	43	
Sandstone, massive, cross-bedded	8	
Clay, sandy	20	
Sandstone, shaly	7	
Sandstone, yellow, cross-bedded	5	
Sandstone, yellow, massive	15	
Sandstone, thin bedded, and shale	8	

	Ft.	in.
Shale	8	
Sandstone, yellow, cross-bedded, weathers cavernous	15	
Clay, sandy	8	
Sandstone, massive, cross-bedded	2	
Clay	2	
Sandstone, massive	2	
Shale, sandy	2	
Shale, carbonaceous at bottom, grading upward into clay	6	
Sandstone, white, bedded, beds usually less than 1 foot thick, weathers to rough, irregular forms	18	
Sandstone, white to cream colored, massive to heavy-bedded	15	
Sandstone, yellow, massive, with concretionary layers	16	
Sandstone, platy, and clay (partly concealed)	32	
Sandstone, yellow, massive	9	
Sandstone, gray, hard		6
Clay	2	
	278	6

Section of Judith River formation near south quarter corner sec. 31, T. 28 N., R. 22 E.

	Feet.
Drift.	
Clay shale, dark, gypsiferous, containing narrow band of *Ostrea subtrigonalis* at base	50
Clay, sandy	5
Shale, brown, carbonaceous	4
Clay shale, drab	10
Sand, unconsolidated	15
Shale, carbonaceous	1
Sand	5 (?)
Clay, drab, contains ferruginous concretions and *Ostrea subtrigonalis*, grades into sandy clay below	40
Sandstone, white, with ferruginous members and concretions forming ledges, exposed	60
	190

A complete section of the formation is not exposed at any locality in this district and the total thickness could not be determined. On Missouri and Milk rivers, where the exposures are better, the formation is about 500 feet thick.

The surface distribution of the Judith River formation is probably greater than that of all the other sedimentary rocks in the field combined. This is due to its flat-lying attitude and to the fact that erosion has removed the overlying Bearpaw shale from most of the area but has not yet cut through the Judith River to the underlying formations. Over much of the area these beds are covered by glacial drift and the boundaries of the formation as shown on the map (Pl. XX, p. 350) are more or less hypothetical.

The Judith River formation is conformable with both the underlying and overlying formations. The beds grade into the underlying Claggett through a narrow transition zone at the top of that formation, but are more or less sharply separated lithologically from the dark marine shale of the overlying Bearpaw.

BEARPAW SHALE.

The Bearpaw shale was so named by Stanton and Hatcher[1] from the supposed extent of its outcrop around the Bearpaw Mountains. The Bearpaw shale, in common with the Claggett formation, contains a fauna which elsewhere is regarded as typical of the Pierre. The Bearpaw is therefore the equivalent of the upper part of the Pierre and in areas to the southeast is directly overlain by the Lance formation.

The Bearpaw is a lead-colored marine shale, bearing calcareous concretions which yield most of the fossils so far found. In both lithologic and paleontologic character the Bearpaw is so similar to the Claggett that the two can not be definitely distinguished except by their stratigraphic relations. As only a part of the formation is exposed in this field, its thickness was not determined, but in other localities it is known to be 1,000 to 1,100 feet.

Exposures of this formation are confined to a small area in the northwest corner of T. 30 N., R. 22 E., and to the contiguous portions of adjoining townships, but because of the heavy covering of drift over the greater part of the field exposures are poor and it may be that the Bearpaw occurs beneath the drift at other localities.

The Bearpaw conformably overlies the Judith River formation, from which it is distinguished by its lithologic character, its color, and the marine fossils which it contains.

QUATERNARY SYSTEM.

Glacial drift.—Most of the plains area is covered with glacial deposits, which, except where locally removed along drainage lines, obscure all of the older rocks. These deposits consist of an unassorted mixture of bowlders and finer material. The most common bowlders are of granite, gneiss, and quartzite, which have been transported from localities far to the north in Canada, where similar rocks are found in place. The deposits are terminal and ground moraines. The best example of the terminal moraine is the ridge north of Peoples Creek.

Bench gravel.—Near the Bearpaw Mountains areas which are not drift covered are as a rule overspread by bench gravel derived chiefly from the igneous rocks of the near-by mountains. In general, this bench gravel obscures the outcrops of the older formations almost as completely as does the drift.

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[1] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds, with a chapter on the fossil plants by F. H. Knowlton: U. S. Geol. Survey Bull. 257, p. 62, 1905.

Alluvium.—Alluvial deposits are of minor importance. They occur in narrow belts along the most important streams, especially Suction, Peoples, and Snake creeks.

IGNEOUS ROCKS.

The Bearpaw Mountains consist of igneous rocks of intrusive and extrusive origin and of both acidic and basic character. Dikes and sills of these rocks, radiating from the main mountain mass, outcrop in places at a considerable distance from the mountains. These dikes and sills have had little effect on the inclosing strata, which as a rule are but slightly metamorphosed and have suffered no displacement by the intrusion.

STRUCTURE.

On all sides of the Bearpaw Mountains the strata dip steeply away from the central igneous mass. A short distance away from the mountains, however, the dips are much lower and out on the plain the rocks lie nearly flat. Because of the general covering of glacial drift and alluvium, however, continuous exposures of the underlying formations are lacking and the structure is extremely obscure and difficult to interpret. Except locally, where the drift cover is very thin, exposures of sedimentary rocks are confined to coulees, in which the glacial material has been removed. These exposures show that the original attitude of the rocks has been locally very much disturbed by faulting, but because the stratified rocks are covered by drift the faults are commonly not exposed at the surface. The evidence, moreover, is in general limited merely to a marked change in the dip or strike of the formation at two near-by localities. The locations of a few of the most obvious faults are shown on the map. Suggestions of other fault lines are numerous and it is probable that still others are entirely obscured by the surface covering.

THE COAL.

OCCURRENCE AND DISTRIBUTION.

Coal beds occur in this district only in the upper part of the Judith River formation, none having been found in the Eagle sandstone. In the northeastern part of the area the coal beds are from 15 to about 100 feet below the top of the Judith River, but elsewhere the top of this formation is not exposed and the stratigraphic position of the coal within it has not been definitely established. Because the surface is covered and there are few mines and prospects, coal outcrops can not be traced for any considerable distance. So far as known no coal occurs south of Peoples Creek except near the southwest corner of the field.

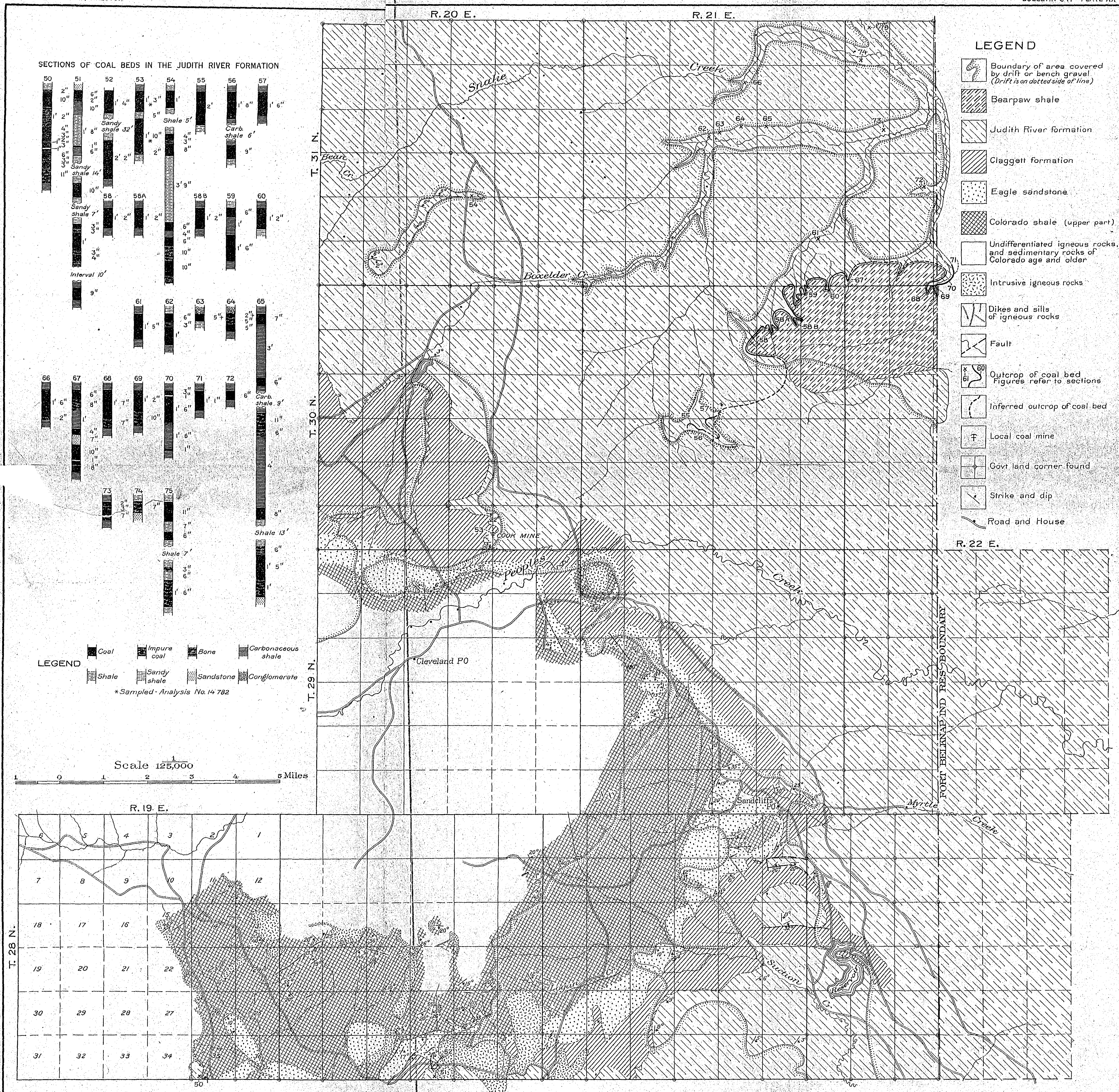
By reference to the graphic sections[1] (Pl. XX) it will be seen that with few exceptions the coal beds where exposed are less than 2 feet thick and that a majority of the outcrops show less than 1 foot 6 inches of coal. Furthermore, where the beds have a thickness of more than 2 feet, partings and impurities detract from the value of the coal.

The Cook mine, at locality 53, T. 30 N., R. 20 E., is the only mine in the field. The bed at this place, represented by section No. 53 (see Pl. XX), contains a total thickness of 3 feet 3 inches of coal, separated into two benches, however, by a shale parting about 5 inches thick. The coal is fairly clean but slacks readily on exposure to the atmosphere. No other outcrops of this coal bed could be found and its extent is not known. It is probably small, however, as the bed appears to be included in a downthrown fault block and is therefore cut off at either end by faults. At the mine the beds dip rather steeply to the south, whereas at only short distances both north and south of the mine the normal dip of the strata is to the north.

In the southwestern part of the field several isolated outcrops of coal were examined, but the beds could not be traced for any distance. The character and thickness of these beds are shown in sections 50 to 52 on Plate XX. In the northeastern part of the field a coal bed whose outcrop is traceable for about 5 miles is exposed and this bed was mapped from sec. 11, T. 30 N., R. 21 E., to the east side of the area. This bed is from 1 foot 2 inches to 1 foot 6 inches thick at localities 58 to 60. At locality 67, where a few ranchers obtain their fuel supply from a surface prospect on this bed, the coal is 1 foot 6 inches thick and has an inch parting near the middle. Above it occur two other thin beds which are 4 and 6 inches thick, respectively. Two miles east of locality 67, sections Nos. 68 to 71 (Pl. XX) were measured on the same bed. At localities 68 and 69 the bed is thicker than at any of the other places at which it was measured. At each of these localities, however, the lower part of the bed is bony and of little value as fuel. In secs. 16 and 21, T. 30 N., R. 21 E., a bed outcrops at about the same horizon and is believed to be the same bed. As shown in coal sections 55 to 57 this bed ranges in thickness from 1 foot 6 inches to 2 feet and consists of clean coal unbroken by partings.

In T. 31 N., Rs. 21 and 22 E., thin beds of coal are exposed at several places on Snake and Boxelder creeks and their tributaries. Sections Nos. 61 to 66 and 72 to 75, measured at the places indicated on Plate XX, show the thickness of the coal at these localities, but the beds can not be traced or correlated. At locality 62 a bed 1 foot 9 inches thick is exposed but is separated into two benches by 3

[1] The numbers used to designate the coal sections correspond with the location numbers on the map (Pl. XX). The first number used is 50 and the last is 75.



GEOLOGIC MAP OF CLEVELAND COAL FIELD, BLAINE COUNTY, MONTANA

By C. F. Bowen

inches of bone, which occurs 6 inches below the top of the bed. The thickness of the lowest bed shown in the section at locality 65 was 2 feet 11 inches, but 6 inches in the upper part and 12 inches in the lower part contain too much shale and bone to be of any value as a fuel, leaving but 1 foot 5 inches of good coal. In the same section four other beds of coal are exposed at higher horizons. Three of these beds are each less than 10 inches thick and the other one consists of 6 inches of bone and 11 inches of impure coal. At locality 66 a coal bed 1 foot 6 inches thick is exposed. At locality 75 there is exposed a bed of very impure coal which is 1 foot 6 inches thick. Above it are two other beds, one of which is 6 inches thick and the other 11 inches. At each of the other exposures in this part of the field the coal is less than 1 foot thick. As the surface in this part of the field is generally covered with drift the coal beds can not be traced and therefore their outcrop is not shown on the map. A surface prospect in T. 31 N., R. 20 E., near the south side of sec. 22 has supplied fuel for settlers for two or three years. This bed is exposed at locality 54, which is at the east end of a prominent ridge forming the divide between Boxelder and Snake creeks. As shown in section No. 54 three beds of coal are exposed here, separated from each other by several feet of shale. The two upper beds are thin and have not been worked. Most of the fuel obtained from the prospect was taken from the lower bed. At the time of the writer's visit the prospect had been abandoned because of the great amount of bone present and the poor quality of the coal. There are no other exposures of this bed and its extent could not be determined. The coal so far as could be ascertained by the writer is very pockety in character and does not give promise of furnishing a good grade of fuel.

In this field the coal differs considerably in thickness and purity at the localities where it is exposed, but as a rule the beds can not be traced laterally and nothing is known of their thickness or of the quality of the coal between the points of exposure. Immediately north of the field along Milk River, where exposures are more numerous because of greater postglacial erosion, Pepperberg [1] found that the coal beds are lenticular in character and range in thickness "from a fraction of an inch to 9 feet at different points on the outcrop."

PROPERTIES OF THE COAL.

Accurate determination of the properties of the coal in this district was difficult, owing to the fact that for the most part only weathered coal could be obtained. At the Cook mine, however, fresh coal was available and at this and other localities where the coal seemed least altered the following properties were observed: The coal is black to

[1] Pepperberg, L. J., The Milk River coal field, Mont.: U. S. Geol. Survey Bull. 381, p. 88, 1910.

brownish black but becomes brown on weathering, streak brown, luster bright to dull, fracture irregular, texture dense, coherence tough to brittle. In places the coal shows a tendency to prismatic jointing. The observed impurities consist of flakes of selenite in crevices and seams and a brownish coating of an undetermined substance on weathered surfaces.

One sample for analysis was taken from the Cook mine, the only working mine in the field. In taking the sample the face of the bed was first freed from all impurities and the bed was then trenched across from top to bottom. The thickness and character of the bed at the point of sampling is indicated by section No. 53 (Pl. XX). At that place the bed has a total thickness of 3 feet 8 inches, but the sample, from which the shale and bone were excluded, represents a thickness of only 3 feet 1 inch. The sample was taken from a freshly broken face at the end of the mine workings, which consist of a devious entry about 500 feet long having a general southward course. At the point of sampling the bed is about 65 feet below the surface. The analysis (No. 14782) is presented below together with representative analyses of samples from the Milk River, Big Sandy, and Great Falls coal fields.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the sample as it comes from the mine. This form is not well suited for comparison because the amount of moisture in coal as it comes from the mine is largely a matter of accident and may vary widely. Analysis B represents the sample after it has been dried at a temperature of 30° to 35° C. until its weight becomes constant. This form of analysis is best adapted to general purposes of comparison. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated, and analysis D its composition after all moisture and ash have been theoretically removed. This is supposed to represent the true coal substance free from the most significant impurities. Forms C and D, which represent conditions that do not actually exist, are derived from the others by recalculation.

In making these analyses the volatile matter in analyses 14782, 9150, 6318, 6380, and 14613 was determined by the modified method, whereas in the other analyses the volatile matter was determined by the official method. The difference between these two methods lies in the fact that in determining the volatile matter by the modified method the sample is first given a preliminary heating of 4 minutes over a small flame and a final heating of 7 minutes over a flame 20 centimeters high, whereas in the official method the preliminary heating is omitted. This preliminary heating allows the moisture to escape slowly and thus prevents the sputtering which occurs when coal that is high in moisture is placed directly over a hot flame. The mechanical loss due to such sputtering, though almost negligible in bituminous coal, may amount to as much as 25 per cent in some lignite. With lignite the modified method, by reducing the mechanical loss caused by sputtering, has the effect of decreasing the percentage of volatile matter and increasing the percentage of fixed carbon. It is now customary to use this method in determining the volatile matter in lignite, subbituminous coal, and all other coal which has a moisture content of more than 10 per cent.

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Analyses of coal samples from the Cleveland and adjacent coal fields.

[Made at the Pittsburgh laboratory of the Bureau of Mines, F. M. Stanton and A. C. Fieldner, chemists in charge.]

Laboratory No.	Locality.	Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
		Quarter.	Sec.	T. N.	R. E.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
	CLEVELAND FIELD.																	
14782	Cook mine	SW	35	30	20	7.1	A	18.8	31.5	40.4	9.3	0.73					5,075	9,140
							B	12.5	33.9	43.5	10.1	.79					5,465	9,830
							C		38.8	49.7	11.5	.90					6,250	11,250
							D		43.8	56.2		1.02					7,060	12,710
	MILK RIVER FIELD.																	
9150	Chinook district, Roder prospect.	NW	5	31	19	14.7	A	21.4	28.0	41.6	8.99	.58	5.84	51.96	1.22	31.41	4,965	8,940
							B	7.9	32.8	48.8	10.54	.68	4.94	60.91	1.43	21.50	5,820	10,480
							C		35.7	52.9	11.44	.74	4.40	66.11	1.55	15.76	6,315	11,370
							D		40.2	59.8		.84	4.97	74.65	1.75	17.79	7,135	12,840
6318	Tumbler mine	NW	32	32	19	11.8	A	21.5	26.6	41.1	10.83	.64	5.73	50.43	1.09	31.28	4,810	8,650
							B	10.9	30.2	46.6	12.28	.72	5.01	57.18	1.24	23.57	5,450	9,820
							C		33.8	52.4	13.79	.81	4.26	64.19	1.39	15.56	6,120	11,020
							D		39.3	60.7		.94	4.94	74.45	1.61	18.06	7,100	12,780
6380	Matheson mine	SW	10	33	20	14.9	A	23.3	29.9	33.1	13.74	.72	5.80	44.90	.89	33.95	4,330	7,800
							B	9.9	35.1	38.9	16.15	.85	4.86	52.76	1.05	24.33	5,090	9,160
							C		38.9	43.2	17.91	.94	4.18	58.52	1.16	17.29	5,645	10,160
							D		47.4	52.6		1.15	5.09	71.29	1.41	21.06	6,880	12,380
6479	Havre Fuel Co. mine	NW	31	33	16	15.5	A	22.0	23.8	43.9	10.34	.60	5.67	47.98	.99	34.42	4,565	8,210
							B	7.6	28.2	52.0	12.24	.71	4.67	56.78	1.17	24.43	5,400	9,720
							C		30.5	56.3	13.25	.77	4.14	61.48	1.27	19.09	5,845	10,530
							D		35.2	64.8		.89	4.77	70.88	1.46	22.00	6,740	12,130
	BIG SANDY FIELD.																	
14613	Mackton mine	SW	18	28	14	1.8	A	13.0	36.3	40.1	10.6	.53					5,340	9,620
							B	11.4	37.0	40.8	10.8	.54					5,440	9,790
							C		41.7	46.1	12.2	.61					6,140	11,060
							D		47.5	52.5		.69					6,995	12,590
	GREAT FALLS FIELD.																	
4119	Gerber mine at Sand Coulee.	NE	23	19	4	2.6	A	7.5	27.3	51.4	13.78	2.32	4.68	62.21	.88	16.13	6,115	11,010
							B	5.0	28.1	52.8	14.15	2.38	4.51	63.87	.90	14.19	6,280	11,300
							C		29.5	55.6	14.90	2.51	4.16	67.25	.95	10.23	6,610	11,900
							D		34.7	65.3		2.95	4.89	79.02	1.12	12.02	7,765	13,980

A comparison of the results of the analyses given in the above table shows that there are no essential differences between the coal of the Cleveland field and that of the Milk River field.

As compared with the coal of the Big Sandy field, the coal of the Cleveland field is considerably higher in moisture, slightly higher in fixed carbon and in heating value, and somewhat lower in volatile matter and ash. The essential difference between the coal from these two fields lies in the greater amount of moisture contained in the Cleveland coal. Because of this the coal slacks much more readily when exposed to weathering.

The coal of the Cleveland field is very much higher in moisture, somewhat higher in volatile matter, and considerably lower in fixed carbon, ash, and heating value than the coal of the Great Falls field. The Cleveland coal is therefore inferior in quality to the coal of the Great Falls field.

The coal of the Cleveland field contains a high percentage of moisture. When it is exposed to the atmosphere the moisture evaporates, and as a result the coal cracks badly and finally crumbles to pieces. This property of the Cleveland coal separates it from the bituminous coal of the Great Falls field and all other high-grade coals. On the other hand, its black color and lack of woody structure separate it from lignite. The coal of the Cleveland field belongs, therefore, to the subbituminous class.

DEVELOPMENT.

The one mine in the Cleveland field is the Cook mine, situated near the west quarter corner of sec. 35, T. 30 N., R. 20 E. It is operated during the winter season and has an output of about 600 tons a year. At this place the bed has a total thickness of 44 inches, of which 37 inches is coal. There is evidence of structural disturbance in this vicinity, for the beds at the mine dip rather steeply to the south, whereas the normal direction of dip, both north and south of the mine, is to the north. It is probable, therefore, that the Cook coal occurs in a downfaulted block and that the bed is of small horizontal extent.

A surface prospect near the south side of sec. 22, T. 31 N., R. 20 E. (location 54), has supplied coal to settlers for two or three seasons, but has been practically abandoned because the coal is impure and difficult to obtain.

The thinness of the beds and the impurity of much of the coal in this area, together with the occurrence of coal of better quality on Milk River immediately north of this district, render it probable that there will be little or no systematic development of the coal beds of this field.

THE BIG SANDY COAL FIELD, CHOUTEAU COUNTY, MONTANA.

By C. F. Bowen

INTRODUCTION.

The Big Sandy field as here defined comprises an area of about 345 square miles included in Tps. 25 to 28 N., Rs. 13 and 14 E., and Tps. 25 and 26 N., R. 15 E. of the Montana principal meridian. It lies in north-central Montana, north of Missouri River and for the most part west of the Bearpaw Mountains. Its location is shown on the index map, figure 9 (p. 294).

In the Big Sandy field coal occurs in the Eagle sandstone and Judith River formation of Cretaceous age and the Fort Union formation of Tertiary age. The importance of the field as a coal producer is almost entirely dependent on the extent of the Fort Union coal. These beds occupy a small area in the vicinity of the Mackton mine, about 6½ miles northeast of Big Sandy. The areal extent of the coal, though not accurately known, is probably small. At the present time no beds of commercial value are known to occur outside of sec. 18, T. 28 N., R. 14 E. The coal in the Eagle sandstone and Judith River formation occurs in the southern part of the field. These coal beds are too thin and irregular in character to be of present commercial importance.

During a part of the field season of 1912 this area was examined to obtain data for the classification and valuation of the land with respect to its coal content. In this report, the general geology of the field, the character of the coal, and the distribution of the coal beds, so far as could be ascertained, are set forth.

The stratigraphy of the southwestern part of the area has been described by Weed[1] and the glacial geology by Calhoun.[2] The coal resources have been briefly discussed by L. J. Pepperberg, who visited the Mackton coal mine in 1908 and made a brief examination of mines and prospects in the vicinity.[3]

The geologic mapping upon which the present paper is based was done by Harvey Bassler and the writer, assisted by T. K. Harns-

[1] Weed, W. H., U. S. Geol. Survey Geol. Atlas, Fort Benton folio (No. 55), 1899.
[2] Calhoun, F. H. H., The Montana lobe of the Keewatin ice sheet: U. S. Geol. Survey Prof. Paper 50, 1906.
[3] U. S. Geol. Survey Bull. 381, pp. 102–103, 1910.

berger and J. R. Jaquet, who, although engaged as camp hands, rendered considerable scientific assistance. The writer acknowledges his indebtedness to the residents of the district for their generous hospitality, and is especially obligated to Messrs. Paul H. Schwartz, president of the Mackton Mine Co., and John Pearson, foreman of the mine, for much valuable information regarding the geology in the vicinity of their property.

As land classification was the prime object of the investigation, the General Land Office plats were made the base for geologic mapping, and all locations were made with reference to the established land corners. The work was done on a 15-inch plane table on a scale of 2 inches to the mile, using telescopic alidade and stadia for tracing coal beds and open-sight alidade and pacing for meandering geologic boundaries.

The accompanying map (Pl. XXI, p. 372) was compiled from the field sheets made in the course of the writer's examination and also from the General Land Office plats, from which most of the drainage and roads were taken. The map presents the distribution and attitude of the geologic formations as interpreted from a study of the scanty exposures, the outcrops of the principal coal beds, the locations of measured coal sections, and also the principal roads and streams of the district. The greater part of the area is covered by glacial drift, which obscures the outcrops of the older formations and renders both the geologic structure and the positions of the formation boundaries uncertain; in many places, therefore, the distribution of the formations shown on the map is partly hypothetical. The boundaries are indicated by solid lines where there is reasonable certainty regarding their location and by broken lines where there is less certainty; where their location is entirely hypothetical they are omitted. In the northern part of the field, in the vicinity of the Mackton mine, the drift covering is so nearly universal, and the structure of the older rocks where they are exposed is so complicated, that it was not possible to determine the extent of the coal-bearing formation; therefore, on that part of the map only the drift is shown.

The Montana Central division of the Great Northern Railway, extending from Great Falls to Havre, crosses the extreme northwestern corner of this field. All parts of the area are accessible by wagon roads from the railroad town of Big Sandy. Because of the somewhat rugged character of a portion of the area the roads in general follow the crests of ridges.

At present the area is very sparsely settled. Big Sandy, which has a population of about 250, is the only town and is the distributing center for a large extent of country. Considerable stimulus has recently been given to the acquisition and settlement of lands in this part of the State by the method of raising crops without irrigation, known as "dry farming." Farming and stock raising are the principal industries.

TOPOGRAPHY.

This coal field lies in the Great Plains province, which extends from the Rocky Mountain front eastward. In this part of Montana the plains are broken by numerous isolated mountain ranges, one of which, the Bearpaw Mountains, lies partly within the Big Sandy field and extends eastward for a distance of about 40 miles. The remainder of the field is an elevated, somewhat dissected plain. Locally badlands are developed, being especially prominent along Missouri River in the southwestern part of the area. There the river is bordered by vertical sandstone cliffs 75 to 100 feet high known as the "stone walls," which are sculptured by weathering into many curious and picturesque forms. Another modification of the prevailing type of topography occurs in the northwestern part, where a broad, flat alluvial valley, the preglacial channel of Missouri River,[1] forms a marked contrast with the other topographic features.

The area is drained by branches of Missouri River. Most of the streams are small and enter that river directly, but some of them flow into Milk River, which joins the Missouri about 160 miles farther east. The more important tributaries of Missouri River are Eagle Creek, Sheep Coulee, Alkali Coulee, and Little Sandy Creek; those of Milk River are Big Sandy and Gorman creeks. There is an interesting adjustment of drainage in the western part of the area, where Big Sandy and Little Sandy creeks are diverted almost at right angles from their westward courses. Big Sandy Creek on entering the abandoned channel of Missouri River follows it northward to Milk River, whereas Little Sandy Creek on entering this same channel turns toward the south just west of the area mapped and flows to the present channel of the Missouri. In this old channel the divide separating Big and Little Sandy creeks is so low that it is scarcely perceptible to the eye, but according to Calhoun[1] it is formed by a terminal moraine that marks the southernmost extent of the last advance of the ice sheet.

GEOLOGY.

STRATIGRAPHY.

OCCURRENCE AND CHARACTER OF THE ROCKS.

The sedimentary rocks exposed in the Big Sandy field consist of beds of sandstone, shale, and clay of Upper Cretaceous and Tertiary ages and deposits of glacial drift and alluvium of Quaternary age.

[1] Calhoun, F. H. H., op. cit.

Inasmuch as the coal, with which this report is primarily concerned, occurs in the Montana group of the Cretaceous and in the overlying Fort Union formation, the field study was confined chiefly to these formations and they are discussed in more detail than are those that contain no coal. These rocks have been previously studied in adjacent areas in Montana by Weed [1] and by Stanton and Hatcher,[2] who have subdivided them into groups and formations and determined their geologic ages. The following table shows the stratigraphic succession, character, and thickness of the formations in the Big Sandy field:

Generalized section of the sedimentary rocks of the field.

System and series.	Group and formation.		Thickness.	Character.
Quaternary.	Alluvium.		*Feet.* 0-20±	
	Bench gravel.		0-10±	A mixture of gravel and finer material derived from the near-by mountains.
	Glacial drift.		0-50±	Contains numerous bowlders of granite, gneiss, and quartzite; a loess-like material containing a few waterworn pebbles caps the bluffs along Missouri River and its tributaries.
Tertiary (Eocene).	Fort Union formation.		700±	A lower massive sandstone, overlain by thin sandstone beds, alternating with clay shale; contains the best coal in the field.
Cretaceous (Upper Cretaceous).	Montana group.	Bearpaw shale.	(a)	Dark-colored marine shale, containing calcareous concretions in which are found *Baculites ovatus*, *B. compressus*, *Scaphites nodosus*, and other Pierre forms.
		Judith River formation.	500±	Brown to light-yellow sandstone and ash-colored clay and shale, containing fresh and brackish water invertebrates; also remains of vertebrates; contains thin beds of low-grade coal.
		Claggett formation.	350-500	Like the Bearpaw both lithologically and paleontologically.
		Eagle sandstone.	250-300	Thin-bedded to shaly sandstone, some massive to heavy-bedded white to buff sandstone, drab to light-colored clay and shale, some of which is carbonaceous and contains thin beds of low-grade coal.
	Colorado shale.		(a)	Dark marine shale alternating with thin beds of sandstone and sandy shale.

a Undetermined.

[1] Weed, W. H., op. cit.

[2] Stanton, T. W., and Hatcher, J. B., Geology and paleontology of the Judith River beds: U. S. Geol. Survey Bull. 257, 1905.

CRETACEOUS SYSTEM.

COLORADO SHALE.

The oldest formation exposed in the field is the gray Colorado shale. This shale outcrops along Missouri River and its lower portion is typically developed at Fort Benton, 30 miles to the southwest, which is the type locality of the Benton shale. In the Dakotas, Nebraska, Colorado, and elsewhere the upper limit of the Benton shale was fixed by an overlying limestone—the Niobrara—which is typically developed on Missouri River at the mouth of the Niobrara. These two formations—the Benton and Niobrara—constitute the Colorado group, but in this field, as elsewhere in north-central Montana, the Niobrara limestone as such is not present and the Colorado shale appears to be the time equivalent of both the Benton shale and Niobrara limestone of other localities. It has therefore become customary to refer to the formation in this part of the State as the Colorado shale rather than as the Benton shale.

The upper part of the Colorado consists of lead-gray shale alternating with thin beds of sandy shale and impure sandstone. Lower down in the formation the shale is more homogeneous and uniformly dark gray. The shale contains limestone concretions in which marine fossils are found. Only the upper part of the formation is exposed in this field and the entire thickness of the formation was therefore not determined; in the Fort Benton quadrangle its thickness as measured by Weed[1] is 1,850 feet, but this includes, at the base, part of the rocks now referred to the Kootenai formation. The Colorado shale is exposed in the Big Sandy field only in the valley of Missouri River. In general only a few feet of the formation is exposed above water level, but in some places it has been elevated by faulting to the top of the river bluffs, as for example at the mouth of Alkali Coulee.

EAGLE SANDSTONE.

The Colorado shale is overlain by the Eagle sandstone, so named[1] from its excellent exposures at the mouth of Eagle Creek in the southwest corner of the field. This sandstone, according to Stanton and Hatcher[2] represents the lower part of the Montana group; all the fossils collected from it by the writer have been reported by Stanton to be of Montana age.

As developed in this locality, the Eagle consists, typically, of three members. The lowest is a massive cross-bedded and locally heavy-bedded white sandstone, containing numerous small sandstone concretions that appear rusty on the weathered surfaces; the maximum thickness of this member is 120 feet. The middle division consists

[1] Weed, W. H., op. cit.
[2] Stanton, T. W., and Hatcher, J. B., op. cit., pp. 63, 66.

of 75 to 100 feet of dark-colored shale, which is carbonaceous at some horizons and contains thin irregular beds of coal. The upper division consists of thin-bedded gray sandstone. The total thickness of the formation is 250 to 300 feet, but its full thickness is not exposed in any one section. It outcrops only in the southwestern part of the area along Missouri River and its tributaries, where the overlying glacial drift has been removed by erosion. The massive sandstone at the base of the formation is more resistant than the underlying and overlying shales and forms cliffs 75 to 100 feet high.

The Eagle sandstone lies conformably on the Colorado shale, from which it is distinguished by its striking lithologic differences, but below the base of the Eagle as here considered there is a transition zone consisting of alternating beds of shale and sandstone that are of lighter color and more sandy than the typical Colorado shale. No fossils from which age determinations can be made were found in the transition beds, but lithologically they seem to belong to the Colorado, and because of the change from them to the overlying massive sandstone the base of the sandstone is taken as the line of separation between the Eagle and the Colorado.

CLAGGETT FORMATION.

The Claggett formation, so named by Stanton and Hatcher,[1] is in this area a dark-colored marine shale overlying the Eagle sandstone. The Claggett formation has been determined to be the equivalent of a part of the Pierre shale. It contains *Baculites ovatus*, *Baculites compressus*, *Inoceramus barabini*, *Gervillia borealis*, and other forms characteristic of the Pierre.

The Claggett consists chiefly of dark-gray shale containing numerous calcareous concretions, the largest of which are several feet in diameter. These concretions contain most of the fossils found in the formation. Because of poor exposures the thickness of the formation was not determined in the Big Sandy field, but in the vicinity of Judith, about 40 miles farther east, the shale is about 500 feet thick.

The lower part of the formation is well exposed in the southwestern part of the field along many of the coulees tributary to Missouri River, but elsewhere it is in general covered by glacial drift and the boundaries can not be accurately located except in a few places. For this reason the boundaries shown on the map are only approximately correct. For the most part the outcrop of the Claggett occupies a zone between the exposures of the Eagle sandstone and those of the Judith River formation, but in some places in the vicinity of Big Sandy Creek small exposures of dark shale are apparently surrounded by the Judith River formation. These are represented as

[1] Stanton, T. W., and Hatcher, J. B., op. cit., p. 13, 1905.

Claggett on the map, on the assumption that the shale underlies the Judith River and has been exposed by folding and erosion. It is possible, however, that the shale exposed at some of these localities belongs in reality to the Bearpaw, and has been faulted down among the Judith River beds.

The Claggett overlies the Eagle sandstone conformably and is rather sharply contrasted with it lithologically by reason of its shaly character, its dark color, and the presence of limestone concretions. At the base of the Claggett, however, a zone of sandy shale constitutes a transition to the Eagle sandstone below, and at the top there is a similar transition zone to the overlying Judith River formation.

At the mouth of Judith River and elsewhere in that region there is between the main body of shale in the typical Claggett and the overlying fresh-water beds from 100 to 200 feet of alternating marine shale and sandstone, which becomes more sandy toward the top, where there is a bed of massive yellow sandstone ranging from a few feet up to 20 feet or more in thickness. This zone of alternating shale and sandstone carries a marine invertebrate fauna which is perhaps most abundant in the upper massive sandstone. Because of the marine fauna and because of the previously defined base of the Judith River formation above them, Stanton and Hatcher included these beds in the Claggett formation, although lithologically they are much more closely allied with the Judith River. In the Big Sandy field, however, the sandstone overlying the dark marine shale of the Claggett, although similar in lithologic character and stratigraphic position to the marine sandstone at the mouth of Judith River, is of fresh or brackish water origin. This is proved by the occurrence in it of fresh or brackish water shells and beds of carbonaceous shale. As there is no evidence of an erosion interval between the shale of the Claggett formation and these fresh-water beds, it is possible that these beds are the time equivalent of the marine sandstone at the mouth of Judith River, but to the writer it seems more logical that the name Claggett formation should be restricted in this field to the marine shale and that the overlying sandstone should be included in the Judith River formation.

JUDITH RIVER FORMATION.

The Judith River formation overlies the Claggett and is principally of fresh or brackish water origin. This formation was named by Hayden [1] in 1872, though its stratigraphic relation was not then understood. In their work on the Judith River formation [2] Stanton and Hatcher determined that the formation belongs in the Montana

[1] Hayden, F. V., Geology of the Missouri Valley: U. S. Geol. Survey of Wyoming and portions of contiguous Territories, Preliminary (Second) Rept. progress, p. 97, 1872.

[2] Stanton, T. W., and Hatcher, J. B., op. cit., 1905.

group and is the time equivalent of a part of the Pierre shale. Their conclusion was borne out by the work of the writer in this area.

The Judith River formation consists of light-colored alternating beds of sandstone and shale in which occur thin beds of carbonaceous shale and coal, the latter of little economic importance in this field. In some places the sandstones are cross-bedded and ripple marked and contain ferruginous and sandy calcareous concretions which have a general resemblance to the more sandy concretions of the Claggett. There is considerable lithologic variation in the beds, both horizontal and vertical, which renders it impossible to match up sections measured at separate localities. The thickness of the formation was not determined in this area because of lack of good exposures and uncertainty as to structure. However, in other areas in this part of the State the formation is about 500 feet thick.

The general distribution of the Judith River formation is shown on the map (Pl. XXI, p. 372), but as the formation is largely obscured by glacial drift, the boundaries shown are more or less hypothetical. The formation is believed to underlie different areas in the northern part of the field, but it is impossible from a surface study of the formation to draw the boundary between it and the younger rocks; in that part of the area, therefore, the rocks underlying the glacial drift are not represented on the map.

There is a narrow transition zone between the Judith River and the underlying Claggett, and the formation is also conformable beneath the Bearpaw shale. This normal relation exists over a small area in the northeast part of T. 26 N., R. 15 E., but elsewhere throughout the field the Judith River is cut off by igneous rocks or appears to be in fault contact with younger formations.

BEARPAW SHALE.

The Bearpaw shale was named by Stanton and Hatcher[1] "because it is well exposed in the area south, east, and north of the Bearpaw Mountains." This shale contains a fauna which elsewhere is regarded as typical of the Pierre. The Bearpaw is therefore the equivalent of the upper part of the Pierre and in areas to the southeast, between Missouri and Musselshell rivers, is directly overlain by the Lance formation.

The Bearpaw is a lead-gray marine shale, containing calcareous concretions which yield most of the fossils of the formation. In both lithologic and paleontologic characters the Bearpaw resembles the shale of the Claggett formation so closely that in many places the two can not be definitely distinguished except in their stratigraphic relations. As only a part of the formation is exposed in this field,

[1] Stanton, T. W., and Hatcher, J. B., op. cit., p. 62, 1905.

its thickness was not determined, but in other localities it is known to be 1,000 to 1,100 feet thick.

In the northeastern part of T. 26 N., R. 15 E., a small body of marine shale appears to rest conformably on the Judith River formation and is therefore called Bearpaw. Another small mass of dark shale overlies beds which seem to belong to the Judith River in sec. 24, T. 27 N., R. 14 E., at the base of the Bearpaw Mountains. The only direct evidence of the age of this shale is its apparent stratigraphic position above the Judith River. The structure is doubtful, however, and steep dips and variable strikes in a few small exposures suggest fault relations; it may be, therefore, that the shale represents some other formation. In the vicinity of the Mackton coal mine there are several isolated exposures of similar marine shale which seems to underlie the coal-bearing formation (Fort Union) and to overlie undoubted Judith River beds. The fossils collected from this shale are regarded by Mr. Stanton as more nearly allied to those of the Bearpaw shale than to those of the Claggett. The structural conditions are uncertain at these places, but the apparent stratigraphic relation of the shale and the fossils it contains suggest that it is of Bearpaw age. The distribution of the Bearpaw in the vicinity of the Mackton mine can not be determined because the shale is exposed at only a few places and other evidence indicates the existence of faults by which the shale may in some places be entirely cut out. Its distribution, however, is probably greater than the exposures indicated on the map.

The Bearpaw is conformable above the Judith River, and apparently also underlies the Fort Union formation conformably, except in places where faulting has disturbed these relations. The Fox Hills, Lance, and Livingston formations, which at some localities in Montana occur between the Bearpaw (or Pierre) and the Fort Union, are not present in this or immediately adjacent fields. The absence of these formations indicates either a stratigraphic break or different conditions of deposition at the localities where these beds do not occur. Therefore, although there is apparent conformity between the Bearpaw and the overlying Fort Union formation, there may really be a time break.

TERTIARY SYSTEM.

FORT UNION FORMATION.

The coal-bearing formation at the Mackton mine is classed as Fort Union on the basis of fossil plants collected from it at the mine and at a locality about 2 miles farther east. The stratigraphic position of these beds in the Fort Union has not been determined; their presence at this locality, far removed from all other known areas of Fort Union rocks, is due to faulting, which has brought the beds down to the level of older rocks.

The Fort Union consists of alternating layers of sandstone, sandy shale, and shale. The formation is of variable color, but light shades of buff, yellow, green, blue, and gray predominate. It contains one or more coal beds. A massive cross-bedded yellowish sandstone occurring near the base is relatively resistant to erosion and forms cliffs and ledges. The overlying beds weather down readily and are as a rule not exposed at the surface. The thickness of the formation at the Mackton mine is estimated as about 700 feet, although only about 350 feet are well exposed.

No accurate statement can be made of the distribution of the Fort Union formation in this field, because of the complex structure and the almost universal covering of drift. There is no clue as to the position of the southern boundary of the formation. On the north there are several small isolated exposures of a massive sandstone, similar in appearance to that near the base of the section at the Mackton mine. These exposures extend northeast from a point near the southwest corner of sec. 12, to the north quarter corner of sec. 1, T. 28 N., R. 14 E. If these outcrops represent the same sandstone as that at the Mackton mine, their positions should indicate approximately the northern limit of the formation, unless it is repeated still farther to the north by faulting. On the east the sedimentary rocks are all cut off by igneous intrusions of the Bearpaw Mountains.

QUATERNARY SYSTEM.

The Quaternary deposits comprise glacial drift, bench gravel, and alluvium; the drift is the most widespread of these deposits and covers the surface of almost all the area.

Over most of the district the drift consists of a heterogeneous mixture of sand, gravel, and bowlders, variable in size and in lithologic character. The most numerous and conspicuous erratics are granites, gneisses, and quartzites that obviously have been transported from distant regions, inasmuch as they are totally unlike any rocks occurring in place in this part of Montana. Along Missouri River and its tributaries, however, the bluffs are capped by a deposit of light-yellow, partly consolidated, loesslike sand and clay which is in places apparently stratified and as a rule contains a few small water-worn pebbles. This deposit is doubtless due to some phase of glacial action.

The drift covers almost all the field but does not occur in that part occupied by the Bearpaw Mountains. The boundary of the drift-covered area is shown on the map (Pl. XXI, p. 372).

Near the Bearpaw Mountains those areas that are not drift-covered are in most places overspread by gravel derived chiefly from the igneous rocks of the near-by mountains. In general, this gravel obscures the outcrops of the older formations as completely as does the drift.

The preglacial channel of Missouri River, crossing the northwest corner of the field, is occupied by alluvium. Similar deposits of smaller extent occur along the present channel of Missouri River and some of the small tributary streams.

IGNEOUS ROCKS.

The Bearpaw Mountains consist of igneous rocks of intrusive and extrusive origin and of both acidic and basic character. They have been briefly described by Weed and Pirsson.[1] Dikes and sills of these rocks radiate from the main mountain mass and some of them outcrop at a considerable distance from the mountains. These dikes and sills have had little effect on the inclosing strata, which are but slightly metamorphosed and have suffered no apparent displacement by the intrusion.

STRUCTURE.

Because of the general covering of glacial drift and alluvium, continuous exposures of the underlying formations are lacking and the structure is extremely obscure and difficult to interpret. Except locally where the drift cover is very thin, exposures of sedimentary rocks occur only along the streams and coulees, where erosion has removed the glacial material. A study of these exposures shows that the original attitude of the rocks has been disturbed locally by faulting, but because of the conditions described above the fault lines can not be traced, and in many places the existence of a fault can be inferred only by a pronounced change in the dip or strike of the strata at near-by exposures. Along Missouri River, however, where the best exposures occur, faults are plainly visible; different formations end abruptly against one another along the strike or are repeated in the direction of dip several times in succession, as at the mouth of Alkali Coulee. The location of a few of the most obvious faults is shown on the map. Suggestions of other faults are numerous, and it is probable that still others are entirely obscured by the surface covering.

THE COAL.

OCCURRENCE.

The best grade of coal and the thickest and most extensive beds occur in the Fort Union formation in T. 28 N., R. 14 E., as shown on the map (Pl. XXI, p. 372). Thin irregular beds of poor coal are found in the Eagle and Judith River formations in the southern part of the field. For convenience of discussion the coal beds are grouped

[1] Weed, W. H., and Pirsson, L. V., The Bearpaw Mountains, Mont.: Am. Jour. Sci., 4th ser., vol. 1, pp. 283-301 351-362; vol. 2, pp. 136-148, 188-199, 1896.

according to geologic formations and are so presented in this report. As the area occupied by the Fort Union formation, though not accurately determined, is known to be small, it follows that the commercially valuable coal of the field is restricted to a relatively small area.

COAL IN THE EAGLE SANDSTONE.

Exposures of coal in the Eagle sandstone are confined to the southwestern part of the field. The coal occurs in a zone 50 to 100 feet thick near the middle of the formation and above the white massive basal sandstone. Several coal beds of variable thickness and purity are present, the most important of which is immediately above a black shale containing large ironstone concretions at its base. It is 20 to 30 feet above the top of the white massive sandstone, and the outcrop of the coal bed therefore corresponds closely to that of the upper rim of the sandstone ledge. The coal sections[1] measured on these beds are shown in fig. 11 (p. 373), Nos. 17 to 32.

The lowest bed, here designated bed A, is the most important, ranging in thickness from 15 to 36 inches. It is shown in sections Nos. 22, 23, and 32, and is the lowest bed shown in sections Nos. 24, 25, and 26 (fig. 11). The bed is variable in character; in some places it consists of one unbroken bench, in others it is split by bone or shale partings into several benches, and at locality 23a it consists entirely of carbonaceous shale. At locality 32 there is 31 inches of coal in three benches separated by partings 3 inches thick. The following sections show the character of bed A at different localities:

Section at locality 23, near east quarter corner of sec. 5 (unsurveyed), T. 25 N., R. 13 E.

	Ft.	in.
Coal (section No. 23, fig. 11)	2	4
Shale	10	
Shale, carbonaceous	2	
Clay	10	
Shale, carbonaceous	5	
Clay	10	
Shale, bed A, carbonaceous, with coaly streaks	4±	
Clay, drab, with iron concretions in middle, to white, massive sandstone (estimated)	20	
	63	4

[1] The coal sections are referred to by numbers which correspond with those used on the map (Pl. XXI).

Section at locality 22, on east bank of Missouri River, sec. 9, T. 25 N., R. 13 E.

	Ft.	In.
Coal (section No. 22, fig. 11)		7
Shale and sandstone, alternating	5	9
Clay	9	
Shale, carbonaceous	1	
Coal, bony, bed A		6
Shale, carbonaceous	1	
Clay, black	19	
Shale, carbonaceous, with lenses of coal and carbonized wood		8
Clay	3	
Sandstone, white, massive.		
	40	6

The following sections were measured in the bluffs on the north side of Missouri River in T. 26 N., R. 12 E., which lies just west of the area shown on the accompanying map (Pl. XXI, p. 372):

Section at Coal Banks, on north side of Missouri River, near west side of T. 26 N., R. 12 E.

		Ft.	In.
Clay, gray		10	
Bed A	Shale, carbonaceous	1	
	Coal		3
	Clay		3
	Coal, with 3 inches of bone 6 inches above base	1	2
	Clay and brown shale	1	8
	Coal	1	
Clay, brown		1	3
Sandstone, argillaceous		5	
Clay		2	6
Shale, carbonaceous		1	
Clay			1
Coal			4
Bone			6
Clay		10	
Shale, brown		1	
Clay		5	
Bone			4
Clay			1
Coal			3
Clay			1
Bone			4
Clay		6	
Sand, yellow, loose		6	
Shale		1	
Sandstone, white, massive.			
		56	1

Section on north side of Missouri River, about 1½ miles east of Coal Banks.

		Ft.	in.
Clay, drab		10	
	Bone		10
	Coal		2
Shale		3	6
Bone			8
Clay		14	
Bed A	Coal		5
	Clay		6
	Coal		11
	Shale, carbonaceous	1	
Clay, black, with iron band at bottom		5	
Clay		2	
	Coal	1	1
Clay		5	
		45	1

At an old prospect (now almost obliterated), 50 feet east of the last section, another measurement of bed A was made, as given below. The two sections show the variability of the bed within a short horizontal distance.

Section of coal bed A measured 50 feet east of the preceding section.

	Ft.	in.
Coal	1	5
Clay		2
Coal		7
Clay		6
Coal	1	
	3	8

The overlying coal beds are thinner than bed A, and in most places are less than 15 inches thick, though locally they may be 24 inches thick. Sections Nos. 17 to 31 (fig. 11, p. 373) show the thickness of these beds at the localities indicated on the map.

From the above description it will be seen that the coal beds in the Eagle sandstone in this field are thin and variable, and up to 1912 no attempt had been made to exploit and use the coal. The thinness of the beds and the variability in the quality of the coal militate against development at the present time, but as the country becomes more thickly settled the coal may, to a limited extent, serve the local needs of ranchmen and homesteaders.

COAL IN THE JUDITH RIVER FORMATION.

As shown by surface exposures, the Judith River coal beds are thin and of no economic importance. The few exposures in the eastern part of the field, at which sections Nos. 33, 34, and 35, given below, were measured, show that the beds are thicker in that locality than they are farther west. It is possible that the formation contains some workable coal in Tps. 25 and 26 N., R. 16 E., immediately east of the area here considered, and it is well known that still farther east, on and near Cow Creek, coal beds of considerable thickness occur in the Judith River.

Coal sections Nos. 36, 37, and 38 in the following table, measured on Big Sandy Creek, represent practically all that is known of the Judith River coal in the western part of the field. The formation is largely covered by glacial drift, and the few exposures do not extend through a very great vertical range; consequently it is possible that coal beds which are not exposed at the surface occur in the formation. There is a general absence of coal in the Judith River formation at all existing outcrops, however, and it seems probable that the formation contains no important coal beds in this area.

Sections of coal beds in Judith River formation.

No. on Pl. XXI.	Location.	Section.	Ft.	in.
33	NE. ¼ SE. ¼ sec. 1, T. 25 N., R. 15 E.	Coal		6
		Parting, sandy		1
		Coal, bony	1	3
		Coal	1	3
			3	1
34	NE. ¼ NE. ¼ sec. 36, T. 26 N., R. 15 E.	Bone	1	
		Coal		4
		Bone		1
		Coal	1	
		Shale	3	
		Coal, bony in lower part	1	3
			6	8
35	SW. ¼ NE. ¼ sec. 35, T. 26 N., R. 15 E.	Coal		9
36	SW. ¼ NE. ¼ sec. 12, T. 27 N., R. 13 E.	Coal, impure	1	
		Bone	1	
			2	
37	SW. ¼ NW. ¼ sec. 7, T. 27 N., R. 14 E.	Coal		10
		Bone	1	
			1	10
38	SW. ¼ NW. ¼ sec. 8, T. 27 N., R. 14 E.	Coal		6

COAL IN THE FORT UNION FORMATION.

The coal in the Fort Union formation is of better quality than that occurring in the other formations. The Fort Union occupies a small area in the northern part of the field; its presence in this locality, as stated on page 364, is believed to be due to faulting, by which the beds have been brought down to a relatively lower level stratigraphically than that which they normally occupy. For the sake of clearness in discussion, the coal bed on which the Mackton mine (locality 39) is operated will be called the Mackton bed, and that on which the Mack mine (locality 43) is operated, the Mack bed, although it has not been conclusively demonstrated, as will be seen from the following discussion, that these represent different beds.

The Mackton bed (section No. 39, fig. 11, p. 373) is about 350 feet above the base of that part of the Fort Union formation exposed in the Big Sandy field. This bed has been considered by the Mackton

Coal Co. to be represented farther northeast by the bed on which sections Nos. 40 and 41 were measured, because the sections of the beds are similar. The writer considers this correlation doubtful because all search for the coal bed between the two localities has been fruitless, and further because of the fact that the bed at the Mackton mine (locality 39) is about 200 feet above a massive gray sandstone, not far below which is marine shale, whereas at locality 40 the coal appears to be below a similar massive sandstone and is separated from the underlying marine shale by alternating thin beds of clay and sand. The extent of the Mackton bed itself is not definitely known. From a point about 500 feet north of the mine the bed can be almost continuously traced nearly to the south side of sec. 18, a distance of almost one-half mile. Throughout this distance it has a thickness of 7 to 8 feet. The abrupt ending of all surface indications of the bed at either end of this line of outcrop suggests the presence of faults. There is more or less evidence of this at the southern termination of the coal outcrop, but the evidence is not so apparent at the northern termination. The failure to find the bed beyond these supposed fault lines suggests the possibility that the coal occurs in a small fault block that has been dropped vertically downward into a non coal-bearing formation. The surface covering of drift makes it impossible to trace fault lines or work out fault relations from the surface, and the demonstration of the presence or absence of faults can be made only by underground development. One small fault has already been encountered in the mine, and it seems likely from the evidence at hand that others may be found and that the Mackton bed may prove to be small in extent in the direction of strike. In the underground workings, as far as they have been extended, the structure corresponds exactly with what would be expected from a study of the surface exposures, which show that directly south of the mine, near the southwest corner of sec. 18, the strike of the formation is almost at right angles to the strike at the mine entrance and the south entries of the mine show that underground a similar change in strike takes place in the coal bed. This discordance in strike is one of the strongest evidences of faulting south of the present workings.

The Mackton bed has a total thickness of 7 feet 8 inches at the Mackton mine. A persistent parting of bone and shale 15 to 24 inches thick separates the bed near the middle into two benches; and a 2-inch parting also occurs in the lower part of the upper bench. This necessitates sorting the coal before it is marketed and adds to the cost of mining.

The bed worked at the Mack mine (locality 43) is regarded by Pepperberg[1] as occurring about 35 feet above the Mackton bed. If

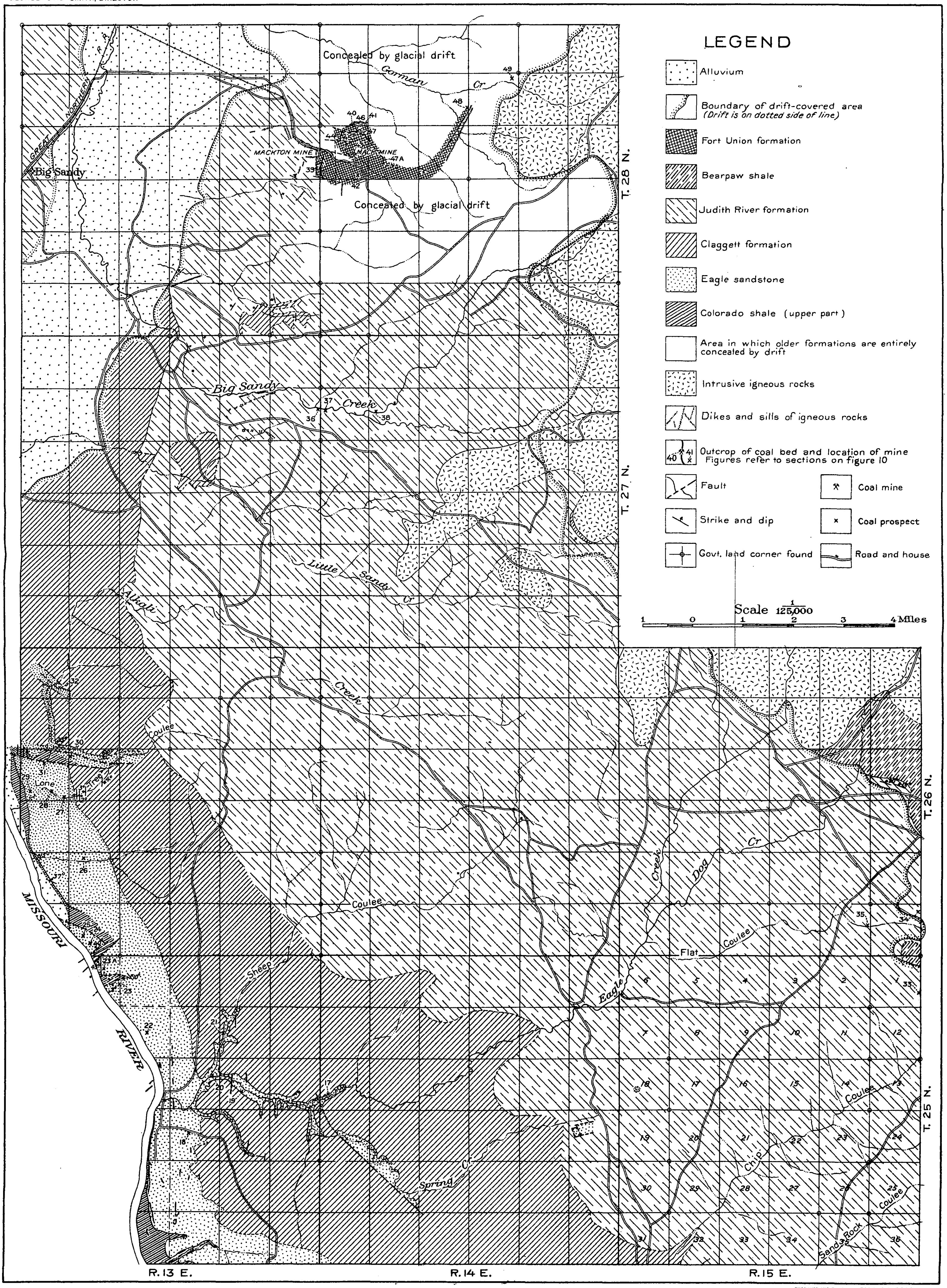
[1] Pepperberg, L. J., The Milk River coal field, Mont.: U. S. Geol. Survey Bull. 381, p. 103, 1910.

this is so, the Mack bed should be found above the Mackton mine, and the Mackton bed should be found below the Mack mine. However, no locality has ever been found in which both beds are exposed unless it can be proved that the bed at localities 40 and 41 is the Mackton bed. Both beds, moreover, occur a short distance above a massive sandstone. On the other hand, a comparison of sections Nos. 39 and 43, at the Mackton and Mack mines respectively, shows that there is no resemblance between the bed worked at the two localities. The evidence tending to show that they are one and the same bed consists therefore in the failure to find the two at the same locality and in the fact that each occurs above a massive sandstone; opposed to this is the dissimilarity in the sections of the two beds. The structure is so complicated and the authentic determination of faults so difficult in this area, owing to discontinuous exposures, that the writer does not attempt any correlation of the coal beds at the two localities. The bed represented by sections Nos. 42 and 44 to 47 is generally regarded as the Mack bed, owing to the resemblance in thickness and quality. A short distance southeast of locality 47 the bed is concealed by drift and can not be traced farther. However, on the dump of an old prospect entry, at locality 47a, there is perhaps a ton or more of slacked coal, which seems to indicate the presence of a bed similar in quality to that at locality 45. The entry at this prospect is now completely caved in and the outcrop of the coal bed is covered by drift, so that the bed could not be examined. About three-fourths of a mile southeast of this old prospect two sills of igneous rock appear nearly at the horizon of the coal bed, but there is no evidence of coal until locality 48 is reached, where a thin bed is exposed just below the lower sill. About 1 mile farther to the northeast, at locality 49, there is another exposure of coal at approximately the same horizon, in close association with a dike or sill, but the bed can not be traced and no other exposures of coal can be found in this part of the field.

The Mack bed is in all probability continuous and thick enough for mining under the drift-covered bench within the curve formed by the coal outcrop between localities 42 and 47. The eastward extent of the bed is not definitely known, but if, as seems probable, it is represented by sections 48 and 49, it is evident that locally at least the bed is considerably thinner to the eastward than in the vicinity of the Mack mine.

PROPERTIES OF THE COAL.

The coal in the Eagle and Judith River formations is black or brownish black in color, has a brown streak, and no pronounced woody structure. The Fort Union coal, as observed in the Mackton mine, has the following physical properties: Color pitch-black, streak brown to black, luster vitreous, structure bedded, jointing or cleavage



ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

GEOLOGIC MAP OF BIG SANDY COAL FIELD, CHOUTEAU COUNTY, MONTANA

By C. F. Bowen

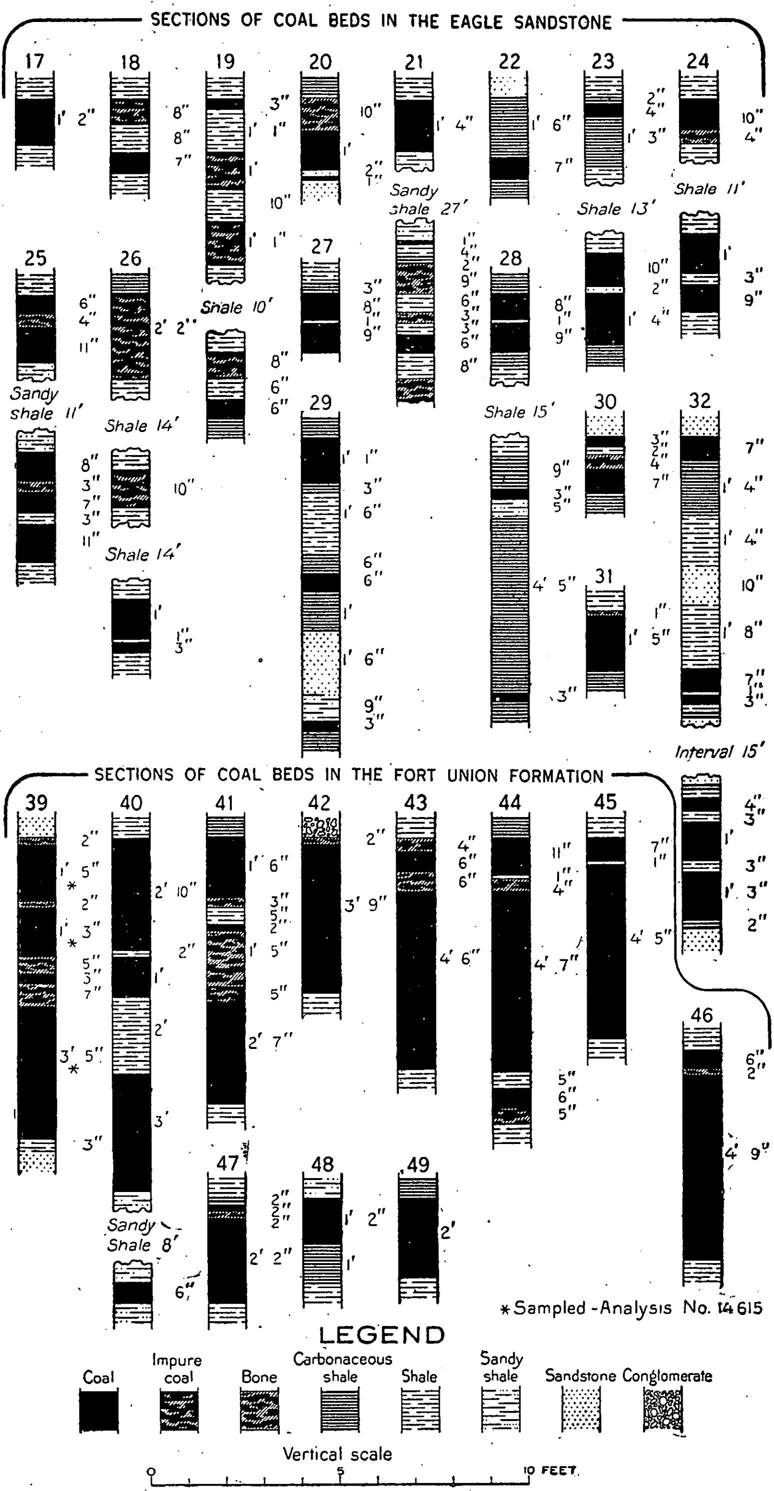


FIGURE 11.—Sections of coal beds in the Big Sandy coal field, Chouteau County, Mont.

in two directions, the coal breaking into subcubical blocks and smaller fragments when reduced, fracture conchoidal to uneven, texture dense, coherence brittle.

Two samples for analysis were taken from the bed at the Mackton mine. Sample 14615 came from the south entry of the first level, 250 feet from the mouth of the entry and 150 feet below the mouth of the slope. The bed at that point is represented by section No. 39 (fig. 11). Its total thickness is 7 feet 6 inches, but the sample, which includes only the coal, represents a thickness of 6 feet 1 inch. Sample 14613 was taken from the north entry of the second level, 140 feet north of the mouth of the entry and 335 feet down the slope. The bed at the place of sampling has the following section:

Section of Mackton coal bed at locality where sample shown in analysis 14613 was collected.

	Ft.	in.
Coal	2	5
Bone		2
Coal		6
Bone and coal (discarded in mining)	1	9
Coal	2	
	7	5

No mining had been done in the upper level for several months; hence this sample does not represent perfectly fresh coal. The other sample was taken from a fresh surface. The mine is dry throughout, so that the conditions under which the two samples were collected were the same except as to the length of time that the sampled surface had been exposed to atmospheric influences. In collecting the samples the face of the bed was first freed from all foreign matter and the bed was then trenched across from top to bottom. In order to compare the coal of the Big Sandy field with other coal with which it must compete in the market, analyses of representative samples of coal from the Havre district of the Milk River field and from Sand Coulee of the Great Falls coal field are also given.

These analyses, contained in the table below, are given in four forms marked A, B, C, and D. Analysis A represents the sample as it comes from the mine. This form is not well suited for comparison because the amount of moisture in coal as it comes from the mine is largely a matter of accident and may vary widely. Analysis B represents the sample after it has been dried at a temperature of 30° to 35° C. 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 its condition after all moisture and ash have been theoretically removed. This form is supposed to represent the true coal substance, free from the most significant impurities. Forms

C and D are obtained from the others by recalculation. They represent theoretical conditions that never exist.

In making these analyses, the volatile matter in samples 14613 and 14615 from the Big Sandy field was determined by the modified method, whereas in all the other samples the volatile matter was determined by the official method. The difference between these two methods lies in the fact that in determining the volatile matter by the modified method the sample is first given a preliminary heating of 4 minutes over a small flame and a final heating of 7 minutes over a flame 20 centimeters high, whereas in the official method the preliminary heating is omitted. This preliminary heating allows the moisture to escape slowly and thus prevents the sputtering which occurs when coal that is high in moisture is placed directly over a hot flame. The mechanical losses due to such sputtering, though almost negligible in bituminous coal, may amount to as much as 25 per cent in some lignite. In such material the modified method, by reducing the mechanical loss caused by sputtering, has the effect of decreasing the percentage of volatile matter and increasing the percentage of fixed carbon. It is now customary to use this method in determining the volatile matter in lignite and subbituminous coal and all other coal which has a moisture content of more than 10 per cent.

The effects of the two different methods of analyses on the Mackton coal of the Big Sandy field, which is a high-grade subbituminous coal, may be seen by comparing analyses 14613 and 14615, made by the modified method, with analysis 6550, made by the official method. Analysis 14615, however, represents coal that may have been slightly weathered. It is consequently less valuable for purposes of comparison than analyses 14613 and 6550, both of which represent perfectly fresh coal taken in the Mackton mine. The differences in results between these two analyses are perhaps no greater than would be obtained from the analysis of any two samples taken from the same bed in different parts of the same mine and both analyzed by the same method. Furthermore, the differences which do occur are the opposite of what would be expected as a result of the methods of analysis employed. The volatile matter is 1.6 per cent lower and the fixed carbon about 1.6 per cent higher in analysis 6550, made by the official method, than in analysis 14613, made by the modified method. It is therefore evident that the slight differences in the results are to be accounted for by some other factor than the methods of analysis employed.

Analyses of coal samples from the Big Sandy and adjacent coal fields, Chouteau County, Mont.

[Made at the Pittsburgh laboratory of the Bureau of Mines, F. M. Stanton and A. C. Fieldner, chemists in charge.]

Laboratory No.	Locality.	Location.				*Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
		Quarter.	Sec.	T. N.	R. E.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
	BIG SANDY FIELD.																	
14615	Mackton mine	SW	18	28	14	1.9	A	12.4	36.9	35.8	14.9	0.70					5,050	9,090
							B	10.7	37.6	36.5	15.2	.71					5,150	9,270
							C		42.2	40.8	17.0	.80					5,765	10,380
							D		50.8	49.2		.96					6,950	12,510
14613	do	SW	18	28	14	1.8	A	13.0	36.3	40.1	10.6	.53					5,340	9,620
							B	11.4	37.0	40.8	10.8	.54					5,440	9,790
							C		41.7	46.1	12.2	.61					6,140	11,060
							D		47.5	52.5		.69					6,995	12,590
6550	do	SW	18	28	14	5.5	A	12.1	34.7	41.7	11.54	.80	5.30	55.85	0.71	25.80	5,330	9,600
							B	7.0	36.7	44.1	12.21	.85	4.96	59.10	.75	22.13	5,640	10,160
							C		39.5	47.4	13.12	.91	4.50	63.52	.81	17.14	6,065	10,920
							D		45.4	54.6		1.05	5.18	73.11	.93	19.73	6,980	12,560
	MILK RIVER FIELD.																	
	Havre district:																	
6473	Electric mine	SW	29	32	16	16.3	A	22.9	29.3	34.6	13.2	.80					4,390	7,900
							B	7.8	35.0	41.4	15.8	.95					5,245	9,440
							C		38.0	44.8	17.2	1.04					5,685	10,240
							D		45.9	54.1		1.26					6,865	12,360
6640	Clacks mine	NE	5	31	17	14.2	A	25.6	28.0	39.1	7.27	.58	6.19	49.08	1.03	35.85	4,605	8,290
							B	13.2	32.6	45.7	8.47	.68	5.39	57.20	1.20	27.06	5,370	9,670
							C		37.6	52.6	9.77	.78	4.50	65.96	1.38	17.61	6,190	11,140
							D		41.7	58.3		.86	4.99	73.10	1.53	19.52	6,860	12,350
	GREAT FALLS FIELD.																	
4119	Gerber mine at Sand Coulee.	NE	23	19	4	2.6	A	7.5	27.3	51.4	13.78	2.32	4.68	62.21	.88	16.13	6,115	11,010
							B	5.0	28.1	52.8	14.15	2.38	4.51	63.87	.90	14.19	6,280	11,300
							C		29.5	55.6	14.90	2.51	4.16	67.25	.95	10.23	6,610	11,900
							D		34.7	65.3		2.95	4.89	79.02	1.12	12.02	7,765	13,980

As the results obtained by the modified and the official methods of analysis are essentially the same for the samples representing the coal in the Big Sandy field, we may compare these results directly with the results of the analyses of the coals in the Milk River and Great Falls fields. The analyses of the air-dried samples show that on the average the coal of the Big Sandy field is about 2 per cent lower in retained moisture, 3 per cent higher in volatile matter, 3 per cent lower in fixed carbon, and about 400 British thermal units higher in heating value than the coal of the Havre district in the Milk River field. As received from the mine, the coal from the Big Sandy field is about 12 per cent lower in moisture than the coal from the Havre district. The essential difference between the Big Sandy and the Havre coal seems to lie in the excessive moisture of the latter. This affects the coal in two ways, first by lowering its heating value, and second by causing the coal to slack much more readily when exposed to the air.

As compared with the coal of the Great Falls field, the coal from the Big Sandy field is about 4.5 per cent higher in retained moisture, 10 per cent higher in volatile matter, 11 per cent lower in fixed carbon, 3.5 per cent lower in ash, and 869 British thermal units lower in heating value. As received from the mine the Big Sandy coal is about 5 per cent higher in moisture than the coal from the Great Falls field. The coal from the Big Sandy field is therefore of lower grade than that from the Great Falls field, with which it must compete in the open market.

The physical and chemical properties above enumerated, the general absence of well-defined cleavage planes, and the development of irregular fractures in the coal when exposed to the atmosphere show that the Fort Union coal in the Big Sandy field belongs to the subbituminous class, but because the coal will withstand weathering for a considerable length of time before crumbling to pieces, and because of its high heat value (nearly 10,000 British thermal units), it is regarded as a high-grade subbituminous coal. The high quality of the coal is perhaps the result of metamorphism and physical conditions produced by the thrusts that have taken place in this area.

DEVELOPMENT.

The Mackton mine consists of a slope about 350 feet long, extending S. 70° E. and inclined in accordance with the dip of the strata at an angle of 40°. At 130 feet down the slope there is an upper level consisting of a north entry 75 feet long and a south entry 250 feet long. About 335 feet down the slope there is a lower level consisting of a north entry 510 feet long and a south entry, having a somewhat devious course, 360 feet long. During the winter season the output is reported to be about 100 tons a day, but in the summer season, when the demand is light, the output is much less and only a few men are employed. The mine is connected with the Great Northern Railway by a narrow-gage railway owned and operated by the mining company. The coal is sorted and sold according to grade. The best grade sells readily at the towns along the railroad in competition with other coal and is preferred to most of the coal from the Milk River field.

The Mack mine supplies a small local trade; it has no shipping connections.

Years ago a mine was operated at locality 46, chiefly to supply the Fort Assiniboine military post; this mine has long since been abandoned.

The future of the district as a coal producer is dependent almost wholly on the Fort Union coals. Because of the complicated structure, the lack of surface exposures, and the small amount of underground development, no definite statement as to the extent of the productive area can be made. It is believed, however, from the evidence obtained, that the productive area is small and is confined to the immediate vicinity of the Mackton and Mack mines.