COAL IN THE TERTIARY LAKE BEDS OF SOUTHWESTERN MONTANA.

By J. T. Pardee.

INTRODUCTION.

The presence of coal in the Tertiary lake beds of certain valleys in western Montana has been known locally for many years. Some localities in the past even experienced brief coal "booms" which, however, usually died before actual development of the coal was accomplished. Systematic mining of the coal was started near Drummond, in a mine idle at present, and is now being carried on near Missoula.

Coal of the type found in this region has until recently been thought worthless, because only coal that would coke or stand shipment without slacking was considered of commercial value. In this part of the West, where high-grade coal is scarce, where the cost of wood has reached $6 or more a cord, and soft coal, imported for domestic use, about $8 a ton, the demand for cheaper fuel is great and the development of these heretofore unused low-grade coals is becoming profitable.

That these low-grade coals may furnish gas of good quality at a moderate cost and briquets suitable for domestic fuel is suggested by the results of experiments with coal of a similar type recently carried on at the University of North Dakota by E. J. Babcock.[1] Therefore an investigation of the coal resources of parts of Missoula, Ravalli, Granite, Powell, Deer Lodge, and Silver Bow counties, in western Montana (see index map, fig. 6), was made in order to obtain data for the classification of the public land in the area and to supply the public with information about the coal. The first object has been accomplished and the present paper is prepared to fulfill the second.

FIELD WORK AND LAND SURVEYS.

The area covered by this report is approximately that portion of Montana west of the Continental Divide and south of the watershed between Flathead River and Clark Fork (Missoula River). (See Pl. XIV.) An examination of Flint Creek valley in northern Granite

[1] Babcock, E. J., Investigation of lignite coal relative to the production of gas and briquets, University of North Dakota, Grand Forks, N. Dak., 1910.

County was made in May, 1910, and a reconnaissance covering the other portions of this region was made in 1911 in connection with other geologic work. In this work locations were made with regard to section corners.

Land surveys of most of the level agricultural lands were made about 40 years ago. Later the bench or grazing lands, and yet more recently some of the mountainous lands, were subdivided. Such corner monuments of the earlier surveys as were of wood have disappeared, their former positions, however, being in general truly marked by fence corners or by stones set by private parties. Corners established by the later surveys can, as a rule, be found without difficulty.

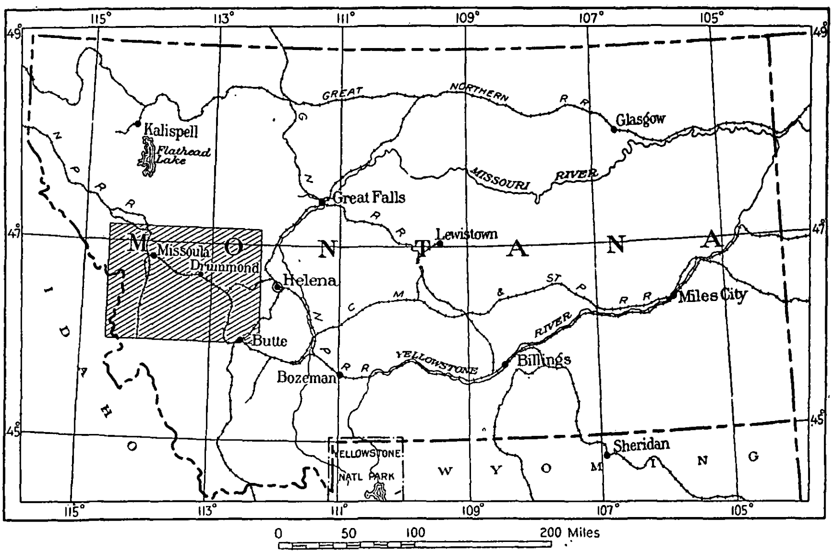

FIGURE 6.—Index map, showing location of certain Tertiary lake beds in southwestern Montana (shaded portion).

EXPLANATION OF THE MAP.

The base of the accompanying map (Pl. XIV) is compiled from the various land and topographic surveys of the Government. The geology of that portion included between the meridians of 113° and 113° 30′ and the parallels of 46° and 46° 30′ is taken from the map of the Philipsburg quadrangle by Emmons and Calkins,[1] and that of a small area west of Butte from the Butte special folio.[2] Camas Prairie and Blackfoot Valley above Lincoln were not visited, but as the topographic maps of the Bonner and Helena quadrangles show these valleys to be well-defined basins similar to the others

[1] Emmons, W. H., and Calkins, F. C., Geology and ore deposits of the Philipsburg quadrangle, Mont.: Prof. Paper U. S. Geol. Survey No. 78, 1913.

[2] Weed, W. H., Butte special folio (No. 38), Geol. Atlas U. S., U. S. Geol. Survey, 1897.

described in this area, there is a strong probability that they likewise contain Tertiary formations, and they are so indicated on the map. Elsewhere the areas shown in pattern were examined by the writer. The unshaded portions represent areas of igneous and older sedimentary rocks not known to be coal bearing. Within the limits of the map it is believed that all the areas of the coal-bearing Tertiary formations worthy of notice are shown. Early Quaternary or late Tertiary sediments, mapped by Calkins[1] as "Terrace gravels," generally veneer the Tertiary rocks, but are not differentiated in the present work. Later Quaternary deposits are shown only where they may overlie the Tertiary rocks.

GEOGRAPHY.

The area considered in this report lies west of the Continental Divide and is drained by Clark Fork of Columbia River. The surface in general is rough, and about five-sixths of the area (represented by the unshaded portions of the map, Pl. XIV) is mountainous, whereas the rest of the area is composed of level or gently sloping valley bottoms and bench lands. These latter areas comprise certain broad basins to which the name "valley" is applied by the inhabitants of the region in contradistinction to the multitude of relatively narrow valleys and gorges which they term "canyons." This classification accords well with a geologic grouping of the valleys of this region based upon their origin and age. Thus the group termed canyons includes only those valleys cut by streams during a late geologic period, whereas the term valley as locally used applies to older lowlands, due mainly to past faulting and folding in the underlying rocks. The coal described in this report is confined to the valleys of the second group.

The principal valleys are elongated basins whose longer axes trend in one of two general directions, either northwest-southeast or nearly north-south. They range in elevation from 3,000 to 5,000 feet above the sea and are surrounded by rugged mountains that rise 2,500 to 6,000 feet higher. Their rather sluggish rivers are bordered by comparatively wide and level bottoms succeeded by terraces or "bench lands" that slope gently upward to the inclosing mountains. Although erosion has apparently modified them to a great extent, it is evident that the valleys are chiefly due to structural movements. Thus the subsidence due to the great Bitterroot fault, as shown by Lindgren,[2] is to a great extent the cause of the formation of the Bitterroot Valley, and there is evidence that a large

[1] Op. cit.

[2] Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, pp. 48-50.

fault, bordering Avon Valley[1] on the northeast, has caused a downthrow valleyward. However, the most striking evidence suggestive of the structural origin of the valleys is their parallelism with the major structural lines of the region. In all the area represented on the map (Pl. XIV) the longer axes of the valleys are in substantial agreement with the dominant strikes of the older rocks.

A rather marked deviation from the general trend of the mountains is shown in the Bitterroot Valley south of Missoula and in the valleys of the southeast quarter of the area mapped. The northern ends of these valleys turn abruptly from the general north-south trend and extend in a northwest-southeast course. At the southeast limit of the area shown on the map the valleys again assume the northwest-southeast trend. This buckle is the northernmost of several similar irregularities in trend, coupled with increase in width of the western mountain system within the United States, which suggest a lengthwise shortening of the mountain chain that may be ascribed to crustal shortening acting at right angles to the forces that produced the dominant northwest-southeast folds.

GEOLOGY.

STRATIGRAPHY.

AGE OF THE ROCKS.

Within the area shown on the map (Pl. XIV) rocks ranging in age from Algonkian to Recent are present, but inasmuch as the only important coal beds known occur in the Tertiary lake beds no attempt has been made to show the distribution of the older rocks. As shown on the map, the Tertiary lake beds occur only in present or old valleys in this area.

The following table gives a general idea of the Tertiary and Quaternary formations of the central part of the region:

[1] Avon Valley, the broad lowland that extends about 20 miles northwesterly from Little Blackfoot River, at the towns of Avon and Elliston, and separates Garnet Range and the Continental Divide.

Section of Tertiary and Quaternary formations in the Flint Creek Basin.

System.	Series.	Character.	Thickness in feet.
Quaternary.	Recent.	Alluvium (gravel, sand, and silt).	
		Unconformity	
	Pleistocene.	Coarse to medium textured terrace gravel, locally gold bearing.	0-50
		Unconformity	
Tertiary.	Miocene.	Mostly massive, slightly indurated tuff, composed in part of clay; prevailing colors light yellow to brown. Contains some beds of fairly pure volcanic ash, impure limestone, sand, and fine, light-gray gravel; fossiliferous, yielding bones of oreodonts and other vertebrates.[a]	1,000+
		Unconformity (?)	
	Oligocene (?).	Mostly massive, slightly indurated tuff, composed in part of clay; prevailing colors light shades of gray and cream. Contains some thin beds of fairly pure volcanic ash, shale, and impure limestone, the latter yielding remains of fresh-water mollusks.	200
		Mostly massive, slightly indurated tuff, composed in part of clay; prevailing colors very light shades of gray and cream; some beds of brownish and greenish tints, the whole divided by many thin layers of fairly pure volcanic ash, impure limestone, thinly laminated or "papery" shale containing fragments of plants, and a few layers of sand and fine gravel.	1,300
		Impure limestone or marl ("cement")	10
		Massive tuff composed in part of clay; prevailing colors light gray to brown.	490
		Coal	4±
		Massive, greasy gray to red clay	96
		Unconformity	
		Basalt. Andesite. Rhyolite.	
		Unconformity	
Pre-Tertiary.			

[a] Douglass, Earl, New vertebrates from the Montana Tertiary: Carnegie Mus. Annals, vol. 2, 1903, pp. 153, 171-180.

PRE-TERTIARY ROCKS.

The rocks that form the floors of the basins in which the Tertiary sediments and lavas accumulated are collectively referred to as pre-Tertiary and are not discussed individually because they contain no commercial bed of coal. They range in age from Algonkian to middle Cretaceous and include many varieties of sedimentary and igneous rocks. All are readily distinguished from the Tertiary formations by their comparatively great hardness. They are usually referred to by the layman as the "true bedrock."

TERTIARY ROCKS.

That the Tertiary period was one of almost continual volcanic activity in this general region is shown not only by the remnants of extensive lava flows but by the large proportion and vertical distribution of volcanic ash in the formations. Although these ash beds form much the greater volume of the bench lands, they are in most places concealed beneath a superficial cover of gravel. Perhaps the best exposures are those afforded by ravines that dissect the benches east and west of Flint Creek, near Drummond. As indicated by their history, they are apt to be lenticular, and no stratigraphic section is representative over a large area.

In the massive tuff of the upper portion of the Flint Creek section Douglass found Miocene vertebrate remains.[1] The lower beds, which contain the coal, are here doubtfully referred to the Oligocene, no distinctive fossils having as yet been found in this locality. Douglass[2] referred these beds to the White River.

The section given above appears to be fairly typical of the Tertiary formations in all the valleys enumerated. In the northern half of Avon Valley yellow to brown, somber-hued tuffaceous clays prevail, whereas in the southern half light-colored tuff, thought by Douglass to be White River,[3] is exposed. In the Philipsburg area massive cream-colored to brown tuff, that is thought to be of Miocene age, occurs.

At Campbell ranch, in Douglas Creek valley, northeast of Drummond, the cream-colored tuff and marl is underlain by buff-colored shale crowded with tiny ostracodes, the whole resembling the Oligocene(?) beds of Flint Creek Valley.

In the foothills north of Missoula the following section is exposed:

Section of strata exposed north of Missoula, Mont.

	Feet.
Clay, gray to cream-colored and volcanic ash containing one or more coal beds	200+
Sandstone, light gray, micaceous	40±
Coal	7±
Clay, greasy gray	50±
Clay, brown to red.	
	297±

The ash beds near Missoula containing fossil leaves have been described by Rowe.[4]

In Bitterroot Valley north of Stevensville, Douglass[5] found a few Miocene vertebrate remains in light-colored sand and tuff. Farther south white to gray beds, mostly volcanic ash (Oligocene?), predominate.

[1] Douglass, Earl, New vertebrates from the Montana Tertiary: Carnegie Mus. Annals, vol. 2, 1903, pp. 151, 153, 164–165, 171–180. (Refers to beds near Drummond and New Chicago, Mont., and describes remains of dogs, oreodonts, and other vertebrates found in them.) Also, Rhinoceroses from the Oligocene and Miocene deposits of North Dakota and Montana: Carnegie Mus. Annals, vol. 4, 1908, pp. 256 et seq. (Describes and figures skull of a rhinoceros *Aphelops montanus* from the beds near New Chicago, Mont., to which he applied the name Flint Creek beds.)

[2] Douglass, Earl, Fossil Mammalia of the White River beds of Montana: Trans. Am. Philos. Soc., new ser., vol. 20, 1902, pp. 237–238. (Gives brief lithologic description and reference to fossils found in Tertiary beds near New Chicago, Granite County, Mont.)

[3] Idem, pp. 238–241.

[4] Rowe, J. P., Some volcanic ash beds of Montana: Bull. Univ. Montana No. 17, 1903, pp. 21–23, Pls. VI, VII, and VIII.

[5] Personal communication.

STRUCTURE.

The Tertiary lake beds of this region were deposited subsequent to the epoch of great folding in the Rocky Mountains. Since their deposition, however, structural movement has folded the Tertiary rocks into broad, shallow synclines or monoclines, and in places the beds have been faulted. In general the lake beds near the margins of the valleys dip moderately toward the center of the basin, but this dip decreases until near the middle of the basins the beds are practically horizontal. Exceptions to this general rule occur north of Missoula, where, at the mine of the Hell Gate Coal Co., the beds dip away from the center of the basin, and farther to the northwest, where rather complex folds are exhibited.

Steeply inclined normal faults of small throw are numerous in the marginal portions of Flint Creek Valley and are to be expected in the more severely deformed beds elsewhere. Slightly tilted beds, however, exhibit few if any faults.

GEOLOGIC HISTORY.

The geologic history of the basins and basin deposits is clearly displayed. At the close of a long period of sedimentation that extended from Algonkian into middle Cretaceous (Colorado) time dynamic forces compressed the beds into a great series of northwest-southeast folds and caused great overthrust faults, mainly from the west, great granitic batholiths invaded the sedimentary beds, and the region became an elevated rugged land.

Subsequent erosion, long continued, removed a great thickness of rocks, leaving only those portions of the younger beds that had been downfolded in synclines, and reduced the surface to a peneplain. Remnants of this peneplain still remain as small flats on the summits of ridges at elevations ranging from 6,500 to 7,500 feet above the sea in most of the mountainous portions of the area.

To the west this peneplain is correlated with similar ones described by Lindgren[1] in the Clearwater Mountains and by the writer[2] in the St. Joe region of Idaho.

After this great planation faulting that followed the established structural trend, accompanied by warping, formed depressions that grew slowly and have since been modified by various geologic events, but in the main still survive as the present "valleys" of this region.

The inception and growth of these depressions were accompanied by general volcanic activity. At first lavas were outpoured that

[1] Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, pp. 59–61.

[2] Pardee, J. T., Geology and mineralization of the upper St. Joe River basin, Idaho: Bull. U. S. Geol. Survey No. 470, 1911, pp. 42–43.

partly filled the basins in many places; afterwards repeated explosive eruptions spread volcanic ash over wide areas. From the surrounding lands ash and soil washed into the lakes that filled the basins and formed gravel and mud flats, which may have in some places extended across them. Plants grew on the flats, and the accumulated vegetable matter was from time to time overflowed and covered with thin layers of silt that settled from the muddy waters.

The basins deepened intermittently and sedimentation similar to that described above continued into Miocene time. These sediments later became indurated and the accumulated vegetable matter was transformed to coal.

At the close of the Miocene, elevation began which finally converted this region into a plateau ranging in elevation from 6,500 to 7,500 feet above the sea. With brief halts this uplift continued slowly into Quaternary time and may be still in progress. It was accompanied by moderate deformation, which as a rule warped the Tertiary beds into broad shallow synclines or monoclines and locally caused faults in them. The uplift rejuvenated the streams, which thereupon deepened their channels, dissected the plateau, drained the basins, and rapidly eroded away the comparatively soft Tertiary formations.

In early Quaternary time, during a halt in the downcutting, the streams established a temporary base-level, at which they truncated the tilted Tertiary formations and exposed the coal beds; but immediately thereafter they spread a gravel cover over the eroded surfaces. Later, downcutting having been resumed, the terraces or "bench lands" were carved from these gravels and the underlying lake beds.

This last downcutting was interrupted in the glacial period by ice dams that formed a temporary lake in the Clark Fork drainage basin.[1] Sediments deposited in the lake and material transported by glaciers choked the main stream in places, above which thick beds of alluvium accumulated that now form the valley bottoms.

THE COAL.

OCCURRENCE.

Pre-Tertiary coal.—Between Drummond and Blossburg two or more beds of black shale in the Cretaceous formation are exposed in several places. The very noticeable dark color of the soil derived from this shale has attracted the attention of prospectors, who have explored it more or less thoroughly. However, to date only

[1] Pardee, J. T., The glacial Lake Missoula: Jour. Geology, vol. 18, No. 4, 1910, pp. 376-386.

a few thin beds of coal have been found in the pre-Tertiary formations of this region.

Tertiary coal.—The few exposures of coal in the Tertiary formations do not form a good basis for a discussion of the character and continuity of the beds. Consideration of their history as set forth on pages 11–12 leads to the conclusion that the coal beds are apt to be lenticular in shape and variable in thickness and that they probably occur at different stratigraphic horizons.

Natural exposures of these coals are scarce, because the coal-bearing formation is generally covered by gravel, and even where exposed the coal crumbles and loses its characteristics very rapidly. Therefore, even good surface exposures usually do not fairly represent the coal in its unaltered condition. In the limited areas free from gravel it is possible, with difficulty, however, to trace the outcrop of the coal bed by means of "blossoms," which consists of fine particles of coaly matter and a reddish-brown material resembling rotten wood, mixed with the soil.

CHARACTER.

A fresh sample of the coal obtained from the open pit near the Old Northern Pacific mine, a few miles west of Drummond, is indistinctly banded from dull to bright black, dense, brittle, has a semiconchoidal fracture, black streak, exhibits two systems of joints at right angles to each other, and splits along the bedding planes. On exposure it slowly crumbles. At the Bielenburg & Higgins shaft a dump that had evidently been exposed over winter was thoroughly slacked to a depth of 6 inches or more. The above description applies also to the coal bed exposed in the Hell Gate Coal Co.'s mine, except that some layers are rather tough and woody and the whole gives a more or less brownish streak. This coal does not slack seriously during two or three weeks' exposure in bins or with ordinary handling. Specimens, said to be from the Thibodeau prospect, in T. 14 N., R. 20 W., are rather tough, brownish, and woody.

Except that they produce an objectionable amount of ash, coals from the Bielenburg & Higgins and Hell Gate mines are reputed to be satisfactory steam and domestic fuels.

Within the area under discussion there are few mines from which samples of fresh coal could be obtained for analysis. However, the analyses of four samples obtained under conditions described on page 240 are given in the following table and represent in general the chemical character of the coal of this field.

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

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

Analyses of coal samples from southwestern Montana.

[Made at the Pittsburgh laboratory of the Bureau of Mines, A. C. Fieldner, chief chemist, and the St. Louis laboratory of the Geological Survey, F. M. Stanton, chief chemist.]

Laboratory No.		Location.				Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
		Quarter.	Sec.	T. N.	R. W.			Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
13541	Mine of Hell Gate Coal Co.	....	4	13	19	16.3	A	24.7	a 29.3	26.1	19.86	0.85	5.56	39.04	0.74	33.95	3,735	6,730
							B	10.0	35.1	31.2	23.73	1.01	4.48	46.64	.89	23.25	4,465	8,040
							C	....	38.9	34.7	26.37	1.13	3.74	51.85	.98	15.93	4,965	8,930
							D	....	52.9	47.1	....	1.53	5.08	70.42	1.33	21.64	6,740	12,130
13542	.....do.	....	4	13	19	16.7	A	25.2	a 29.2	26.0	19.6	.76	....	....	....	....	....	....
							B	10.2	35.1	31.2	23.5	.91	....	....	....	....	....	....
							C	....	39.0	34.8	26.2	1.02	....	....	....	....	....	....
							D	....	52.9	47.1	....	1.38	....	....	....	....	....	....
3589	Mine of D. D. Nicholson	NE...	34	4	21	20.0	A	30.6	36.2	20.8	12.4	.66	....	....	....	....	....	....
							B	13.2	45.3	26.0	15.5	.82	....	....	....	....	....	....
							C	....	52.2	30.0	17.8	.95	....	....	....	....	....	....
							D	....	63.5	36.5	....	1.15	....	....	....	....	....	....
10534	Prospect near old Northern Pacific mine.	NW..	35	11	13	9.3	A	19.4	a 37.7	26.0	16.92	1.37	6.44	45.98	.63	28.66	4,830	8,700
							B	11.1	41.6	28.6	18.65	1.51	5.96	50.69	.69	22.50	5,325	9,590
							C	....	46.8	32.2	20.99	1.70	5.32	57.04	.78	14.17	5,995	10,790
							D	....	59.2	40.8	....	2.15	6.73	72.20	.99	17.93	7,585	13,650

a Volatile matter determined by the modified method.

Sample No. 13541.—This sample is from the mine of the Hell Gate Coal Co., about 2½ miles north of Missoula. It was collected by the writer from the bunker at the mouth of the mine and represents an average of the coal as mined from the east entry. The coal had been exposed to the atmosphere for about a week and was therefore somewhat weathered.

Sample No. 13542.—This sample was taken in the mine of the Hell Gate Coal Co., by the owner, about 600 feet north and 300 feet east of the opening, where the bed is 6 feet 10 inches thick. It was taken according to the method prescribed by the Geological Survey, which, in brief, is as follows: From a clean face a channel is cut perpendicularly across the entire bed, discarding partings three-eighths inch or more in thickness and lens impurities more than 2 inches in diameter and one-half inch thick. Material is pulverized to ½-inch size and sample reduced to about 1 quart, which is placed in a galvanized-iron can, sealed, and sent immediately to the laboratory.

Sample No. 3589.—This sample was taken in 1906 by J. P. Rowe from the mine of D. D. Nicholson, 4 miles north of Darby, in the NW. ¼ NE. ¼ sec. 34, T. 4 N., R. 21 W. The sample, which was somewhat weathered, was taken according to the method prescribed by the Geological Survey.

Sample No. 10534.—This sample was taken by the writer from an open prospect near the Old Northern Pacific mine, in the NW. ¼ NW. ¼ sec. 35, T. 11 N., R. 13 W., near Drummond.

The heating value of sample No. 13541, which is 8,040 British thermal units (air dried), is comparable to that of ordinary lignite. Its high percentage of ash is due to numerous thin clay partings. If these could be removed, either by more careful mining or by washing, the value of the coal would be considerably enhanced.

The analysis of sample No. 13542, which was taken by the owner of the mine, is very similar to the sample taken later by the writer (No. 13541). Sample No. 3589 shows a higher moisture content but lower ash and sulphur than the other samples.

Sample No. 10534 appears to be comparatively high in moisture and ash but not unduly so in sulphur. Its heating value, 9,590 British thermal units (air dried), together with its other characteristics, indicates that it should be classed as subbituminous. A comparison with analyses of coals from other parts of Montana shows close agreement in character between this one and the Cretace us subbituminous coals of Havre, Chinook, and Harlem, in the Milk River field.

LOCAL FEATURES.

Although the coal-bearing Tertiary formations are in most places covered by gravel and alluvium, an idea of the character and extent of the coal beds may be derived from a study of the outcrops in a few scattered localities.

In the Missoula Valley the Tertiary lake beds which are exposed in the high terrace north of Clark Fork, have been folded so that dips as steep as 70° are exhibited, and in places the beds have been cut by faults.

At the mine of the Hell Gate Coal Co., 2 miles north of Missoula, in sec. 4, T. 13 N., R. 19 W., the lowest of three beds of coal is being exploited. One of the upper beds is reported by Rowe[1] to be 4 feet thick. The main slope of the mine follows the coal bed (dip 20° N.) for 600 feet and entries at the bottom have been driven 150 feet and 400 feet to the east and west respectively. A sample for analysis (No. 13542, p. 239) was taken by the owner of the mine in the east entry about 300 feet from the slope, where the bed is reported to have a thickness of 6 feet 10 inches. A second sample (No. 13541) was taken by the writer from coal in the bunker at the mouth of the mine and represents an average of the coal as mined in the east entry. The following section was measured in the east entry about 350 feet from the slope:

Section of coal bed in east entry of Hell Gate Coal Co's. mine.

	Ft.	in.
Roof, sandstone, gray.		
Clay and coal	1	
Coal with some clay	1	6
Coal	3	
Clay		6
Coal	2	4
Clay, greasy, gray.		
	8	4

The mine is equipped with a small electric hoist and a coal bunker. An electric pump, operated 2 hours a day, drains the mine. The coal bed contains many clay partings in the west drift but is much cleaner in the east. The product of the mine is hauled to Missoula by wagon and sold locally for $5 a ton.

Thomas Thibodeau reports having uncovered a coal bed on Butler Creek (No. 1 on the map), about 6 miles northwest of Missoula, where the following section is exposed:

Section of coal bed in the NE. ¼ sec. 26, T. 14 N., R. 20 W.

	Ft.	in.
Coal	3	6
Clay	1	2
Coal	5	
	9	8

The bed strikes northwest, dips 44°–70° SW., and has been cut by faults.

Coal was noted by Schrader[2] at the Kennedy Creek Placer Co.'s mine, about 30 miles northwest of Missoula (No. 2 on the map), in T. 16 N., R. 23 W.

In the Bitterroot Valley, south of Hamilton, coal is exposed at several localities and has been mined on a small scale in at least two places. Rowe[1] reports two beds of coal being mined on the west

[1] Rowe, J. P., Montana coal and lignite deposits: Bull. Univ. Montana No. 37, 1906, p. 60.
[2] Schrader, F. C., Gold-bearing ground moraine in northwestern Montana: Bull. U. S. Geol. Survey No. 470, 1911, p. 64.

side of Bitterroot River, 15 miles south of Hamilton; and in 1910 a sample of coal (No. 3589) for analysis by the Geological Survey, was obtained by him from the mine of D. D. Nicholson in sec. 34, T. 4 N., R. 21 W. The mine, as described by Rowe in his published report, consists of a drift 75 feet long on the upper bed (5 feet thick) and one 90 feet long on the lower (8 feet thick). The geologic relation of these coal beds is not known, but probably they occur in the same formation as the beds mined elsewhere in the field.

Near Alta, a small town 28 miles south of Darby, near the head of Bitterroot River, coal has been reported at several localities. Lindgren[1] mentions coal near the head of South Fork of Bitterroot River. Rowe[2] reported a bed of coal on "Coal Creek, which measures 13 feet;" also "deposits of lignite on Hughes Creek, a short distance east of the Coal Creek area," where beds "are said to run from 5 to 25 feet in thickness." The Tertiary lake beds occupy an area of several square miles in the valley of Flint Creek south of Drummond, and coal beds are exposed at several localities. Near the junction of Flint Creek and Clark Fork coal beds have been explored to a greater extent than elsewhere in the field.

The rocks of the coal-bearing formation exhibit different dips within this area, but in general the beds occupy a structural basin of considerable size.

At the Old Northern Pacific mine, about 2 miles west of Drummond, in the NW. ¼ sec. 35, T. 11 N., R. 13 W., two slopes, now caved, follow a coal bed reported to be 5 feet or more thick, dipping 10° SW. A short distance to the northwest a small open pit on the south bank of a ravine exposes the following section:

Section of coal bed at prospect near Old Northern Pacific mine.

	Ft.	in.
Coal and clay in thin alternate layers	2	
Coal	3	
Clay		6
Coal	1	6
Bottom not exposed.		
	7	

A sample (No. 10534, p. 239) was taken by the writer from the prospect and analyzed at the chemical laboratory of the Bureau of Mines.

Numerous small faults are reported to have been encountered in the Old Northern Pacific slopes, and to these, together with the presence of large quantities of water in the workings, is attributed the failure of the mine as a commercial undertaking.

[1] Lindgren, Waldemar, A geological reconnaissance across the Bitterroot Range and Clearwater Mountains in Montana and Idaho: Prof. Paper U. S. Geol. Survey No. 27, 1904, pp. 111-112.

[2] Op. cit., p. 63.

The Bielenberg & Higgins mine, about 2½ miles southwest from Drummond, in the SE. ¼ sec. 34, T. 11 N., R. 13 W., consists of an abandoned slope and a newly timbered shaft. According to Mr. W. I. Higgins, one of the owners, the slope was sunk 300 feet on the coal bed, which dips about 30° E. and averages 6 feet thick. This opening is probably the one referred to by Rowe [1] as the Parry property, which was being operated in 1905.

The shaft was flooded when visited by the writer. Mr. Higgins states that it penetrates a bed 9 feet thick at a depth of 100 feet. The coal is separated into benches by three or four thick clay partings.

On Rock Creek, in T. 8 N., R. 10 W. (No. 7 on the map), a coal bed 1 foot or more thick is reported near the old Mullan road crossing, about 8 miles northwest of Deer Lodge.

Near Anaconda, in T. 5 N., R. 11 W. (No. 5 on the map), thin coal beds crop out in the Tertiary rocks immediately north and south of the town. Considerable prospecting has been done in this locality, but no bed of commercial size has been found. A coal bed 3 feet thick is reported on Lost Creek, about 2 miles north of Anaconda.

In the Avon Valley thin beds of coal have been reported at three localities.

On Dog Creek, in T. 9 N., R. 8 W. (No. 6 on the map), a coal bed 1 foot or more thick is reported at a point near the wagon road from Deer Lodge to Avon, about 5 miles south of the latter place.

Near Ophir, in T. 11 N., R. 8 W. (No. 8 on the map), placer mining in Ohio Gulch, 1 mile west of the town, is reported to have uncovered one or more thin beds of coal in Tertiary clay.

On Nevada Creek, in T. 12 N., R. 9 W. (No. 9 on the map), placer miners report having found 1 foot or more of coal a short distance above the mouth of Jefferson Gulch.

Tertiary lake beds are exposed in other parts of the field, but so far as known to the writer no coal has been found other than that mentioned above.

PRODUCTION.

The production of the Flint Creek basin in 1905 is given by Rowe [2] as 500 tons. Insufficient data are available upon which to base an estimate of the total coal mined to date, but it has evidently not been large.

The Hell Gate Coal Co.'s mine produced 500 tons in 1910 and 2,200 tons in 1911 and the first six months of 1912. The coal is delivered in Missoula at an average cost to the consumer of $5 a ton. The capacity of the mine as equipped is 18 tons per day.

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[1] Rowe, J. P., Montana coal and lignite deposits: Bull. Univ. Montana No. 37, 1906, p. 52.
[2] Idem, p. 71.

QUANTITY OF COAL AVAILABLE.

The few openings and natural exposures of coal beds are confined to the margins of the basins. Whether the coal is limited in extent or persists across the basins can not be determined until deep wells or drill holes are made. It appears probable, however, that a workable thickness of coal within a reasonable depth underlies the western portion of the "bench lands" west of Flint Creek and north of the latitude of Hall village, also a considerable portion of the foothills north of Missoula.

Based on the data available, guesses rather than estimates of the coal tonnage of the Flint Creek and Missoula fields may be permissible, as follows:

On the assumption that four sections in the bench lands west of Flint Creek are underlain by a 5-foot coal bed, the total tonnage is approximately 23,000,000, or the recoverable tonnage approximately 12,800,000.

On the assumption that two and one-half sections north of Missoula are underlain by a 6-foot coal bed, the total tonnage is approximately 17,700,000, or the recoverable tonnage approximately 9,800,000. Data in other areas are insufficient to afford a basis for even a fair guess as to the available coal.

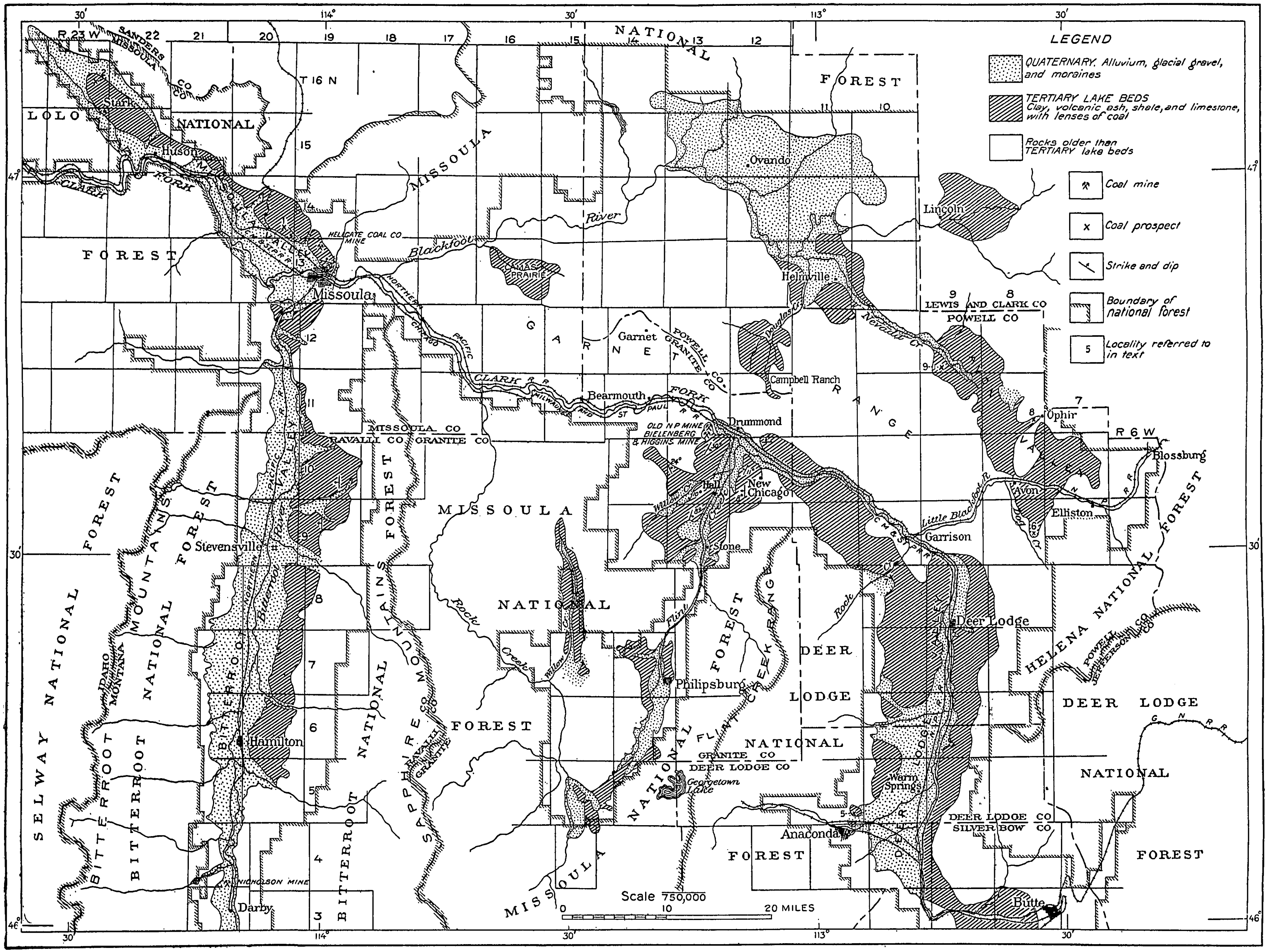
CONDITIONS OF MINING.

Owing to numerous small faults, clean separation of the coal and clay in mining is said by S. M. C. Hughes, of Hall, to have been difficult in the Northern Pacific slope. That this difficulty may be quite generally expected along the margins of the coal formations in the Flint Creek basin is indicated by the structure.

In the mining of steeply dipping coal beds unusual and expensive methods are necessary and the percentage of coal recovered is materially reduced; and as in these Tertiary basins considerable quantities of water are present, pumping is necessary in order to prevent the flooding of mine workings. In view of these unfavorable conditions, it is highly probable that coal will never be mined on a large scale in this field.

FUTURE DEVELOPMENT.

Though a local demand for cheap domestic fuel will cause some further development of these coals, anything like a rapid future development of them will depend on an increased use of producer gas for the generation of power, for which these coals seem well suited, or the introduction of briquetting machinery which will convert the easily slacked coal into briquets that may be shipped and stored without deterioration.



MAP OF A PORTION OF SOUTHWESTERN MONTANA, SHOWING AREA OCCUPIED BY TERTIARY LAKE BEDS.