CONTRIBUTIONS TO ECONOMIC GEOLOGY, 1908, PART II.

MINERAL FUELS.

MARIUS R. CAMPBELL, *Geologist in Charge.*

INTRODUCTION.

By MARIUS R. CAMPBELL.

During the year 1908 considerable progress was made by the United States Geological Survey in the study of the mineral fuels of the country. This included the examination of a number of coal and oil fields and also some work on the quality of the fuel and the best method of its utilization. Complete and detailed reports covering this work will be published as soon as the investigations of a particular field have been completed, or as soon as the problems of correlation, development, and utilization have been solved. In the meantime brief, preliminary statements have been prepared by the men engaged in the work, embracing most of the points of economic importance, and these have been assembled into the present volume, which is conformable with Bulletins 316 and 341. It is hoped that by this method of publication the public may receive at an early date the results of work done by this Survey, in order that the mineral resources of the country may be developed to the fullest extent compatible with legitimate demand and supply and a due regard to the conservation of these resources for future generations.

In the conduct of the field work on which these reports are based, two objects have been particularly prominent and have governed the character of the investigations: These are (1) the examination of the land for the purpose of classifying it as to its mineral or nonmineral character and, in the case of coal land, of determining its

selling value; and (2) a general investigation of the scientific questions involved in any particular field and the determination of its commercial value and the best method of development.

The first or dominant factor was the determination of the character and the valuation of the public land. These determinations were made wholly for the use of the Government itself in disposing of its mineral land. The second or general investigation of the mineral resources of the country was made for the benefit of the public at large and the results of this work are embraced in the series of reports of which this volume is one. The order in which the fields are examined depends entirely on the needs of the Government in disposing of its land now on the market, but in general the more important fields in the public-land States have been examined first.

The work has been done under the general direction of the writer, who has been most ably assisted in the coal work by Cassius A. Fisher and all the men engaged in the work. It is impossible to enumerate the services performed by each man, but the success of the work has been due to the individual efforts of every member of the force and also to the hearty cooperative or team work without which it would have been impossible to carry on the work successfully. Although economic questions had to be given prominence, the writer wishes to congratulate each geologist on the amount of scientific data which have been accumulated and on the permanent value of the results and their bearing on the vexed question of the stratigraphy of the American Mesozoic and Tertiary rocks. The writer desires particularly to acknowledge his indebtedness to T. W. Stanton and F. H. Knowlton, who have so ably assisted in field and office in collecting and interpreting the fossils associated with the coal beds. This work has been invaluable, for without it the tangled problems of correlation and stratigraphy could not have been solved.

For forty years the age of the coal-bearing rocks of the Rocky Mountain States has been in dispute, and while it can not be claimed that the question is settled, still the Survey's systematic examination of the coal fields during the last three years, in connection with the classification of the lands, has gradually brought order out of chaos. Now the end seems to be nearly in sight, and it is confidently believed that a few years' work will completely solve this perplexing problem.

Necessarily, the classification and valuation of coal land presupposes a careful study of the coal itself to determine its physical and chemical properties and its heating value. In order to make such a study, samples have been collected from all the fields examined and either proximate or ultimate analyses made in accordance with regulations adopted by the American Chemical Society, the highest authority in this country. Sampling was done systematically and uniformly, and it is believed that the resulting analyses will be

accepted as representative of the coals of the various fields. No other organization can carry on analytical chemical work so extensively and impartially, and the results should become the standards not only for buying and selling coal, but also for buying and selling coal land. The coal analyses already made by the United States Geological Survey number many thousand, and all of these are strictly comparable, except in a few cases, where weathered coal not typical of the bed or of the field was included in the sample. The analyses contained in this volume are published for the first time and they constitute an important addition to the mass of data already available regarding the composition and relative values of American coals.

COAL AND LIGNITE.

STRATIGRAPHY AND COAL BEDS OF THE INDIANA COAL FIELD.

By GEORGE H. ASHLEY.

INTRODUCTION.

In 1898 the State Survey of Indiana published a detailed report on the coal deposits of that State. In the years between 1898 and 1908 the coal industry of the State expanded greatly, several hundred new mines having been opened and literally thousands of drillings having been put down. The result of this work was to multiply greatly the available knowledge of the coal measures, as well as to show the existence of errors in the earlier report. In cooperation with the State the United States Geological Survey therefore made a reexamination of the area of development in 1908, the work being done by the writer with the assistance of E. F. Lines. The economic results will be published by the state geologist of Indiana, W. S. Blatchley, in his annual report for 1908. The scientific results will be published by the United States Geological Survey in a future report on the Eastern Interior coal field. The present paper is a brief preliminary general account of the stratigraphy and coal beds of the Indiana coal field.

THE INDIANA COAL FIELD.

The coal measures of Indiana lie in the southwestern part of the State, extending from Warren County on the north to Ohio River on the south, and eastward to a northwest-southeast line running from Warren County to Perry County. They cover practically all of sixteen counties and parts of nine additional counties. The Indiana field is part of the Illinois coal basin, or the Eastern Interior coal region. This region has a true basin shape, being deepest in the center in southeastern Illinois and rising to a rim on all sides. The Indiana

field is a part of the eastern or northeastern rim, extending in the southwest corner of the State well into the center of the basin.

The coal measures have a total thickness of approximately 2,000 feet, of which about 1,300 feet occurs in Indiana. Of this 1,300 feet there are 600 feet of barren beds at the top, then a 500-foot interval which contains most of the workable coals, followed in descending order by 200 feet or more of rocks consisting mainly of sandstone. Recent work of David White indicates that the rocks of the upper 600 feet are of post-Allegheny age, those of the next 450 feet of Allegheny age, and the lower rocks of Pottsville age.

THE COAL BEDS.

OCCURRENCE.

Coal occurs at about thirty-four different horizons, of which about twenty-five have a fairly wide persistence. Of these beds one is workable nearly everywhere in the State where it outcrops and eight others are workable over large areas. Several of the smaller beds are workable locally. The average thickness of all the beds of the State is probably less than 2 feet, but the workable beds range from 3 to 8 feet. The most important bed in the field probably averages 5 feet within its outcrop, and over large areas averages 6 to 8 feet. Many of the other beds average 6 to 8 feet over several hundred square miles, but are thin or absent over adjacent areas. The maximum thickness measured was 10 feet 2 inches, though thicknesses of 11 to 15 feet are reported in "swamps."

A few individual coal beds can be traced the whole length of the Indiana coal field. In one case this tracing appears to be thoroughly reliable, and in several others it is apparently good, though the possibility of error must be admitted. Still other coal beds can be traced with only a fair degree of probability. On the other hand, beds which maintain a thickness of 6 or 8 feet over large areas thin out within the space of a few miles. In some beds such thinning out is against the edge of its basin, and though the horizon of the coal can be traced for miles no further indication of coal can be seen within the State. In other beds the coal is very regular over large areas and very irregular over similarly large areas beyond.

In general the upper beds are much more regular than the lower beds. In fact, the lowest beds occur in small, nearly detached basins, usually lying in a west of north and east of south direction and ranging from a few acres to several square miles in extent. In the center of one of these basins the coal may have a thickness of 5 feet, but between the basins on the ridges the thickness may decrease to as many inches. In these basins it is observed that where the coal has

several benches the lowest benches thin out first in approaching the rise, so that the coal going over the divide into the next basin may represent only the upper part of the top bench. Of even more interest is the fact that at two horizons where the coal in the basins has a somewhat distinctive section, the same section is repeated from basin to basin over hundreds of square miles.

NAMES OF COAL BEDS.

Probably no coal field in the United States of equal size has been studied so completely and is now so well known as the Indiana field. One result of this study has been to show that as a rule thick or workable coals are found at only a few horizons. These horizons have been designated by Roman numerals from II to VII. Intermediate coals have been named by the addition of a small letter to the name of the first principal coal below. Thus the rider of coal V is coal Va; the still higher thin coal would be Vb, etc. Coal II is the lowest of the coals that David White has thought will prove to be of Allegheny age. To the underlying coals, thought by him to be of Pottsville age, local names have been given.

TYPE SECTION OF COAL BEDS.

One of the interesting things that have been emphasized by the results of recent drilling is the tendency of the coals in Indiana to reach their best development midway between the north and south boundaries of the field. Thus, several coals that are 6 to 8 feet thick in Sullivan, Greene, Clay, and Vigo counties are thin or lacking toward the north and south ends of the coal field and, with possibly one exception, all the workable coals of the State are workable in that area. The coals from coal III to coal VIII are best known in Sullivan and Greene counties, where each of the numbered beds ranges from 4 to 8 feet in thickness, with sections so distinctive that they can hardly be confused, and where about four hundred detailed sections, many of which show every foot of rock from coal III up to coal VIII, help to make the stratigraphy quite clear. Though considerable drilling has shown the relation of coal III to all the lower coals in Greene County, they are still better known in northeastern Vigo and northern Clay counties.

The portion of the following section from the Merom sandstone down to coal III is therefore taken in Sullivan County and the portion from coal III to the Lower Block coal in northeastern Vigo and northern Clay counties. The beds above the Merom sandstone are best exposed in Gibson County.

Type section of coal measures in Indiana.

	Thickness of beds.	Total thickness.
Gibson County.	*Feet.*	*Feet.*
Sandstone	6	
Shale, etc., with 6 inches local coal	20	
Sandstone, hard bedded	15	
Shale, partly covered	25	
Shale, sandy	8	
Shale, blue and argillaceous	8	
Limestone, soft and shaly to very hard	4	
	86	86
Aldrich coal	1	87
Shale, coaly	2	
Sandstone (sandstone of Mansfield Hills, etc.)	28	
Limestone, hard, gray, and fossiliferous	3	
Shale, black	3	
	36	123
Friendsville coal (0–4 feet)	2	125
Clay	1	
Sandstone, upper part massive (sandstone of Gordon Hills)	35	
Limestone or calcareous and fossiliferous sandstone	3	
Shale, black	5	
	44	169
Parker coal	1	170
Shale	16	
Sandstone	20	
Shale	10	
Sandstone, soft, and sometimes shaly	20	
Clay shale, bluish	5	
Sandstone, shaly	20	
Shale	25	
Top of Inglefield (Merom?) sandstone.		
Merom, Sullivan County.		
Sandstone, Merom	40	
"Productal" limestone, rich in fossils	3	
Shale, calcareous	1	
Shale, dark, bituminous	5	
	165	335
Coal VIIIb, rash	1	336
Fire clay	2	
Clay shale, dark	4	
Sandstone, coarse, hard	3	
Limestone, crinoidal, shelly	1	
	10	346
Place of coal VIIIa (?).		
Fire clay	½	
Sandstone, flaggy	3	
Shale, drab, with large iron nodules	10	
Shale, gray, with pyritous partings	25	
Sandstone, quarry	15	
Clay shale, hard, siliceous	4	
Clay shale, siliceous, with large iron nodules	7	
Clay shale, light-colored, with small round iron nodules	5	
	69½	415½
Coal VIII	3½	419
Sullivan and Greene counties in general.		
Clay	5	
Limestone	4	
Shale	8	
Sandstone	20	
Shale	20	
Sandstone, shaly	10	
	67	486
Coal VII (3–6 feet)	4	490
Clay	5	
Limestone	6	
Shale	3	
Sandstone	15	
Shale	10	
	39	529
Coal VI (5–9 feet)	6	535
Clay	5	
Coal	0–1	
Shale	5	
Sandstone	10	
Shale	23	
	44	579

Type section of coal measures in Indiana—Continued.

	Thickness of beds.	Total thickness.
Sullivan and Greene counties in general—Continued.	*Feet.*	*Feet.*
Coal Va	2	581
Clay	3	
Sandstone	10	
Shale	10	
Limestone	5	
Shale, black, sheety, with pyrite concretions	5	
	33	614
Coal V (0–11 feet)	7	621
Clay	4	
Limestone	2	
Shale	20	
Sandstone	25	
Shale	15	
Limestone	1	
Shale, black, sheety	2	
	69	690
Coal IVa	2	692
Clay	3	
Sandstone, shaly	30	
	33	725
Coal IV (4–6 feet)	5	730
Sandstone	30	
Shale	10	
Limestone	1	
Shale, black, sheety	2	
	43	773
Coal IIIa	1½	774½
Clay	3	
Shale	15	
	18	792½
Coal III (0–13 feet)	6½	799
Clay	6	805
Northeastern Vigo County and northern Clay County.		
Coal	1	806
Clay	1	
Shale	15	
	16	822
Coal	1½	823½
Clay	2	
Shale	2	
Sandstone	3	
Shale	10	
	17	840½
Coal	2	842½
Clay	3	
Shale	3	
Sandstone	8	
Shale	2	
Limestone	2	
Sandstone, shaly	10	
	28	870½
Coal	1	871½
Shale	10	881½
Coal II (0–4 feet)	2½	884
Clay	2	
Limestone	10	
Shale, black	3	
	15	899
Coal, Minshall (0–6 feet)	3	902
Clay	4	
Shale	7	
Sandstone	12	
Shale	7	
	30	932
Coal, upper block (0–5 feet)	3½	935½
Clay	4	
Shale	7	
Shale, sandy ("fake")	20	
	31	966½
Coal, lower block (0–5 feet)	3	969½
Clay	3	
Sandstone, Mansfield, replaced with shale at many places in the basin	70	
Shale	10	
	83	1,052½
Coal	1½	1,054
Clay	2	
Shale	10	
	12	1,066
Top of lower Carboniferous.		

The above section does not include the uppermost members in Gibson County nor the lowest members in the southeastern part of the field.

To give a better idea of the relation of the intervals between the different coal beds and the relative thickness of these beds in different parts of the coal field, the following table is inserted:

Intervals and thickness, in feet, of principal coals at a number of points over the Indiana coal field.

	Clinton district.	Northwestern Vigo County.	Northeastern Vigo County.	West Terre Haute.	Northern Sullivan County.	Central Sullivan County.	Southern Sullivan County.	Northern Knox County.	Washington, Daviess County.	Central Gibson County.	Northwestern Warrick County.	Central Warrick County.	Evansville.	Western Kentucky.
Coal VII	4½	5	.....	5	4½	4	3	3	.....	3½	3	2½	3	2–7
Space	55	50	.....	50	40	30	55	40	.....	15	10–½	10	15	3–40
Coal VI	0	0	.....	0	5½	7	4½	5½	.....	0–4½	3–0	2–0	0	0–9
Space	50	50	.....	45	45	45	45	50	.....	80	90	65	60	80
Coal Va	1½	1½	.....	1	2½	3	2	3	2	1–0	1–0	0	0	0
Space	20	35	.....	30	35	30	35	30	35	50	25	25	25	25
Coal V	6	5	.....	5	6	6	5	7	7–4	6	4½	4–9	4	5
Space	60	60	.....	63	65	85	85	75	90	90	50	45	45	.....
Coal IVa	1	2	.....	2	2	3	1½	1	1½	1–0	1	½	0	.....
Space	30	35	.....	45	45	25	30	25	35	20	45	45	40	.....
Coal IV	4	4	.....	5	3½	5	0	4	1	4	2½	2½	3	.....
Space	45	40	30	30	45	30	35	....	40	.....	.....	40	....	.....
Coal IIIa	2	2½	1½	2	1	1	1	....	1½	.....	.....	0	....	.....
Space	40	40	25	25	20	25	25	....	40	.....	.....	35	....	.....
Coal III	6	6½	7	6	7	6½	5	....	2	.....	.....	0–3	....	.....
Space	.....	.....	110	....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....
Minshall coal	.....	.....	4	....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....
Space	.....	.....	30	....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....
Upper Block coal	.....	.....	3	....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....
Space	.....	.....	30	....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....
Lower Block coal	.....	.....	4	....	.....	.....	.....	.....	.....	.....	.....	.....	....	.....

INDIVIDUAL COAL BEDS.

In discussing the coals it is convenient to take coal V as a base horizon. It is a thick coal with certain peculiarities of roof which render its recognition possible through the whole length of its outcrop in Indiana. It is at almost every point characterized by a roof of black sheety shale, the under surface of which contains pyrite concretions that, as a rule, project downward into the coal. In some mines these concretions are very abundant, the roof being almost botryoidal from their presence. In other mines they are only scattered, possibly one or two to a room, but they are absent in few of the mines. Some of them project down into the coal as much as 4 or 5 feet. Overlying the black shale is a limestone. Similar black shales overlie other coals and are in turn overlain by limestones, but these coals are almost invariably thin, the accompanying limestone is usually thin, and the presence of the pyrite concretions is not everywhere obvious. There is only one other coal, lying about 300 feet stratigraphically below coal V, whose overlying limestone is thick at

many places and which is itself of workable thickness. Its position so far below coal V, however, insures its outcropping well to the east of the outcrop of that coal, so that, although the two have often been confused in the past, there is no danger, with the present knowledge of the coal field, of their being taken for the same coal. Coal V has a thickness of 4 to 10 feet, averaging from 5 to 8 feet over a large part of the area within which it outcrops and maintaining this thickness with considerable uniformity from southwestern Vermilion County, where it enters the State, to Ohio River.

About 70 feet above the top of coal V, in Sullivan County, lies coal VI, ranging in that county from 6 to 8 feet in thickness. Practically everywhere it is divisible into four benches—an upper bench of about 2½ feet, a thin bench of 4 to 6 inches, a lower bench of about 2½ feet, and a bottom bench of 1 foot. The two main benches range from 2 to 2½ feet or more. Between these benches occur gray-shale partings that are nearly everywhere half an inch thick. When exposed to the atmosphere in the entries of the mines this gray shale weathers to a white clay, so that in the mines on this coal bed there appear to be two white chalk marks about midway of the wall at every point. Practically no doubt can therefore exist as to the correlation of this coal within that district. The bottom bench of 1 foot is bony and is usually left in the mine. At the north edge of Sullivan County this coal becomes irregular, in places appearing to run out entirely, and north of that point neither drilling nor mining finds any trace of it in Indiana. It appears to maintain its thickness south of Sullivan County as far as Bicknell and for several miles farther south, though it becomes broken up toward the southwest. From that locality southward it disappears as a regular bed, in many places being entirely absent and in others appearing as a thin bed of 1 or 2 feet. It reaches a workable thickness in a few localities and is commercially worked at two points in Gibson County. Apparently it approaches nearer and nearer to the overlying coal toward the south, until the two range from 20 feet to 6 inches apart, and in at least one place the two coals have been mined together. It will be discussed further in connection with the occurrence of coal VII, in the southern part of the State.

About 40 feet above the top of coal VI in Sullivan County comes coal VII, which is practically everywhere a solid coal from 3 to 6 feet in thickness, overlain by shale or sandstone. North of Sullivan County this bed is readily traced past Terre Haute and through the southwest corner of Vermilion County out of the State. West of Terre Haute and to the north it shows a thickness of 4 to 5 feet of good coal, overlain by 1 to 2 feet of bony coal. A few feet below this coal, in all of the northern part of the coal field, is a limestone

that is believed to be one of the persistent members of the coal measures. South of Sullivan County this coal bed can be traced through Wheatland, in the hills west of Petersburg, and on to Ohio River, with a thickness of 4 feet or less, becoming rather thin as Ohio River is approached. As stated above, the underlying coal VI is close beneath it from Gibson County southward, and in one place in western Warrick County they are worked together. In general the limestone below coal VII lies between the two coals, and in many places where the two coals are close together the limestone forms the only parting. This condition continues into western Kentucky, where coal VII is known as Kentucky 12 and coal VI as Kentucky 11. Coal V of Indiana corresponds to coal 9 of Kentucky.

Above coal VII in Indiana, as a rule, only thin coals are found. In a few places these coals reach a thickness of 3 or 4 feet, but in nine out of ten drillings they show thicknesses of less than 2 feet, and commonly less than 1 foot. Small coals occur between coal V and coal IV, and though in some places they reach a thickness of 3 feet, as a rule they are thin, and in the presence of much thicker coals above and below they will not be considered of workable character for a long time.

Coal IV, the bed extensively worked around Linton, is from 100 to 130 feet below coal V. It is commonly a solid coal, with a sandy shale or sandstone roof and a sandstone or sandy clay floor. It shows a tendency to split in many districts, the splitting being in places rather extensive, so that the benches are separated by 10 to 15 feet or more. It can be traced northward to Seelyville, where it is the surface bed, ranging from 3 to 6 feet in thickness, and on to the horseshoe bend of Little Vermilion River, being of workable thickness nearly everywhere, except as it may be broken up by one or more large partings. It is a coal of excellent quality. To the south the thickness of this coal is somewhat less, usually not being more than $3\frac{1}{2}$ feet and toward Ohio River averaging probably less than $2\frac{1}{2}$ feet. In that district it is nearly everywhere a solid coal, with either a shale or a sandstone roof.

About 70 feet below coal IV in Greene County is coal III, a bed 6 to 8 feet thick, almost invariably with one or more regular partings. It maintains this thickness northward through western Clay County and eastern Vigo County, being the large bed worked around Turner and Stanton and the principal bed at Seelyville, Fontanet, and Rosedale. It tends to be a strong steam coal, but in many places has a high content of sulphur. In the Rosedale-Fontanet district the sulphur occurs in the form of one or more regular partings and therefore is more easily separated. North of Coxville this bed occurs in scattered patches for a distance of 6 or 8 miles, beyond which it is

absent altogether. South of Greene County no bed of this character is found, and it is possible that the coal runs out entirely. In many places one or more thin coals are found about in the position of coal III, and it has been assumed that they may possibly represent this coal. Few of these thin coals south of Greene County, however, are workable, though here and there they increase to 3 feet in thickness. The coal called the Rock Creek coal in the Ditney folio possibly belongs at the horizon of coal III of Greene County.

About 100 feet below coal III in northeastern Vigo County is a coal bed that is being worked around Fontanet, Minshall, and Mecca, and at other points. It has been called in the trade the Minshall coal, and this name has been retained for it, as it comes below the bed called coal II in the general columnar section. It is a coal of variable thickness, lying in basins and ranging from 5 feet to a fraction of an inch. Overlying it in many places is black shale, which is not everywhere sheety, and above that a heavy limestone. A limestone underlain by a coal that is in some localities of workable thickness occurs at many points through the northern part of the Indiana coal field in Parke, Fountain, and Warren counties. It has been assumed to belong at the horizon of the Minshall coal. In the Brazil district of Clay County this bed has been called the Rider Block coal, as it lies only about 30 feet above the Upper Block coal.

In the Brazil district the two block coals lie about 30 feet apart. Each may have a thickness of about 5 feet in the center of the basins and thin down to a few inches on the hills between the various basins. The Upper Block coal has slightly the greater thickness. It is usually a solid coal, with a 2-inch band of brittle coal a little below the middle. It is also distinguished from the Lower Block coal by the fact that the vertical joints that characterize both the block coals are in the Upper Block coal more open at the top and are indistinct below this brittle "bench mining." The Lower Block coal is a solid coal except for a smooth parting 6 to 10 inches from the top. The coal above that parting is not of the block character. The joints are more open at the bottom and, as a rule, do not penetrate this upper bench of coal. In the center of the basins below the main bench there usually occurs clay, then 1 to 2 feet or more of bony coal, then, locally, up to 2 feet of good coal, with clay underneath. Toward the edges of the basins these underlying benches thin out one at a time, beginning at the bottom, and at the crest of the divide even the lower part of the main coal has thinned out, leaving possibly only the thin upper bench to pass over to the next basin. The two block coals can be traced northward into Fountain County, though the Lower Block appears to be absent in Warren County. The block coals extend southward with their characteristic features into

southern Clay County and central and eastern Greene County. South of that region their characteristics have not been recognized, and correlations made with them are only suggestional in character. Through Daviess, Pike, Dubois, Warrick, Spencer, and Perry counties a large number of coals are found, but no extensive drilling and relatively little mining have been done, so that the correlation of these coals from point to point is very uncertain. Furthermore, the fact that they occur in basins, like the coals of corresponding position to the north, means that at many points where they appear they may be only a few inches thick and not recognized as the same coal that may be opened by a country bank a few hundred yards away. The fact that the coal on the divides between the basins ranges from 20 to 50 feet higher than the coal in the center of the basin also confuses any attempt at correlation on the meager information at present in hand. In some areas it has been possible to make correlations for short distances. For example, a coal that is overlain by limestone and that lies about in the position of the Minshall coal in the northern part of the State and was called the Holland coal in the Ditney folio has been recognized on Sugar Creek, in southeastern Daviess County; over a considerable territory south of White River, north and south of Holland, in Dubois County; and around Buffaloville and Newtonville, in Spencer County. Although present knowledge of the coals of these southern counties does not seem to hold out hope of a large coal output, it is quite possible that the coals there, when better known, may show the presence of as much coal in this part of the section as is found in Clay or other more northern counties. In the southeastern part of the coal field is a coal that has been long extensively worked at Cannelton, from which it has been called the Cannelton coal. Like the other coals, it occurs in basins, ranging where present from 4 feet in thickness down. It has been recognized along Anderson River, as far north as St. Meinrad. It is possible that it is the same coal that locally shows a workable thickness around Shoals.

THE WASHBURN LIGNITE FIELD, NORTH DAKOTA.

By CARL D. SMITH.

INTRODUCTION.

The Washburn field, a small part of a large area of lignite-bearing rocks of Tertiary age which covers the western half of North Dakota, comprises parts of McLean, Oliver, Mercer, and Burleigh counties

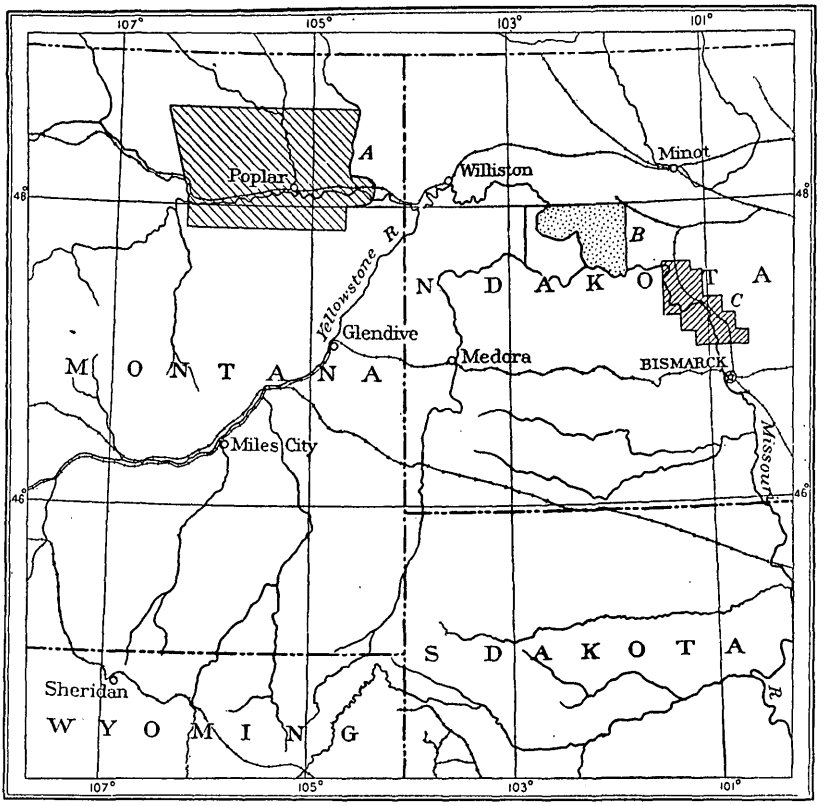


FIGURE 1.—Index map showing location of Washburn (*C*), Fort Berthold Indian Reservation (*B*), and Fort Peck Indian Reservation (*A*) lignite fields, North Dakota and Montana.

and lies a short distance to the southwest of the center of the State, 40 miles up Missouri River from Bismarck. (See fig. 1.) The investigation of this field was undertaken primarily to obtain information

regarding the character, depth, and horizontal distribution of lignite beds within reach of irrigable lands along Missouri River, which it is proposed to water by pumping, with lignite as fuel.

That part of the field east of Missouri River is traversed by a branch of the Minneapolis, St. Paul and Sault Ste. Marie Railway. A projected branch of the Northern Pacific Railway, leaving the main line at Mandan, follows closely the west bank of the Missouri through the field. At certain seasons the river furnishes transportation to and from the region.

Acknowledgments are due to Mr. Jay W. Bliss for his able assistance in the field work, and to Mr. T. R. Atkinson, state engineer, for additional notes and data concerning lignite near Wilton.

TOPOGRAPHY.

The field is mainly a smooth, rolling prairie with bluffs and badlands here and there along the larger streams. The elevation of the water surface of the Missouri at ordinary stage at Washburn is 1,656 feet above sea level. Away from the immediate valley of the Missouri the general elevation averages from 200 to 350 feet higher than the river.

The presence of glacial material left by the retreat of the great ice sheet, which covered this part of the State in comparatively recent geologic time, has no doubt had a tempering effect on the topography. In other parts of the State, beyond the limit of glaciation, where conditions are otherwise similar to those around Washburn, badlands topography is common along the larger streams. Although the direct effects of glaciation are not now apparent, probably on account of the softness of the local formations and the consequent rapid weathering, indirect results appear in numerous intermittent lakes and abandoned stream channels.

GEOLOGY.

STRATIGRAPHY.

All the stratified rocks described here belong to the Fort Union (early Eocene) formation. In the past these rocks have been generally referred to the Laramie (Cretaceous), but later work in the region has proved that they are Tertiary. The formation consists of sands, clays, and sandy clays, in about equal proportion in alternating layers, with beds of lignite scattered throughout. The clays and sandy clays are usually dark gray or somber in color; the sands and sandstones vary in shade from light blue to buff. All of this material, except local sandstone lenses and irregular sandstone layers, is soft and weathers rapidly.

Overlying the Fort Union formation is a mantle of glacial drift, varying greatly in thickness and made up of a variety of materials

foreign to this general region. It is usually covered by soil, but in places erosion has tended to segregate the bowlders at the bases of steep slopes or has partly swept away the soil, thus leaving the bowlders on or near the surface. They vary in size from mere pebbles to masses several feet in diameter and are used principally for building foundations.

STRUCTURE.

So small an area was covered by this investigation that little can be said of its structure. Evidence now in hand, however, indicates that there is a slight dip of the formations toward the east, probably not more than 2 feet to the mile. This is inferred from the fact that a bed of lignite, which is low in the section on the west side of the field dips beneath the river toward the east. So far as mining is concerned the lignite beds and containing formations may be regarded as lying flat.

THE LIGNITE.

GENERAL STATEMENT.

By reference to the columnar section on the map accompanying this report (Pl. I) it will be seen that workable beds of lignite occur at six horizons in the 315 feet of strata lying above river level. The exact relation of the beds mined at Wilton to those about Washburn is not known, but it is thought that they are slightly higher. No records of deep wells in this area have been obtained, hence it is impossible to say anything positive concerning lignite beds that may underlie the field at greater depths than river level. It is probable, however, that many workable beds of lignite could be found to a depth of 1,500 feet.

Heretofore the lignite beds of this general region have been described as lenticular and impossible of correlation for distances exceeding 2 or 3 miles. It is true that the lignite varies considerably in thickness from point to point, but the term "lenticular" is misleading and considerable work in this general field has proved that some of the more important beds can be correlated or even traced in their outcrops for much greater distances than 2 or 3 miles.

Many outcrops of lignite beds, covered by glacial material or talus, are marked by springs and seepages. Beds of lignite seem to be the best carriers of underground water. This is probably due to the variable character of the sands and clays which make up the section. Although a formation at a certain horizon may be in one place a porous sand well adapted to carrying water, its character may so change within a short distance horizontally that water can not find its way through. In this way the lignite beds, which are fairly homogeneous in texture and more persistent laterally than other formations, become the water-bearing beds.

The accompanying map (Pl. I) shows the locations of the principal mines and prospects in the field, with a columnar section indicating the vertical distribution of the various beds of lignite. This section was compiled from widely separated exposures, and it is not to be assumed that fuel will be found at a given elevation in all parts of the area.

It is quite probable that a number of lignite exposures and mines not represented on the map are to be found in the field. As few townships as possible have been used to show the general connections of the different districts discussed and the positions of the railroads. Hence, if any mines in the field are not here discussed, the omission is due not to oversight but to lack of time in which to visit them.

DETAILED DESCRIPTION OF LIGNITE EXPOSURES.

A few representative detailed sections of lignite beds in the area covered by this report are given in the following pages.

OLD COAL HARBOR DISTRICT.

Joe Mann mine.—At the base of the bluff in the NW. ¼ sec. 34, T. 147 N., R. 84 W., lignite is being mined at present. The method used is a combination of stripping and drifting.

Section at Joe Mann mine.

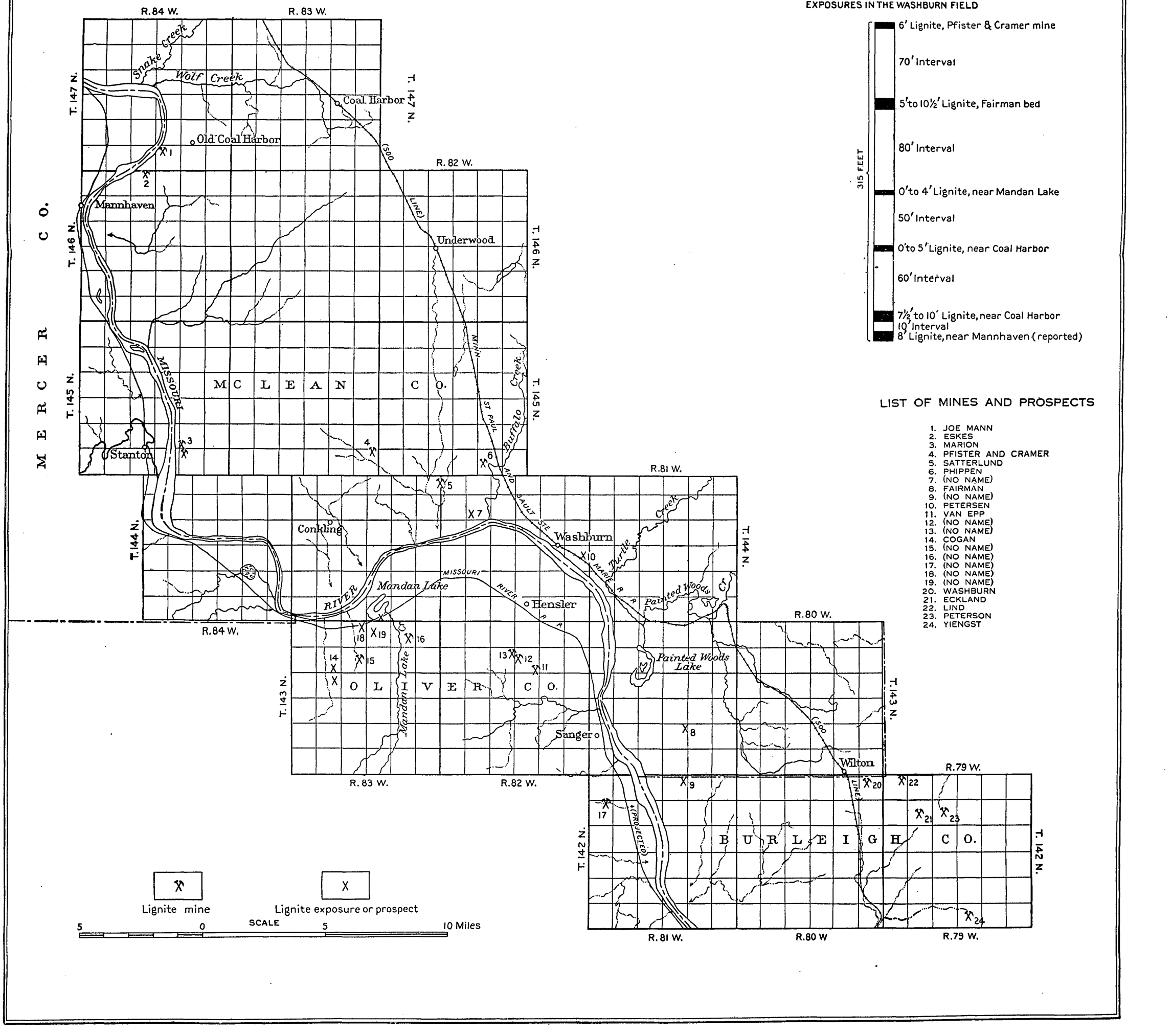
	Ft.	in.
Clay roof.		
Lignite	2	10
Clay		6
Lignite	4	6
Clay, sandy	1	2
Lignite	2	5
Total lignite	9	9

Both up and down the river from this locality the lignite has been burned along its outcrop, producing a red clinker. A short distance north of the mine the lignite is on fire at present. Its horizon lies from 15 to 30 feet above water level at ordinary stage. The fuel is mined for local neighborhood use and is delivered by wagons.

Eskes mine.—About 1 mile southwest of the Joe Mann mine, in the NE. ¼ sec. 4, T. 146 N., R. 84 W., Eskes & Son are stripping a bed of lignite in the face of the bluff, 50 feet above the bed at the Joe Mann mine.

Section at Eskes mine.

	Ft.	in.
Clay roof.		
Lignite	2	7
Clay and lignite		2
Lignite	2	6
Total lignite	5	1



COMPOSITE SECTION COMPILED FROM EXPOSURES IN THE WASHBURN FIELD

315 FEET

- 6′ Lignite, Pfister & Cramer mine
- 70′ Interval
- 5′ to 10½′ Lignite, Fairman bed
- 80′ Interval
- 0′ to 4′ Lignite, near Mandan Lake
- 50′ Interval
- 0′ to 5′ Lignite, near Coal Harbor
- 60′ Interval
- 7½′ to 10′ Lignite, near Coal Harbor
- 10′ Interval
- 8′ Lignite, near Mannhaven (reported)

LIST OF MINES AND PROSPECTS

1. JOE MANN
2. ESKES
3. MARION
4. PFISTER AND CRAMER
5. SATTERLUND
6. PHIPPEN
7. (NO NAME)
8. FAIRMAN
9. (NO NAME)
10. PETERSEN
11. VAN EPP
12. (NO NAME)
13. (NO NAME)
14. COGAN
15. (NO NAME)
16. (NO NAME)
17. (NO NAME)
18. (NO NAME)
19. (NO NAME)
20. WASHBURN
21. ECKLAND
22. LIND
23. PETERSON
24. YIENGST

MAP OF WASHBURN LIGNITE FIELD, NORTH DAKOTA.

By C. D. Smith.

The outcrop of this bed can be easily followed to the south for 4 or 5 miles. At several places it has been stripped and is marked by a fringe of clinker, having been burned. The bed is extremely variable in thickness, its position in the section at other localities being occupied by bituminous clay or thin, valueless seams of lignite.

Marion mine.—In the SW. ¼ sec. 26, T. 145 N., R. 84 W., an entry has been driven on the Joe Mann bed of lignite, which is easily traceable from the Joe Mann mine southward to the Marion mine by the clinker produced by burning along its outcrop. The section at the Marion mine shows 7 feet 9 inches of lignite, with clay roof and clay floor.

About one-fourth mile south of the Marion mine another entry is being driven on the same bed, the thickness being about the same.

A short distance south of these openings the outcrop of this bed of lignite, as marked by the clinker, disappears below the lowland bordering the river, and was not seen again in the field.

The writer did not visit the region west of the river opposite the points mentioned above. F. A. Wilder[a] gives the following measurements of beds seen along the bluff from Mannhaven to Stanton:

Section near Mannhaven.

	Feet.
Lignite, good	6
Clay	2
Lignite	1
Clay	1
Lignite, good	2
Clay	10
Lignite, good	8
Sand to river level	10
Total lignite	17

Wilder states that this section may be seen for 2,000 feet along the river.

Section 3 or 4 miles south of Mannhaven.

	Ft.	in.
Lignite	3	
Clay		6
Lignite	3	
Clay	2	
Lignite	3	
Total lignite	9	

This bed probably represents the upper part of the section at Mannhaven.

According to Wilder a 7-foot bed outcrops near river level at the edge of the flat 2 miles above Stanton. This bed doubtless cor-

[a] The lignite of North Dakota and its relation to irrigation: Water-Supply Paper U. S. Geol. Survey No. 117, 1905.

responds to the bed seen by the writer at the Marion mine, east of the river, opposite Stanton.

WASHBURN DISTRICT.

Pfister & Cramer mine.—At an elevation of 250 feet above river level, in the NE. ¼ sec. 36, T. 145 N., R. 83 W., Pfister & Cramer are mining a bed of lignite by stripping. The bed measures 6 feet thick, but the upper 1½ feet is weathered and worthless.

Satterlund mine.—At an elevation of about 180 feet above the level of Missouri River occurs a bed of lignite, which is for convenience of reference called the Fairman bed. It is exposed at a number of places about Washburn. The Satterlund mine, in the NE. ¼ SE. ¼ sec. 1, T. 144 N., R. 83 W., is probably on this bed.

Section at Satterlund mine.

	Ft.	in.
Clay roof.		
Lignite	7	
Clay		½
Lignite	2	
Clay		3
Lignite (thickness reported)	1	6
Total lignite	10	6

The cover above the lignite is here 25 to 40 feet thick. The mine is operated by a drift 400 feet in length, and its output amounts to 30 or 40 tons a day. The product is consumed by residents of Washburn and vicinity.

Phippen mine.—Northeast of the Satterlund mine, in sec. 35, T. 145 N., R. 82 W., lignite is being taken out at present by stripping. The mine is known locally as the Phippen mine, and is probably in the same bed as the Satterlund. At the time this mine was visited only the lower part of the bed could be seen. A section of the part of the bed exposed shows 5 feet 4 inches, including two partings.

Section at Phippen mine.

	Ft.	in.
Débris roof (top of bed not seen).		
Lignite		8+
Clay		4
Lignite	2	8
Clay		5
Lignite	1	3
Total lignite	4	7+

Lignite is mined here to supply local demands, and is variously reported from 6 to 14 feet thick. A considerable area about the mine is underlain by this bed, but the cover is relatively light.

On the point of the hill west of the wagon road, in sec. 8, T. 144 N., R. 82 W., an opening has been made at the horizon of the Fair-

man bed, 180 feet above river level, but the lignite was found to be replaced by several feet of carbonaceous clay, or "black jack."

In the river bluff south of Conklin the stratigraphic position of the Fairman bed is occupied by two thin beds separated by a large parting. The lignite is here burned along its outcrop for several miles and may be locally workable. Near old Coal Harbor the horizon of the Fairman bed is occupied by thin, worthless seams of lignite.

Old Fairman mine.—Lignite at the old Fairman mine, in the NE. ¼ sec. 27, T. 143 N., R. 81 W., shows a thickness of 7 feet of apparently good coal, with two thin partings.

Section at Fairman mine.

	Ft.	in.
Clay roof.		
Lignite	1	3
Clay		6
Lignite	1	6
Clay		3
Lignite	3	6
Total lignite	6	3

Due south of the old Fairman mine, in sec. 3, T. 142 N., R. 81 W., is a partial exposure of a bed of lignite at the same elevation, which is taken to be a continuation of the Fairman bed. Its thickness at this locality could not be measured.

Between the Fairman bed and Missouri River level, in the Washburn district, no lignite of any consequence has been observed. A bed 75 feet above water level has been mined by Mr. Petersen at his house, in sec. 24, about 1 mile southeast of Washburn. The bed here varies in thickness from 1½ to 2 feet and is underlain by 4 feet of "black jack" or bituminous shale. In a small draw which runs southward through sec. 8, T. 144 N., R. 82 W., a number of seepages indicate that one or two beds of lignite, probably thin, are to be found about 50 feet above river level.

DISTRICT SOUTH AND WEST OF MISSOURI RIVER.

Van Epp mine.—A bed of lignite that corresponds in elevation to the Fairman bed is mined by stripping in the SE. ¼ sec. 10, T. 143 N., R. 82 W., 3 miles south of Hensler post-office. The bed is 6 feet 4 inches thick, without partings. One mile northwest of this opening are two others, one in sec. 10, the other in sec. 9, both of which show 5 feet of clean, hard lignite. These are doubtless on the same bed as the Van Epp mine.

Old Cogan and other mines.—About 6 miles west of the above-mentioned locality, in the SE. ¼ sec. 8, T. 143 N., R. 83 W., a bed of lignite at the same horizon was formerly mined by stripping at the Cogan mine, but the workings have been abandoned and have caved

in. The bed measures 3 feet 10 inches and is very hard and free from partings. About 1 mile east of Cogan's mine, near the middle of sec. 9, an opening on the same bed shows a thickness of 3 feet 9 inches. Fuel is mined here for local use.

In the SE. ¼ sec. 2, T. 143 N., R. 83 W., a bed of lignite 100 feet above Missouri River is mined for local use. The bed is 4 feet 4 inches thick, with a 2-inch parting 4 inches from the bottom.

Along the gulch which runs northward through secs. 17, 8, and 5, a short distance west of Cogan's mine, lignite varying in thickness from a few inches to 3½ feet outcrops in many places.

Along an eastward-flowing stream in the northern part of sec. 7, T. 142 N., R. 81 W., lignite is being mined for local use from three small strip pits. In the easternmost of these pits the bed measures 3 feet 6 inches, but is said to contain much "slack" or dirty lignite. There are probably two beds here, the upper being mined farther west, up the draw. These beds are about 80 feet above river level, and are probably the same as the beds noted near the mouth of Mandan Lake Creek at the same elevation.

In the NE. ¼ sec. 4, T. 143 N., R. 83 W., about half a mile southwest of Mandan Lake, 50 feet above river level, a bed of lignite 2 feet thick was measured. About half a mile south of Mandan Lake, in sec. 3, a bed of lignite has been mined by stripping. It is about 100 feet above river level. The whole thickness of the bed was not seen, but it is at least 2 feet 6 inches thick.

WILTON DISTRICT.

For information concerning mines in the Wilton district the writer is indebted to Mr. T. R. Atkinson, state engineer of North Dakota. In 1907 the Washburn Lignite Coal Company's mine was visited by the writer, but its location and additional data as to the output and equipment have been furnished by Mr. Atkinson.

The exact relation of the deposits mined about Wilton to those near Washburn is not known, but it is believed that they are slightly higher in the geologic section.

Washburn mine.—The Washburn mine, in sec. 1, T. 142 N., R. 80 W., is the largest and most thoroughly equipped mine in the State. Its output for 1907 and 1908 amounted to 109,992 tons. The lignite is reached by a shaft 60 feet deep, which represents the average thickness of the cover. The underground equipment is very complete and efficient and consists of electric undercutting machinery and electric motors for haulage. The lignite ranges from 8 to 13 feet in thickness, and has a variable parting 1½ feet from the bottom. The entries are unusually wide, and timbering is necessary. As a rule, 6 or 8 feet of the bed is taken out first, leaving lignite for a roof, which is taken down when pillars are pulled.

Eckland mine.—In sec. 8, T. 142 N., R. 79 E., is a small opening known as the Eckland mine. The lignite is about 8 feet thick, and has about 45 feet of cover. The annual production is 800 tons.

Lind mine.—In the NE. ¼ sec. 6, T. 142 N., R. 79 E., at the Lind mine, the lignite is 11 feet 10 inches thick, under a cover of 35 feet. The production is about 700 tons annually.

Peterson mine.—In sec. 9, T. 142 N., R. 79 E., at the Peterson mine, the bed is 11 feet thick, under a cover of 40 feet. The annual production is about 2,000 tons.

Yiengst mine.—At the Yiengst mine, in sec. 34, T. 142 N., R. 79 E., the lignite is 6 feet thick, under 60 feet of cover. The roof and floor are clay. The annual output is about 1,000 tons.

CHARACTER AND USES OF THE LIGNITE.

GENERAL CHARACTER.

The lignite of this field is dark brown in color and tough and woody in structure, but the woody structure is not so evident as in lignite from other parts of the State. It slacks rapidly on exposure to air and sunlight, especially when much handled or subjected to long hauls by rail.

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

On weathering, the lignite, which is usually lusterless and massive, breaks into small, shiny cubical blocks, which appear black, but give a brown streak or powder.

Because of the scarcity of timber in this general region lignite is almost the only fuel available for domestic purposes. The state institutions use native lignite exclusively, and to supply this demand, together with a growing demand from manufacturing plants, several well-equipped mines are in operation on main lines of transportation in various parts of the State.

LIGNITE AND IRRIGATION.

The impracticability of irrigating lowlands along the Missouri by gravity canals has led to the establishment of a pumping plant at Williston, N. Dak., and to the investigation of many other projects for raising water to the desired elevations with lignite as fuel. Two such projects in the Washburn field are now under consideration by the United States Reclamation Service. It is, of course, desirable that lignite be found within easy reach of the proposed location of pumping stations, but this can not always be done, notwithstanding

the general distribution of the fuel. However, there are relatively few irrigable flats along the Missouri between Bismarck and the North Dakota-Montana line where lignite can not be found in minable thickness either at hand or within a few miles.

CHEMICAL ANALYSES AND STEAMING AND PRODUCER-GAS TESTS.

The following analyses and tests [a] were made at the Geological Survey's fuel-testing plant in St. Louis:

Brown lignite from Wilton mine, Washburn Lignite Coal Company, 1 mile east of Wilton, McLean County, N. Dak., on the Minneapolis, St. Paul and Sault Ste. Marie Railway.

This sample was made up of lump lignite and was shipped under the supervision of M. R. Campbell, of the United States Geological Survey. It was used in making steaming test No. 206 and producer-gas test No. 67.

Mine samples Nos. 1935 and 1938 were taken at widely separated points in the mine for chemical analysis.

Analyses of samples as received.

		Mine samples.		Car sample, Laboratory No. 2243.
		Laboratory No. 1935.	Laboratory No. 1938.	
	Air-drying loss	32.30	33.50	12.70
Prox.	Moisture	40.53	41.88	35.96
Prox.	Volatile matter	27.05	26.11	31.92
Prox.	Fixed carbon	27.37	26.73	24.37
Prox.	Ash	5.05	5.28	7.75
Ult.	Sulphur	.76	.96	1.15
Ult.	Hydrogen	.....	.....	6.54
Ult.	Carbon	.....	.....	41.43
Ult.	Nitrogen	.....	.....	1.21
Ult.	Oxygen	.....	.....	41.92
	Calorific value determined:			
	Calories	3,691	.....	3,927
	British thermal units	6,644	.....	7,069

STEAMING TEST.

Test 206, North Dakota No. 3.—Size as shipped, lump. Size as used, average diameter 3 inches, 76.5 per cent; ½ inch to 1 inch, 10.6 per cent; ¼ inch to ½ inch, 4.9 per cent; under ¼ inch, 8 per cent. Duration of test, 5.72 hours. Kind of grate, rocking.

	Test 206.
Heating value of coal, B. t. u. per pound dry coal	11,036
Force of draft:	
Under stack damper, inch water	0.65
Above fire, do	[b] .10
Furnace temperature, °F.	2,093
Dry coal used per square foot of grate surface per hour, pounds	27.99
Equivalent water evaporated per square foot of water-heating surface per hour, do	3.24
Percentage of rated horsepower of boiler developed	90.7
Water apparently evaporated per pound of coal as fired, pounds	3.52
Water evaporated from and at 212° F.:	
Per pound of coal as fired, do	4.13
Per pound of dry coal, do	6.45
Per pound of combustible, do	7.47
Efficiency of boiler, including grate, per cent	56.44
Coal as fired:	
Per indicated horsepower hour, pounds	6.85
Per electrical horsepower hour, do	8.46
Dry coal:	
Per indicated horsepower hour, do	4.38
Per electrical horsepower hour, do	5.41

[a] Bull. U. S. Geol. Survey No. 290, 1905, pp. 138, 139. [b] Forced draft.

PRODUCER-GAS TEST.

Test 67, North Dakota No. 3.—Size as shipped, lump. Size as used, over 1 inch, 85 per cent; ½ inch to 1 inch, 6 per cent; ¼ inch to ½ inch, 3 per cent; under ¼ inch, 6 per cent. Duration of test 50 hours.

Average electrical horsepower	195.5
Average B. t. u. gas per cubic foot	158.9
Total coal fired, pounds	30,250

	Test 67.		
	Coal as fired.	Dry coal.	Combustible.
Coal consumed in producer (pounds per horsepower per hour).			
Per electrical horsepower:			
Available for outside purposes	3.27	2.10	1.89
Developed at switchboard	3.10	1.99	1.79
Per brake horsepower:			
Available for outside purposes	2.78	1.78	1.61
Developed at engine	2.63	1.69	1.52
Equivalent used by producer plant (pounds per horsepower per hour).			
Per electrical horsepower:			
Available for outside purposes	3.42	2.20	1.98
Developed at switchboard	3.24	2.08	1.87
Per brake horsepower:			
Available for outside purposes	2.92	1.87	1.68
Developed at engine	2.75	1.77	1.59

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

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

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

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

THE FORT BERTHOLD INDIAN RESERVATION LIGNITE FIELD, NORTH DAKOTA.

By CARL D. SMITH.

INTRODUCTION.

The Fort Berthold Indian Reservation, in North Dakota, about 1,500 square miles in area, is divided approximately in half by Missouri River and lies about midway between Bismarck and the point where the Missouri enters the State. In this paper only the part of the reservation north of the river is considered, and as the area lies wholly within the large region of lignite-bearing rocks which covers the western half of North Dakota, it has no natural boundaries. (See fig. 1.)

Heretofore this region has been remote from any railway, but recently a branch of the Minneapolis, St. Paul and Sault Ste. Marie Railway has been extended northwestward from Washburn, crossing the extreme northeast corner of the reservation. The Missouri River Railway, a proposed branch of the Northern Pacific, leaving the main line at Mandan, will follow closely the south bank of the Missouri, if built as surveyed. At certain seasons of the year Missouri River furnishes transportation to and from the field.

The writer was efficiently assisted in the field work on which this paper is based by J. A. Davis, E. B. Hopkins, E. L. De Golyer, and Jay W. Bliss. Mr. De Golyer also assisted in the office work.

TOPOGRAPHY.

The region is essentially a smooth plain into which the Missouri has cut a valley varying in width from 1 to 2 miles and in depth from 100 to 500 feet. At many points along the river the change from the smooth uplands to the river valley is abrupt and is marked by a narrow strip of bluffs and badlands. At other points, especially where the larger streams enter the river, the gradation is gradual.

The field considered here lies within the area once covered by the great continental glacier, whose effect on the topography is everywhere noticeable. In other parts of this general region, beyond the limit of glaciation, where the surface is not protected by the mantle of drift left by the retreating ice sheet, the territory bordering larger streams is in general minutely dissected into a badland belt several miles in width. In the glaciated area the mantle of drift has so tempered erosional action that badlands appear only where degradation has been extremely rapid.

Intermittent lakes occupying depressions that were probably former stream valleys are also features of the region due to glacial action. The valley of Missouri River between the mouth of Little Knife Creek, at the north boundary of the reservation, and the mouth of Shell Creek is comparatively narrow, indicating that it is probably new. It is probable that the river formerly occupied a depression which now lies in a straight line between the mouths of Little Knife and Shell creeks. Another depression southwest of this one, but joining it at the mouth of Shell Creek, may represent a second abandoned valley of the Missouri before it reached its present position.

GEOLOGY.

STRATIGRAPHY.

All the stratified rocks in the reservation are of Fort Union (early Eocene) age. Heretofore they have been classed as "Laramie and Fort Union" without differentiation, but recent investigations in this general region have proved conclusively that they are Tertiary and they probably correspond to the upper part of the so-called "yellow beds" in the Sentinel Butte field of North Dakota, the Miles City field of Montana, and the Sheridan field of Wyoming. In this region the beds present a rather monotonous sequence of somber-colored clays and sandy clays interstratified with buff sands and sandstones and beds of lignite. The clays and sandy clays predominate, thus lending to the whole series a somber hue. The sandstones are usually fine grained and soft, but at many places they contain irregular concretion-like masses of hard sandstone of the same color and texture as the matrix.

The greater part of the field is overlain by a mantle of glacial drift of Wisconsin age. This material is of variable thickness and contains a variety of rocks foreign to the region.

The following detailed section, made at the big bend of Missouri River 10 miles above the mouth of Shell Creek, gives some idea of the character of the Fort Union formation:

Section at big bend of Missouri River.

	Ft.	in.
Débris	5	
Sand, cream colored	20	
Lignite	1	8
Clay	1	3
Lignite	1	8
Clay	5	5
Lignite	3	9
Clay, somber, sandy, contains irregular masses of hard sandstone, some thin lignite seams, and carbonaceous layers	160	
Lignite	4	6
Clay, somber, somewhat sandy	16	
Clay, carbonaceous, with lenses of lignite	2	
Clay, somber, sandy	5	
Clay, yellowish, with sandstone lenses	8	
Clay, carbonaceous	1	
Sand, clayey	23	
Clay, somber, sandy	5	6
Clay, gray	17	
Clay, carbonaceous		4
Lignite		6
Clay, carbonaceous	1	6
Lignite	2	10
Clay, gray	2	
Clay	5	
Clay, yellowish, sandy	6	
Lignite	1	
Clay, yellowish	14	
Sand, yellowish, clayey, some carbonaceous clay	5	6
Lignite	7	2
Clay, greenish gray with carbonaceous streaks	17	
Sand, somber, clayey, contains ferruginous layers	17	
Clay, greenish gray	10	
Clay, somber, sandy	7	
Clay, greenish, white sand at top	6	
Sand and clay, somber	18	
Lignite		9
Clay, carbonaceous	1	
Lignite	1	1
Clay, carbonaceous	2	6
Clay, bluish	4	
Lignite	1	6
Clay, bluish	15	
Clay, carbonaceous	1	
Clay, sandy, somber	10	
Clay, carbonaceous	4	
Clay, sandy, somber, contains hard sand in places	55	
Lignite	1	

	Ft.	In.
Clay, carbonaceous		6
Clay, sandy, somber, upper 6 feet contains thin seams of lignite	18	
Lignite	1	6
Clay	3	
Sand, somber	12	
Clay, somber, sandy, contains thin lignite seams	35	
Lignite	1	6
Sand, clayey	25	
Clay, somber, with thin seams of lignite	40	
Lignite	5	
Clay	5	
Lignite	7	
Clay and sand, reddish brown at base	100	
Lignite	14+	
Water level in river.		
	765	11+

The members of this formation are extremely variable horizontally as well as vertically. No particular sandstone or clay bed can be selected as a key rock for purposes of correlation from one part of the field to another. Lignite beds, on account of their greater persistence laterally than the containing rocks, furnish the only means of correlation, and they are uncertain where large areas between outcrops are concealed.

STRUCTURE.

The strata of the reservation lie almost horizontal. At some places, however, evidence of a slight eastward dip is unmistakable. This was discovered by tracing some of the more persistent lignite beds whose outcrops as followed downstream either approach or dip below river level. The dip is not constant in degree. There are broad areas where the strata lie horizontal, the whole thus constituting a series of gentle undulations. The amount of the dip at any point is very little more than the fall of the river, and so far as mining operations on a small scale are concerned it may be disregarded.

THE LIGNITE.

GENERAL DESCRIPTION.

Lignite beds occur at intervals throughout the rock section exposed. They are variable in thickness and horizontal extent, but as some of the important beds have been traced continuously for 12 miles by their outcrops they can not justly be described as lenticular. The covering of glacial drift has prevented the tracing or correlation of beds from one part of the field to another. No direct evidence has been obtained as to the thickness of lignite-bearing strata that may

underlie the field at a greater depth than river level, but observations made in this same general region lead to the belief that workable beds of lignite can be found to a depth of 1,000 feet or more.

On account of the smooth character of the country no exposures of lignite were noted in the uplands away from the breaks of the river, but it is probable that lignite beds occur there and could be found by prospecting.

As lignite is more or less porous and jointed it is a much better medium for the travel of underground water than the fine-grained variable clays and sands which make up the rest of the section. It happens, therefore, that at many places springs and seepages mark the outcrops of lignite beds that are covered by débris.

Wherever exposed in the badlands the thicker beds have been burned along their outcrops, producing a red clinker which consists of baked and partly fused sands and clays. The material immediately underlying a burned-out bed is only slightly affected, while the material overlying it may be metamorphosed for a thickness of 20 or 30 feet, depending on the thickness and purity of the bed burned. It is evident, then, that in prospecting for a bed of lignite where its outcrop is fringed by clinker, the base of the clinker, which is usually well marked, will be found on a level with the unburned body of lignite. The distance back from the outcrop of a bed to which burning may take place depends on the thickness of the cover, but in this connection it is difficult to give exact figures. To an observer it is at many places an obvious matter. The persistence of clinker along an outcrop serves to some extent as an index to the character of the bed burned, as thick, pure beds are more apt to burn than thin, impure ones.

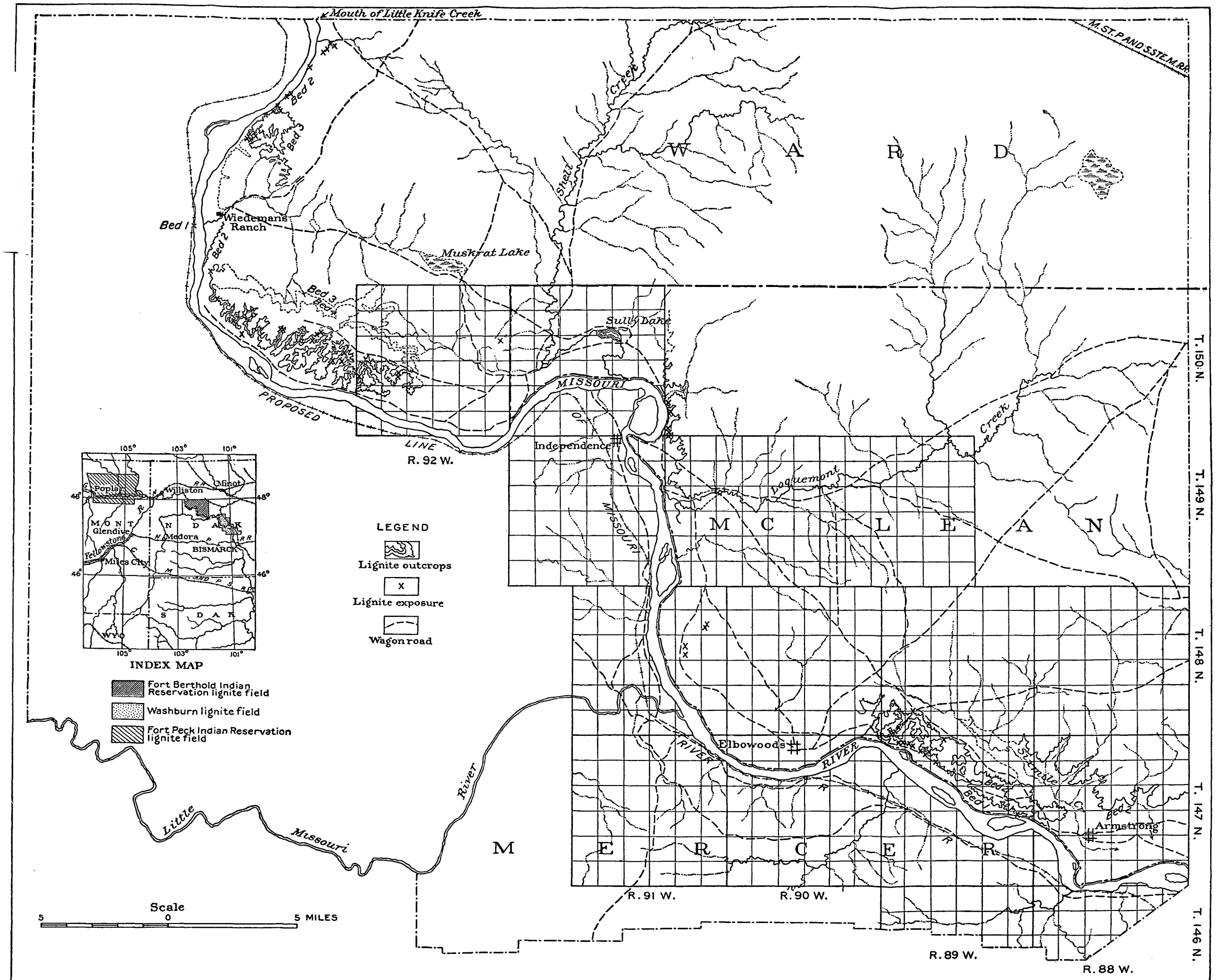
The outcrops of the important beds in this field have been traced and are shown on the map (Pl. II). The outline of the whole reservation is shown, but little is known of the region south of the river except that its topography is considerably rougher than on the north side.

DISTRIBUTION OF THE LIGNITE.

The lignite beds will here be described by districts, beginning at the north boundary of the reservation and following in order down the Missouri to the east boundary.

BIG BEND DISTRICT.

After entering the reservation the Missouri makes a U-shaped bend which terminates near the mouth of Shell Creek. This bend is bordered by high bluffs in which a number of lignite beds ranging in thickness from a few inches to more than 14 feet have been observed. Only four of these beds are of sufficient thickness for mining.



MAP OF FORT BERTHOLD INDIAN RESERVATION LIGNITE FIELD, NORTH DAKOTA.

By C. D. Smith.

Bed 1.—The lowest bed, more than 14 feet thick, is exposed in the west bank of Missouri River, opposite and a short distance below Wiedeman's ranch. Water in the river at ordinary stage conceals the base of the bed and at flood time covers it completely. The exposure of the bed is due to an eastward-pitching anticline of local extent, and it disappears below river level both up and down stream within a few hundred feet of the point where it was measured. The portion of the bed seen is free from partings and appears to be of excellent quality.

Bed 2.—The next bed of consequence exposed in the big-bend district lies about 100 feet stratigraphically above bed 1. Its outcrop has been traced from a point 1 mile below the mouth of Little Knife Creek, at the north boundary of the reservation, to a point 2½ miles south of Wiedeman's ranch, and is shown on the map (Pl. II). North of Wiedeman's the bed is in one bench, 4 to 5½ feet thick, and lies from water level to 30 feet above. Its outcrop is in the base of the bluff which forms the east bank of the river and is therefore everywhere near the river. For this reason the bed is almost inaccessible to any means of transportation except by water. Local landslides caused by the undermining action of the river against its bank have broken great masses of lignite from the bed, and these, after being washed clean of sand and clay, lie exposed on the bank. Steamboats plying the river frequently stop here for the fuel which can be so easily obtained.

South of Wiedeman's ranch the outcrop of bed 2, which is there made up of two benches, has been traced for about 2 miles. The effect of the local anticline mentioned in connection with bed 1 is felt by bed 2, which for a mile or so rises to an elevation of 50 feet above the river.

Section of bed 2 about 2 miles south of Wiedeman's ranch.

	Ft.	In.
Clay roof.		
Lignite	4	6
Clay, sandy	4	9
Lignite	3	5
Clay		3
Lignite	3	5
Concealed to river level.		
Total lignite	11	4

Near the point where the river turns from a southward to an eastward course bed 2 disappears beneath the hill wash that borders the bottom lands along the river, and was not seen again in the field. Except for a few thin partings bed 2 is comparatively clean, and its quality seems to be good.

Beds 3 and 4.—In the badlands bordering the river between Wiedeman's ranch and the mouth of Shell Creek beds 3 and 4 are exposed and their thicknesses are sufficient to deserve some notice. These beds are 300 and 375 feet, respectively, above river level. They vary considerably but have not been observed to exceed 4 feet 6 inches in thickness. Immediately south of Wiedeman's they are thin and worthless. They appear to reach their greatest thickness a few miles west of the west line of T. 150 N., R. 92 W. These upper beds are well exposed on the south side of the high bluff, but glacial drift so conceals their northern outcrops that their positions are indefinite. It will be seen from the map (Pl. II), where their outcrops are shown, that these two beds are outliers, cut off from the region to the north by the low depression which lies between Wiedeman's ranch and Shell Creek.

North of Wiedeman's ranch a part of the outcrop of bed 3 has been traced and is shown on Plate II. The bed has not been observed to exceed 4 feet in thickness and lies near the top of the bluff 300 feet above river level.

South of a small stream which flows westward into the Missouri, about 1 mile south of the north boundary of the reservation, lignite is exposed in several places, and is 2½ to 3½ feet thick.

LOQUEMONT CREEK DISTRICT.

About 4 miles north of the mouth of Loquemont Creek the Missouri swings against its east bank, forming a bluff in which several beds of lignite are exposed. A section of the bluff follows:

Section 4 miles north of mouth of Loquemont Creek.

Débris.	Ft.	in.
Clay, carbonaceous	4	
Sand, clayey	65	
Clay, carbonaceous	4	
Lignite	5	11
Sand and clay with some thin lignite seams	100	
Lignite	1	6
Clay	5	8
Lignite (poor)	3	3
Clay	5	
Lignite	2	10
Concealed to river level	50	
	247	2

The lower beds of the foregoing section are exposed at several places near the wagon road which runs between the bluff and the river. The upper bed appears well up in the bluff, or 170 feet above river level. Its outcrop, shown on Plate II, has been traced for 6 or

8 miles, and in places it has been burned. It is 5 to 6 feet thick and seems to be of good quality. Near the mouth of Loquemont Creek it is so concealed that no measurements could be made. The position of the bed makes it easily accessible for mining purposes, and is such that it must underlie a large territory to the east, if it is continuous in that direction.

ELBOWOODS DISTRICT.

Between Elbowoods and the mouth of Sixmile Creek the north bank of Missouri River is bordered by a strip of badlands from 1 to 2 miles wide, in which several beds of lignite are exposed. They are nearly everywhere fringed by clinker produced by combustion along their outcrops. Two of them have been mapped, and for convenience of reference are designated as beds 1 and 2.

Section 5 miles east of Elbowoods.

	Ft.	in.
Sand, somber, clayey	50	
Lignite	3	
Clay, sandy	8	
Lignite	4	
Clay, somber	34	
Lignite (bed 2)	6	6
Clay, somber	20	
Lignite	1	
Clay, somber	9	
Lignite	2	
Sand and clay, some carbonaceous layers	35	
Sand with irregular hard lenses	45	
Lignite (bed 1)	7	
Clay, somber, sandy	22	
Lignite	1	9
Clay, gray	1	4
Lignite	2	7
Clay, somber, sandy	14	5
Concealed to river level, about	60	
	326	7

Bed 1.—At a point about 4 miles east of Elbowoods, where Missouri River swings to the north against the badland bluffs, bed 1, the lowest considered in the section, is about 70 feet above water level, or 50 feet above the flood plain of the river. To the southeast it outcrops in the base of the bluff everywhere near the edge of the river flat, and dips gradually eastward to the western part of T. 147 N., R 88 W., where it disappears below the alluvium. The bed is nearly everywhere fringed by clinker and for that reason is easily traceable. Near Elbowoods bed 1 is badly split up by part-

ings, but they appear to die out to the southeast. Some sections of the bed follow:

Section of bed 1 in S. ½ sec. 31, T. 148 N., R. 89 W.

	Ft.	in.
Lignite		9
Parting		9
Lignite	1	
Parting		6
Lignite	2	6
Total lignite	4	3

Section of bed 1 in NE. ¼ sec. 6, T. 147 N., R. 89 W.

	Ft.	in.
Lignite	2	6
Parting		4
Lignite	2	
Parting		2
Lignite	2	
Total lignite	6	6

In the N. ½ sec. 24, T. 147 N., R. 89 W., bed 1 is about 7 feet thick and free from partings.

Bed 2.—About 125 feet above bed 1, or 200 feet above river level, is another bed which has been traced from a point near Elbowoods eastward to the boundary of the reservation. It has been burned almost continuously along its outcrop, and its thickness was measured in only two places, where it was 4 feet and 6 feet 6 inches thick. To judge by the thickness and persistence of clinker produced by its burning, it is probably a workable bed throughout the distance traced.

Between Missouri River and Sixmile Creek bed 2 lies in a narrow strip with disconnected outliers. From Sixmile Creek eastward to the boundary of the reservation bed 2 is about 125 feet above river level and outcrops at the north edge of the lowland bench, 2 to 4 miles from the Missouri.

In the hills north of Elbowoods no lignite is exposed, but springs and seepages, probably indicating the outcrops of beds, are abundant, especially near the north edge of the lowlands on which the town of Elbowoods is situated.

In the eastern part of T. 148 N., R. 91 W., northwest of Elbowoods, several thin beds of lignite are exposed, but none of them has been observed to exceed 3 feet 8 inches in thickness.

CHARACTER AND USES OF THE LIGNITE.

The lignite on the reservation does not differ in character and composition from that in other parts of the same general region. It is dark brown in color, tough, and woody in structure. The greatest disadvantage encountered in dealing with a lignite is its tendency to slack or break down into small fragments on exposure

to the atmosphere. Attempts have been made to overcome this difficulty by briquetting the fuel, but the scheme has not yet come into practical use. When, however, the lignite is not handled much and is kept under shelter away from the action of sunlight and rain it has been known to hold together in good condition through the winter months.

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

On weathering the lignite, which is usually lusterless and massive, breaks into small, shiny cubical blocks which appear black but give a brown streak or powder.

In the absence of timber lignite is used generally over the region for domestic purposes and is coming into favor as a fuel for various manufacturing industries throughout the State. As most of the inhabitants of the Fort Berthold Reservation live near Missouri River, where timber is plentiful, very little lignite is mined, and that only where conditions are extremely favorable—for example, in places where it can be taken from open pits and it is necessary to remove very little cover to reach the fuel. Timber suitable for mining purposes can be obtained only in the valley of Missouri River.

FUTURE DEVELOPMENT.

Owing to the wide distribution of lignite in this general region it is not likely that any part of the area will develop far in advance of any other part. Some small advantage would arise, of course, should a certain field have extremely favorable conditions as to transportation and thickness and purity of fuel. It seems probable, however, that the lignite will have only a local use for many years to come.

Probably the greatest future use of the lignite will be to generate power for pumping plants to irrigate lands along the larger streams in the State. A number of such projects on Missouri River are now under consideration by the United States Reclamation Service and by the State. One such plant has already been established at Williston. Should these numerous projects be completed great quantities of lignite would be necessary not only for their use, but also to supply settlers attracted by irrigated lands with fuel for domestic purposes, and to supply industries that would probably spring up with an influx of immigration.

North Dakota brown lignite has been tested with great success in the producer-gas plant, as shown by the statement quoted on pages 28–29.

THE FORT PECK INDIAN RESERVATION LIGNITE FIELD, MONTANA.

By CARL D. SMITH.

INTRODUCTION.

The Fort Peck Indian Reservation lignite field lies in the northeast corner of Montana, partly in Valley County and partly in Dawson County. (See fig. 1.) Missouri River flows eastward through the field and forms the south boundary of the reservation. The Great Northern Railway follows the valley of the Missouri across the field. At certain seasons of the year the river is navigable, but it is rarely used as a means of transportation.

The investigation on which this paper is based was made in 1908. In the surveyed parts of the field locations were obtained by means of horseback traverses, with frequent ties to established land corners. Where the land has not been surveyed, the main control lines were run by plane-table and buggy-wheel traverses, which were tied to established corners wherever possible and were supplemented by horseback traverses. At the time geologic examinations of the field were being made topographic surveys were in progress on a part of the reservation, but these were not available in the field.

This paper is intended to be entirely of an economic nature, hence little attention is given to matters that do not immediately concern the lignite. As a result of the work of 1908 the mapped area of formations barren of lignite has been extended eastward along Missouri River for a distance of 60 miles.

The writer is deeply indebted to Messrs. J. A. Davis, E. B. Hopkins, and E. L. De Golyer, whose interest and able assistance in the field work have contributed greatly to whatever value this report may have. Mr. De Golyer also rendered able assistance in the office.

TOPOGRAPHY.

The valley of Missouri River divides the field into two distinct topographic provinces. North of the river for a distance of 15 to 20 miles the slopes are as a rule gentle and, with a few exceptions, the valleys are broad with gently sloping sides. Farther north the relief becomes bolder and the large streams are in places bordered

by abrupt escarpments and hills ranging in elevation from 200 to 500 feet. The interstream areas are usually broad and flat.

In the north-central part of the reservation, south of Poplar River and Cottonwood Creek, is a gravel-covered terrace about 300 feet above stream level, which slopes gently to the southeast. A remnant of a similar terrace appears in the highlands north of Cottonwood Creek.

South of Missouri River bluffs and hills rise abruptly from the edge of the flood plain to an elevation of several hundred feet. Near the river the topography is rough and in places the country is dissected into badlands, but farther to the south the badlands blend with rolling prairies of low relief.

The entire field considered here lies within the area once covered by the great continental ice sheet, whose effects on the topography are everywhere evident. Preglacial streams have been caused to abandon their channels, which now appear either as broad depressions containing intermittent lakes or as broad valleys occupied by streams of insignificant size. The movement of the glacier over the region has no doubt had a tendency to smooth away preexisting inequalities of the surface, and the retreating ice sheet has left a mantle of drift which has protected underlying formations from the erosion into badland forms common in regions not so protected. South of Missouri River evidences of glaciation are not so marked as they are north of the river.

GEOLOGY.

STRATIGRAPHY.

The following table gives a summary of the formations occurring in this field:

Stratigraphy of the Fort Peck Indian Reservation lignite field, Montana.

System.	Formation.	Thickness.	Description.
		Feet.	
Quaternary	.....	.....	Alluvium.
	.....	.....	Glacial drift.
Tertiary	Fort Union formation	1,000+	Yellowish sands and sandstones interbedded with gray clays and lignite.
(?)	.....	200	Somber-colored sands and clays with numerous carbonaceous layers and a few lignite beds.
Cretaceous (?)	Fox Hills (?) sandstone	200	Buff-colored soft sandstones interstratified with some gray clay.
Cretaceous	Pierre shale	1,000+	Dark-gray shale, in places brown. Very soft and friable.

PIERRE SHALE.

The basal member of the rock section occurring in the Fort Peck field is a dark-gray shale, in places brown, which is as a whole very soft and friable, but contains at irregular intervals thin layers of

limy material. Near the top of the formation appear many bowlder-like limy concretions, 1 to 2 feet in diameter, some of which are made up almost wholly of fossil shells. Others contain no fossils and many are intersected by a network of calcite veins which are usually of a lighter color than the matrix.

According to T. W. Stanton fossils collected from this formation are very distinctive. "In fact, they are characteristic of a horizon in the upper Pierre corresponding to the shale above the Judith River formation which farther west in Montana has been called the Bearpaw shale."

As indicated on the accompanying map (Pl. III) the Pierre shale covers the greater part of the west end of the field and extends eastward in an area of varying width along Missouri River nearly to the town of Brockton, on the Great Northern Railway. The base of the shale does not appear in the Fort Peck field, but there is reason to believe that it is more than 1,000 feet thick, as at least that thickness occurs in this field. The Pierre shale is barren of coal, and so far as known carries no other economic product, with the possible exception of clay for brickmaking. As the shale contains no ledge-making material bluffs are rare in the area which it underlies as the surface rock. Streams whose courses lie in the shale are usually more alkaline than those elsewhere.

FOX HILLS (?) SANDSTONE.

Conformably overlying the Pierre shale is a series about 200 feet thick consisting of buff sandstones interstratified with some gray clay. As a rule the sandstone is soft, but in places it appears as hard concretion-like masses which stand out as ledges in the process of weathering or as masses of cannon-ball shape embedded in a matrix of softer rock. The material shows great irregularity of bedding, is extremely variable in character horizontally, and is in places cross-bedded and conglomeratic.

The age of these beds is doubtful. They occupy a position in the section which to the south and southeast is occupied by the Fox Hills sandstone, but no fossils could be found in the beds; hence further work in the region will be necessary to determine their age. For the present they are called Fox Hills (?) sandstone. Like the Pierre shale these buff beds are barren of coal. Excellent exposures of this formation can be seen in the part of the field south of Missouri River, especially in the high river bluff south of Brockton. North of the river glacial drift so conceals the formation that good exposures can be seen at only a few places. These are near the head of Cottonwood Creek in the northern part of the reservation, and on Wolf Creek near the town of Wolf Point.

SOMBER-COLORED BEDS.

About 200 feet of somber-colored sands and clays, with numerous carbonaceous layers and a few beds of impure lignite, overlie the Fox Hills (?) sandstone and are also of doubtful age. They are regarded by F. H. Knowlton as having very strong Fort Union (early Eocene) affinities. In the field covered by this report there is no apparent unconformity between the Fox Hills (?) sandstone and the somber-colored beds. Although the upper part of the somber-colored beds differs from the lower part of the Fox Hills (?) sandstone in character of constituent materials the two formations so grade into each other that their contact is very indefinite. At some places the somber-colored beds contain irregular masses of hard sandstone and thin beds of impure limestone. In weathering this hard material stands out as ledges or serves as protecting caps for pedestals of softer sands or clays. Excellent exposures of the somber-colored beds can be seen in the badlands south of Missouri River, on Cottonwood Creek, and Poplar River in the Fort Peck Indian Reservation. Because of the uncertainty of the position of the contact of the Fox Hills (?) sandstone and the somber-colored beds north of Missouri River they have been grouped together in mapping.

FORT UNION FORMATION.

The uppermost formation in the Fort Peck region is made up of yellowish sands and sandstones interbedded with gray clays and lignite, the sands and sandstones predominating. One thousand feet or more of this formation, which appears to represent more stable conditions of deposition than the Fox Hills (?) sandstone and the somber-colored beds below, is exposed in the field. As a whole this formation has a yellowish hue. According to F. H. Knowlton the beds are Fort Union in age. Their contact with the somber-colored beds below is usually well marked by an abrupt change in color and character of material. Lignite occurs abundantly in these yellow beds, and is much more constant in quality and horizontal distribution than the lignite of the somber-colored beds. Excellent exposures of the yellow Fort Union formation can be seen east of Brockton both north and south of the river, in the northeastern part of the reservation, and in the escarpments bordering the valley of Poplar River.

GLACIAL DRIFT.

Overlying the greater part of the field is a mantle of glacial material of varying thickness, made up principally of igneous bowlders and clay, but containing some fossiliferous limestones. These bowlders vary in size from mere pebbles to masses weighing probably 20 tons. It is probable that this drift formerly covered the entire region like a

huge blanket, but stream action and weathering agencies subsequent to the retreat of the continental ice sheet have cut deep channels through the drift and into underlying formations. It may be readily seen that isolated exposures of the underlying rock not concealed by glacial drift are rather difficult of correlation, and this difficulty is augmented by the variability of the lignite-bearing formations.

STRUCTURE.

As originally deposited the strata which make up the rock section in and near the Fort Peck Indian Reservation were approximately horizontal, but since their deposition some force has so tilted them that they now dip gently toward the east. This dip, however, is not constant in direction nor degree. A low dome, near the center of which Poplar is located, breaks the continuity of the dip, and causes a slight reverse dip to the west, thus producing a shallow syncline pitching southeastward whose axis trends northwest and southeast a few miles east of Wolf Point. The formations immediately concerned in the Poplar dome dip away from it in every direction, the direction of the dip at any particular point being determined by the direction of such a point of observation from the center of the dome. Thus the formations at a point due east of the center dip to the east. The lignite beds along the river east of Brockton dip eastward at about 100 to 135 feet to the mile. In directions other than east of the dome, where its presence only intensifies the general dip, its effect does not reach beyond 15 miles.

THE LIGNITE.

GENERAL DESCRIPTION.

By reference to the sections given on the following pages it will be noted that many lignite beds occur in this field. Relatively few of these beds, however, are of sufficient thickness for consideration as mining possibilities. Wherever wide areas are concealed between the districts discussed no attempt has been made to correlate individual beds from one to another.

The character of the materials that inclose lignite beds is so changeable that it is never possible to predict what the roof and floor of any particular bed are likely to be a few yards from the point of actual exposure. As a general rule it may be said that a few feet of the lignite bed itself, should its thickness permit, will make a much stronger roof than any material that may overlie it. Timber suitable for mine purposes is very scarce except in the valley of Missouri River. Water, while not abundant except in the rivers, could be stored by building reservoirs in small streams and could possibly be obtained from wells.

The lignite beds which occur in the somber-colored formation have shown so much variability in quality, thickness, and lateral

extent that, in the presence of better lignite in the Fort Union formation, they are considered worthless as a whole. In places they have a workable thickness and have been burned along their outcrops, but on account of their uncertainty of character no attempt was made to note them closely.

Lignite beds of workable thickness and purity occur at intervals through the entire thickness of the Fort Union formation exposed in the field. They are much more constant in character than those occurring in the somber-colored beds, and are here treated more in detail. Near Missouri River the outcrops of the principal beds have been traced and mapped, but away from the river no attempt has been made to follow out individual beds.

A feature of the region, especially noticeable south of Missouri River, is the clinker produced by the burning of lignite beds along their outcrops. This material, which is usually red, is an unfailing index to the position of the bed burned. It would, in many localities, be extremely difficult to meander outcrops of beds without the clinker as a guide. To some extent also the persistence and thickness of the clinker give some idea of the persistence, quality, and thickness of the burnt bed, as thick beds of good quality produce a greater thickness and more completely fused zones of clinker than thin or impure beds. The distance back from the outcrop of a bed to which burning may take place is governed by the thickness of cover, which, if great enough, smothers the fire by preventing access of air. In this connection it is impossible to give exact figures, as no mining or prospecting has been done where it was necessary to remove the clinker to reach the lignite. To the observer, however, the width of the clinkered zone is often an obvious matter. In prospecting for lignite on an outcrop that has been burned it may be well to keep in mind the fact that the base of the clinker, which is usually well marked, is on a level with the base of the burnt bed of lignite.

The areal distribution of the formations that occur in this field is shown on Plate III. The principal wagon roads are shown, except those in the valley of Missouri River, where there is such a network of roads that to represent them would only complicate the map.

The outcrops of important beds of lignite in the eastern part of the field are also shown on the map. In the field no attempt was made to map the contact of the river alluvium with older formations. The map is compiled from Missouri River Commission maps and township plats of the General Land Office. The Fort Peck Indian Reservation constitutes the greater part of the field. The north boundary of the reservation is the north boundary of the area mapped. On the west the reservation is bounded by Porcupine Creek, on the south by Missouri River, and on the east by Big Muddy Creek.

DISTRIBUTION OF LIGNITE.

For convenience of description the field is divided into more or less arbitrary districts. The districts nearest the Great Northern Railway and Missouri River, on account of their accessibility, have been examined in greater detail than those more remote from lines of transportation.

BROCKTON-CULBERTSON DISTRICT.

The Brockton-Culbertson district includes the region in the reservation east of Brockton, between Missouri River and the seventh standard parallel, and a small area about Culbertson east of Big Muddy Creek. This district, because of its accessibility, has been studied in more detail than other parts of the field, especially in T. 28 N., Rs. 53 and 54 E., where the two important lignite beds have been followed in their outcrops by means of stadia measurements and where concealed have been prospected by means of a hand drill.

The dip of the lignite beds and containing formations in this district is to the east, its amount ranging from 25 to 135 feet to the mile. A section compiled from scattered exposures and supplemented by observations made south of Missouri River, with unimportant lignite beds eliminated, is given below. For convenience of description, the important beds are designated by letters A, B, C, etc., A corresponding to the lowest workable bed.

Section in Brockton-Culbertson district.

	Ft.	In.
Lignite (bed G)	9	
Clay and sand	90	
Lignite	4–6	
Clay	10–27	
Lignite (bed F)	5	6
Sand and clay	70	
Lignite (bed E)	3–6	
Sand and clay	130	
Lignite	5	7
Clay	6	
Lignite (bed D)	9	
Sand and clay	95	
Lignite (bed C)	2	
Sand and clay	115	
Lignite (bed B)	1–5	6
Sand and clay	275	
Lignite	5	
Clay	15	
Lignite (bed A)	7	7
	884	2

From the above section it may be noted that about 900 feet of strata bearing workable beds of lignite are exposed in the Brockton-Culbertson district.

Only three beds of lignite occurring in this district east of Big Muddy Creek are of sufficient thickness to warrant consideration. On the map these are termed beds F and G, F being made to include the two lower beds, which are so close together in the section that their mapped outcrops practically coincide. The outcrops of these beds are shown on the map (Pl. III). The prevailing eastward dip of the beds is so much less about Culbertson as to be practically negligible so far as its effects on mining is concerned.

Bed A.—In T. 28 N., R. 53 E., bed A lies at the contact of the somber-colored beds with the Fort Union formation above. Another bed appears a few feet above bed A, and it is possible that in attempting to map the outcrop of bed A locations were at some places taken on the upper bed, but they are so near in the geologic section that their outcrops practically coincide.

The outcrop of bed A is shown on Plate III. From the point where Box Elder Creek flows out of the hills into river alluvium the bed rises gradually northwestward to the top of the divide between the river and Lake Creek. From the top of the divide the outcrop of the bed was followed in a northeast course to the seventh standard parallel. The bed dips to the east about 100 feet to the mile and presumably underlies all the territory east of its mapped outcrop. In secs. 21 and 22 bed A has been burned along its outcrop, producing a considerable amount of red clinker. A section of bed A in the NE. ¼ sec. 21, T. 28 N., R. 53 E., shows 6 feet 5 inches of lignite, with sandstone roof and clay floor.

Near the middle of sec. 21, T. 28 N., R. 53 E., bed A is exposed naturally in the point of a hill, where the following section was measured:

Section of bed A near middle of sec. 21, T. 28 N., R. 53 E.

	Ft.	in.
Clay roof.		
Lignite	2	2
Clay		1
Lignite	2	7
Lignite, dirty		4
Lignite	2	6
Total lignite	7	7

A hole drilled in the NE. ¼ sec. 8 revealed only 4 feet 8 inches of lignite. It is probable that the lignite struck here is the smaller upper bed which lies about 10 feet above bed A.

An exposure of the small bed above bed A was seen in the SE. ¼ sec. 22 near the wagon road, just east of Box Elder Creek. A section follows:

Section of lignite bed in SE. ¼ sec. 22, T. 28 N., R. 53 E.

	Ft.	in.
Sandy clay roof.		
Lignite	1	6
Clay	1	
Lignite	3	6
Total lignite	5	

Several attempts were made to reach bed A at points along its outcrop, but it is so concealed by glacial drift that no satisfactory results could be obtained. Bed A wherever measured contains some thin partings, but they are not of sufficient thickness to interfere seriously with mining operations. No attempt was made to follow the outcrop of this bed north of the seventh standard parallel.

Accessible parts of the outcrop of bed A are probably too far from the river to utilize that stream as a source of water for mining purposes, but a reservoir could be formed by damming Box Elder Creek. In case no great amount of water should be needed, it might be obtained from wells, possibly artesian.

Bed B.—In secs. 30 and 31, T. 28 N., R. 54 E., just north of the Great Northern Railway, is a small area of badlands in which bed B is well exposed. It is 300 feet higher in the rock section than bed A, and, like the beds above and below it, rises gradually to the west. Many exposures of the bed were measured, but it shows so much variability in thickness that it is not considered of much value. Its greatest measured thickness is 5 feet 6 inches and its least 1 foot. It is usually very impure.

Bed C.—In the Brockton-Culbertson district bed C is about 2 feet thick and is of little consequence. It is included here principally because it is thicker on the south side of the river. It is about 115 feet above bed B in the rock section, and was measured in only one place, in the western part of T. 28 N., R. 54 E.

Bed D.—For about 500 feet in the section above bed A many thin beds of lignite occur, but none of them has shown workable thickness in the Brockton-Culbertson district. The outcrop of bed D is similar to that of bed A in that it swings to the northwest from the edge of the river alluvium to the top of the divide between the river and Lake Creek, thence northeastward to the seventh standard parallel, beyond which its outcrop was not followed. The outcrop lies almost wholly in T. 28 N., R. 54 E., and the dip of the bed to the east in the western part of the township is about 135 feet to the mile, somewhat more than the dip of bed A. It presumably underlies all the territory east of its outcrop.

East of the point where the outcrop of bed D is concealed by river alluvium there is probably a diminution in the amount of dip. In other words, from sec. 26 eastward to Big Muddy Creek bed D probably lies almost flat, but is still inclined slightly to the east.

Westward from the middle of sec. 20 bed D has been burned for a short distance along its outcrop. Near the middle of sec. 20 a hole was drilled which revealed the following section:

Section of lignite in drill hole in sec. 20, T. 28 N., R. 54 E.

	Ft.	In.
Clay roof.		
Lignite	5	7
Clay, sandy	6	
Lignite (bed D)	9	
Total lignite	14	7

Another hole was drilled through bed D near the middle of sec. 4, and revealed 8 feet 8 inches of lignite.

A bed of lignite 5 feet 7 inches thick overlies bed D, from which it is separated by 6 feet of clay. These beds are so near that the general conditions affecting one also apply to the other.

Bed E.—No exposure of bed E was seen in the Brockton-Culbertson district. The thickness given in the general section was measured on the south side of Missouri River, where the bed is well exposed and lies about 140 feet stratigraphically above bed D.

Bed F.—It will be seen by reference to the map (Pl. III) that bed F underlies considerable territory in T. 28 N., Rs. 55 and 56 E. Its outcrop follows closely the base of the hills bordering the flood plains of Big Muddy Creek and Missouri River, and in elevation it is about 100 feet above the Missouri. Above bed F and separated from it by 10 to 27 feet is another bed which in places reaches workable thickness.

Section of bed F near quarter corner between secs. 5 and 6, T. 28 N., R. 55 E.

	Feet.
Lignite	6
Clay and sand	27
Lignite (bed F)	4+
Total lignite	10+

In this section the base of bed F is concealed. Two exposures about 1½ miles farther northwest showed 6 to 8 feet of lignite, free from partings.

Section of bed F in SW. ¼ sec. 26, T. 28 N., R. 55 E.

	Ft.	In.
Lignite	3	8
Clay and sand	17	
Lignite (bed F)	5	
Total lignite	8	8

Where the bed is not covered by hill wash it is in many places so fringed by clinker that no satisfactory measurements could be made. Both benches of bed F are free from partings and appear to be of excellent quality.

Bed G.—A part of the outcrop of bed G, 115 feet above bed F or 215 feet above Missouri River level, has been mapped near Culbertson. The thickness of the bed was measured in only one place, at the Bruegger mine, 3 miles north of Culbertson, a description of which follows. This bed has been burned somewhat along its outcrop. Its exploitation is considered a safe mining venture, but it is rather inaccessible on account of its elevation and distance from means of transportation.

About 3 miles north of Culbertson the Bruegger mine has been opened on bed G. The main entry runs north and is about 200 feet in length. The bed is 8 feet 6 inches to 9 feet thick, is free from partings, and is of good quality, as shown by the analysis on page 55. The fuel is hauled by wagons to Culbertson for local use.

DISTRICT SOUTH OF MISSOURI RIVER.

The district described here is bounded on the north by Missouri River, on the west by the tenth guide meridian, and on the south by the sixth standard parallel, and extends eastward to a point south of Missouri River opposite Culbertson.

In structure it is similar to the region north of the river. The general dip is to the east or a little south of east, with a slight reverse dip to the west from Redwater River westward for 15 miles. This reverse dip is due to the shallow, southeastward-pitching syncline mentioned above as lying between the Poplar dome and Wolf Point. The effect of this syncline is to bring the lower contact of the Fort Union beds, the principal lignite-bearing formation, to a lower level and therefore nearer the river. Westward from the mouth of Swartz Creek, opposite Wolf Point, the beds rise gradually, thus throwing the Fort Union lignite-bearing formation farther from Missouri River.

The contact of the somber-colored beds with the overlying Fort Union formation, at or above which the better beds of lignite occur, is shown on the map (Pl. III). The lignite which occurs near this horizon, west of Charlie Creek, because of its general inaccessibility in that direction, has not been measured or mapped with as much accuracy as the beds east of Charlie Creek. Workable beds near the river west of Charlie Creek occur as irregular outliers with thin cover, 400 feet or more above the river bottoms. In the southern part of T. 27 N., R. 49 E., a 5-foot bed of lignite occurs in the somber-colored beds and it has been mined to some extent on Nickwall Creek for use at Poplar.

The eastward dip whose effect begins to be felt strongly 10 miles east of Redwater River brings the base of the Fort Union, the principal lignite-bearing formation, down to river level near the mouth of Charlie Creek, eastward from which lignite beds successively higher in the section appear near river level.

East of the mouth of Charlie Creek lignite beds occur in abundance and have practically the same distribution stratigraphically as in the Brockton-Culbertson district. For convenience of description the important beds are designated by letters, similar letters being given to beds correlated as the same in the two districts.

Bed A.—The bed of lignite which occurs at the contact of the Fort Union formation and the somber-colored beds in the Brockton-Culbertson district appears south of the river in T. 27 N., R. 53 E., near Charlie Creek. The bed dips to the east about 100 feet to the mile and disappears below the level of Missouri River a short distance east of the mouth of Charlie Creek. Near the river the outcrop of bed A is so concealed that only a partial exposure could be seen. This was near West Charlie Creek, in the southern part of T. 27 N., R. 53 E. A section follows:

Section of bed A on West Charlie Creek.

	Ft.	In.
Sand roof.		
Lignite		2
Parting		2
Lignite	1	6
Parting		1
Lignite	1	5
Parting		1
Lignite	2	9
Parting		2
Lignite (base concealed)		7
Total lignite exposed	6	5

East of the mouth of Charlie Creek the outcrop of bed A should be found near the river, but its character and thickness there are not known.

Bed B.—South of Missouri River bed B could not be recognized. Its outcrop should lie between the mouth of Charlie Creek and Balls Bluff to the east, but from its character north of the river it is not surprising that the bed should have pinched out here.

East of the mouth of Charlie Creek the outcrops of the principal lignite beds have been followed only near the river, where they are well exposed in the bluffs and badlands.

Bed C.—In Balls Bluff, just south of Missouri River in the north-central part of T. 27 N., R. 54 E., bed C is well exposed and averages 4 to 5 feet in thickness. Here the bed is about 150 feet above the river, but near the east line of the township the eastward dip of the

bed carries it below river level. Westward from Balls Bluff the outcrop of bed C rises rapidly and swings to the south, where it could not be followed because of the smooth, grass-covered character of the country.

Bed D.—In outcrop bed D closely follows bed C, from which it is separated by 50 to 100 feet of sandy clay, but on account of the diminution of the dip to the east it extends down Missouri River nearly to the mouth of Twomile Creek before disappearing. Bed D averages nearly 10 feet in thickness and has in places a few partings that are too thin to interfere with mining. Some detailed measurements of bed D follow:

Section of bed D in eastern part of T. 27 N., R. 54 E.

	Ft.	in.
Sandy clay roof.		
Lignite	6	6
Clay		3
Lignite	2	10
Sand		2
Lignite		6
Total lignite	9	10

Section of bed D at Balls Bluff in north-central part of T. 27 N., R. 54 E.

	Ft.	in.
Soft sandstone roof.		
Lignite, dirty	1	
Lignite	6	6
Clay		2
Lignite	2	6
Total lignite	10	

At a number of points along their outcrops beds C and D are well located with reference to transportation by water, and are easily accessible to mining for domestic purposes.

Beds E, F, and G.—In T. 27 N., R. 54 E., and between Twomile and Hardscrabble creeks, beds E and F appear as narrow outliers capping the highest divides. Their outcrops are nearly everywhere fringed by clinker, making frequent measurements of their thickness impossible by the usual means. Near the east line of T. 27 N., R. 54 E., the eastward dip of the beds is about 100 feet to the mile, but farther east the dip diminishes considerably, probably not amounting to more than 25 feet to the mile opposite Culbertson.

A section of bed E in the northeast-central part of T. 27 N., R. 54 E., shows 8 feet 8 inches of good lignite. To the east the bed diminishes considerably in thickness. In the SW. ¼ sec. 11, T. 27 N., R. 55 E., it is about 4 feet thick, with a thin parting near the base. A measurement of bed E in the N. ½ sec. 8, T. 27 N., R. 56 E., in the south bank of Missouri River opposite Culbertson, shows 4 feet 9 inches of lignite, with three thin partings. East of Hardscrabble

Creek bed F occurs near the top of the bluff bordering the river flat and is burnt continuously along its outcrop. The bed lies about 150 feet above river level near the mouth of Hardscrabble Creek and 100 feet above river level at the ferry south of Culbertson. The dip of the bed to the east is probably not more than 25 feet to the mile, hence so far as mining is concerned it may be regarded as lying flat.

About half a mile west of the ferry south of Culbertson, where the wagon road crosses the point of a hill, 8 feet 6 inches of bed F was measured, the base being concealed. It is here free from partings and appears to be of excellent quality.

Section of bed F in NW. ¼ sec. 9, T. 27 N., R. 56 E.

	Ft.	In.
Sandstone roof.		
Lignite	4	
Clay and sandy clay	15	
Lignite (bed F)	6	6
Total lignite	10	6

One-fourth mile east of this locality a mine has been opened on bed F. A section follows:

Section of bed F in sec. 9, T. 27 N., R. 56 E.

	Ft.	In.
Clay roof.		
Lignite	3	11
Clay		2
Lignite	3	9
Clay		1
Lignite	1	10
Total lignite	9	6

The great thickness of clinker attending bed F is probably due to the combustion of this bed together with the 4-foot bed 15 to 20 feet above.

Bed F, though not ideally situated with reference to water transportation, is at many places near enough to the river to be reached by an incline from the edge of the water. The quality of the bed is everywhere apparently good.

The outcrop of bed G was not traced south of Missouri River. About 2 miles south of Culbertson ferry this bed is exposed and measures 5 feet 6 inches of clean lignite.

NORTHEAST CORNER OF RESERVATION.

No attempt has been made to trace individual beds of lignite in the northeast corner of the reservation, as the region is so covered by glacial material as to make close correlations impossible. As in other parts of the field the contact of the somber-colored beds with

the Fort Union formation above marks practically the lower limit of workable lignite. Above this contact the distribution of lignite beds is probably not radically different from their distribution in the Brockton-Culbertson district, except that beds higher in the stratigraphic section appear. The general dip of the strata is to the east, possibly a little south of east, in amount ranging from a few feet to 100 feet to the mile.

Lignite on Smoke Creek.—Lignite is exposed at many places on Smoke Creek near water level. In all probability these exposures are on the same bed, whose dip to the southeast is practically the same as the fall of the creek. At no place could the full thickness be seen. Near West's ranch the bed has been mined for local use. Some sections follow:

Section about 4 miles up Smoke Creek from West's ranch.

	Ft.	in.
Lignite	2	5
Parting		1
Lignite (base concealed)	4	2

Section in north bank of Smoke Creek at West's ranch.

	Ft.	in.
Lignite	2	5
Parting		1
Lignite (base concealed)	4	2

Section about 6½ miles down Smoke Creek from West's ranch.

	Ft.	in.
Lignite	2	5
Parting		1
Lignite (base concealed)	5	6

In the bluff south of West's ranch a number of lignite beds appear, two of which have been burned along their outcrops and may be of workable thickness. These are 140 and 160 feet above the level of Smoke Creek.

Lignite on Sauerkraut Creek.—A bed of lignite 5 feet 10 inches thick is exposed on Sauerkraut Creek, a small stream that flows southeastward between Smoke and Wolf creeks. About 2½ miles southwest of Scott's ranch on Wolf Creek the lignite has been mined for local use. The bed appears to dip slightly to the southeast and is overlain by sandstone. Other exposures of thin beds of lignite were noted on Sauerkraut Creek.

Lignite near Wolf Creek.—Near the heads of small streams which enter Wolf Creek from the west the country is cut into badlands, exposing several beds of lignite. These beds have been considerably burned in their outcrops, forming a red clinker. A measurement of the thickest bed gave 6 feet of lignite, with a 4-inch parting 1 foot from the top.

MAP OF FORT PECK INDIAN RESERVATION LIGNITE FIELD, MONTANA

By C D SMITH, J A DAVIS, E B HOPKINS, AND E L DeGOLYER

ENGRAVED AND PRINTED BY THE U S GEOLOGICAL SURVEY

A section of the rocks exposed at the head of a small stream entering Wolf Creek from the west 6 miles upstream from Scott's ranch follows:

Section of beds west of Wolf Creek.

	Ft.	in.
Sands and clays, yellowish	150	
Sand, blue and yellow	20	
Clay, carbonaceous		6
Sandstone, yellow	12	
Clay, some lignite	9	
Sand and clay	15	
Clay, carbonaceous	2	
Clay, sandy	21	
Sand	10	
Lignite		8
Clay	10	
Clay, sandy	17	
Lignite		8
Clay	4	
Lignite	1	
Clay	8	
Sand, yellow	16	
Clay and sand	15	
Lignite		3
Sand	6	
Lignite	6	
Clay and sand	15	
Lignite	2	
Sand and clay	60	
Level of Wolf Creek.	401	1

Very little lignite shows in the drainage basin of Wolf Creek, except as noted in the foregoing section, about 75 feet above the level of the stream, although a section of rocks 500 feet or more thick is well exposed in the region.

On the east side of Wolf Creek, 15 miles above Scott's ranch a 5-foot bed was seen. This bed was on fire near the point where it was measured.

Other localities.—On Otter Creek, a small tributary of Big Muddy Creek in the extreme northeast corner of the reservation, a bed of lignite outcrops but has been so completely burned that no satisfactory measurements could be made.

In the west bank of Big Muddy Creek 3 miles northeast of Scott's ranch several thin beds of lignite were noted, but they were not of sufficient thickness to warrant much attention.

From Kern's ranch, on Poplar River, about 9 miles north of the seventh standard parallel, northwestward to the north boundary of the reservation, the contact of the somber-colored beds with the overlying Fort Union formation is easily traceable and

is usually marked by the presence of several beds of lignite, both above and below. From Kern's ranch southeastward to the seventh standard parallel the lower contact of the Fort Union is so generally concealed that its position is indefinite.

On Hay Creek, 3 miles north of Kern's ranch, lignite has been mined for local use. At the time the mine was examined only 3 feet 7 inches of the bed was exposed, the base being concealed. A thin parting occurs near the top of the bed.

The area in the northeast corner of the reservation underlain by the Fort Union formation is shown on the map accompanying this report. Although in this area lignite is exposed only along the large streams it is probable that prospecting elsewhere would reveal many workable beds now concealed by débris.

NORTH-CENTRAL PART OF RESERVATION.

In the north-central part of the reservation, south of West Branch of Poplar River and Cottonwood Creek, is a high plateau whose north boundary is marked by an abrupt escarpment in which the contact of the somber-colored beds with the Fort Union formation above is exposed. This contact, at or near which several beds of lignite usually occur, is about 200 feet above the level of Poplar River. The land between the base of the escarpment and Poplar River has a uniform slope, but is in places deeply trenched by short northward-flowing streams. The highest part of the plateau lies next to its north boundary, from which the slope is gentle to the south for several miles, to a region where streams heading in the plateau gain sufficient strength to cut deep valleys, thus changing the character of the country from a smooth to a rolling prairie with gulches here and there.

The lower contact of the prolifically lignite-bearing formation on the south side of the plateau could not be located with certainty because of the smooth, grass-covered character of the country. The contact of the somber-colored beds and Fort Union formation in this plateau rises gradually to the west to a point a few miles east of the head of Cottonwood Creek, where it is intercepted by a gravel terrace the grade of which, although in the same direction, is slightly less than the rise of the contact.

Section at high white point at east end of plateau south of West Branch of Poplar River.

	Ft.	in.
Sandstone, soft, yellowish	40	
Lignite		5
Clay	1	9
Lignite		7
Clay	2	3
Lignite	6	

	Ft.	in.
Clay and sand, somber	77	
Lignite	4	5
Clay, carbonaceous	2	8
Lignite	1	
Clay, gray	3	
Sandstone, gray	17	5
Lignite	2	1
Clay, carbonaceous	2	3
Sand, clayey	20	
	180	10

Section in badlands southeast of junction of Cottonwood Creek and West Branch of Poplar River.

	Ft.	in.
Gravel	15	
Sandstone, coarse, white	2	6
Sandstone, yellowish, and gray clay	40	
Lignite		5
Clay		6
Lignite	3	
Sand, clayey	20	
Sandstone, soft	10	
Lignite	1	
Sandstone, clayey	15	
Clay, dark gray	40	
Lignite	3	6
Clay	1	6
Lignite	5	
Clay, sandy	4	
Lignite	6	6
Clay	5	
Sand	10	
Clay, sandy, with two thin beds of lignite at top	17	6
Lignite	1	
Clay	12	6
Sandstone, cream-colored	5	
Lignite	2	
Clay	3	
Sand, somber	15	
Lignite	3	9
Clay, sandy, somber.		
	242	8

As shown by the sections, a number of lignite beds occur in this area, but they are rather inaccessible because of their elevation. Water for mining purposes is scarce or lacking altogether.

Section of somber-colored beds in badlands southeast of Kern's ranch.

	Ft.	in.
Sand and clay	12	
Lignite, bony	2	6
Sand, yellow	6	
Lignite, thin		
Sand	2	6
Lignite		8
Sand and clay	10	
Lignite	1	3
Clay and sand	47	6
Lignite	2	
Clay	10	
Lignite	1	
Sand	10	
Lignite, thin		
Clay and sand	28	6
Lignite		8
Sand and clay	65	
Lignite, thin		
Clay	17	
Lignite	1	
Clay, with two thin seams lignite	24	
	241	7

North of Cottonwood Creek and between East and West branches of Poplar River are some small areas underlain by yellow beds of the Fort Union formation, but they are similar to the plateau just described so far as general conditions of accessibility are concerned and will not be discussed further. Their extent is shown on Plate III.

Section of lignite beds in NE. ¼ sec. 6, T. 28 N., R. 47 E.

	Ft.	in.
Gravel and clay	15	
Sand	5	
Clay, sandy	8	
Lignite	1	10
Clay	8	
Lignite	1	10
Clay, sandy	20	
Lignite	1	8
Clay		5
Lignite	1	
	62	9

The lignite beds noted in the foregoing section appear in a high point of land which is crossed by the seventh standard parallel just east of Wolf Creek. A short distance northeast of the point where the section was made one of the beds noted has been mined for local use. About 40 acres of surveyed land is underlain by the lignite.

CHARACTER AND USES OF THE LIGNITE.

The lignite in the Fort Peck field does not differ in character and composition from that in other parts of the same general region. It is dark brown in color, tough, and woody in structure.

The following analysis represents a sample of lignite obtained 3 miles north of Culbertson, which is the only place near the reservation where an unweathered sample could be obtained at the time, but it is thought that fuel in other parts of the field will not differ materially in quality from this sample. The analysis was made at the laboratory of the United States Geological Survey fuel-testing plant, Pittsburg, Pa.

Proximate analysis and calorific determinations of lignite from the Bruegger mine, 3 miles north of Culbertson, Mont.

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

Laboratory No.	7059	Loss of moisture on air-drying	38.70
Sample as received:		Air-dried sample:	
Moisture	43.16	Moisture	7.28
Volatile matter	22.03	Volatile matter	35.93
Fixed carbon	28.99	Fixed carbon	47.29
Ash	5.82	Ash	9.50
Sulphur	.29	Sulphur	.48
Calories	3,333	Calories	5,437
British thermal units	5,999	British thermal units	9,787

This sample was taken according to Survey regulations and represents the whole thickness of the bed. After crushing, the lignite was sealed in a galvanized can and thus reached the laboratory in practically the same condition as it was in the mine. As shown by the analysis the sample as received at the laboratory contained 43.16 per cent of moisture, which is somewhat high even for a lignite. It is probable that the analysis of the air-dried sample represents approximately the condition of the fuel as it would reach the consumer, for much of its moisture is lost through handling.

In the absence of timber, which is almost totally lacking in this region except in the river valleys, lignite is used generally for domestic purposes. However, as most of the inhabitants of the Fort Peck region live near Missouri River, where timber is comparatively plentiful, little lignite is mined. Except at the Bruegger mine it is taken from open pits where it is necessary to remove only a small amount of overburden.

FUTURE DEVELOPMENT.

Lignite is widely distributed in this general region and it is not likely that any part of the area will develop far in advance of any other part, though if a certain field should have extremely favorable conditions of transportation, thickness, and purity of fuel it would derive some advantage therefrom. It seems probable, therefore, that the fuel will have only a local use for many years to come and that it will not enter seriously into competition outside of its own territory with better grades of fuel mined in other parts of Montana.

Probably the greatest future use of the lignite will be in generating power for pumping plants to irrigate lands where gravity systems are impracticable, but lands however irrigated would attract many settlers, thus creating a great demand for fuel for domestic purposes.

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

By R. W. Richards.

INTRODUCTION.

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

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

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

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

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

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

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

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

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

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

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

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

TOPOGRAPHY.

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

GEOLOGY.

STRATIGRAPHY.

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

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

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

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

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

	Ft.	in.
Sandstone, gray (base (?) of Fort Union).		
Sandstone, yellow, coarse, soft	212	4
BIG DIRTY COAL BED.		
Carbonaceous sandstone and shale, with ⅛-inch to 1-inch streaks of coal	10	5
Sandstone, yellow, soft	6	6
Carbonaceous sandstone and shale, with streaks of coal as above	7	9
Sandstone, yellow, coarse, with iron concretions	15	4
Limestone	1	
Sandstone	14	
Coal		8
Shale, yellowish	30	
Sandstone	15	
Coal		4
Shale, gray		4
Coal		8
Shale, gray	34	
Sandstone, with iron concretions	55	
Limestone	3	
Shale, gray	3	4
Coal		3
Bone		3
Coal		7
Shale		4
Coal		3
Sandstone, yellow, weathering into rounded forms	16	
Shale	11	2
Coal		10
Limestone concretions	10	
Shale	30	
Sandstone	15	
Shale	2	
HOMESTEAD COAL BED.		
Coal		11
Shale, carbonaceous		9
Coal	1	1
Shale		1
Coal		11
Shale		1
Coal		6
Shale	18	6
Coal	1	8
Shale	6	
Coal		2
Shale	4	7
Sandstone	2	

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

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

STRUCTURE.

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

[a] Op. cit.

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

COAL.

GENERAL STATEMENT.

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

DETAILED DESCRIPTIONS.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Section of Carpenter coal on Carpenter Creek.

	Ft.	in.
Coal, and some mineral charcoal	5	
Bone		2
Coal	1	1
Shale		1½
Coal, with six ⅛-inch partings	2	11
Total coal	9	

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

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

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

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

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

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

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

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

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

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

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

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

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

	Ft.	in.
Bone		3
Coal	6	
	6	3

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

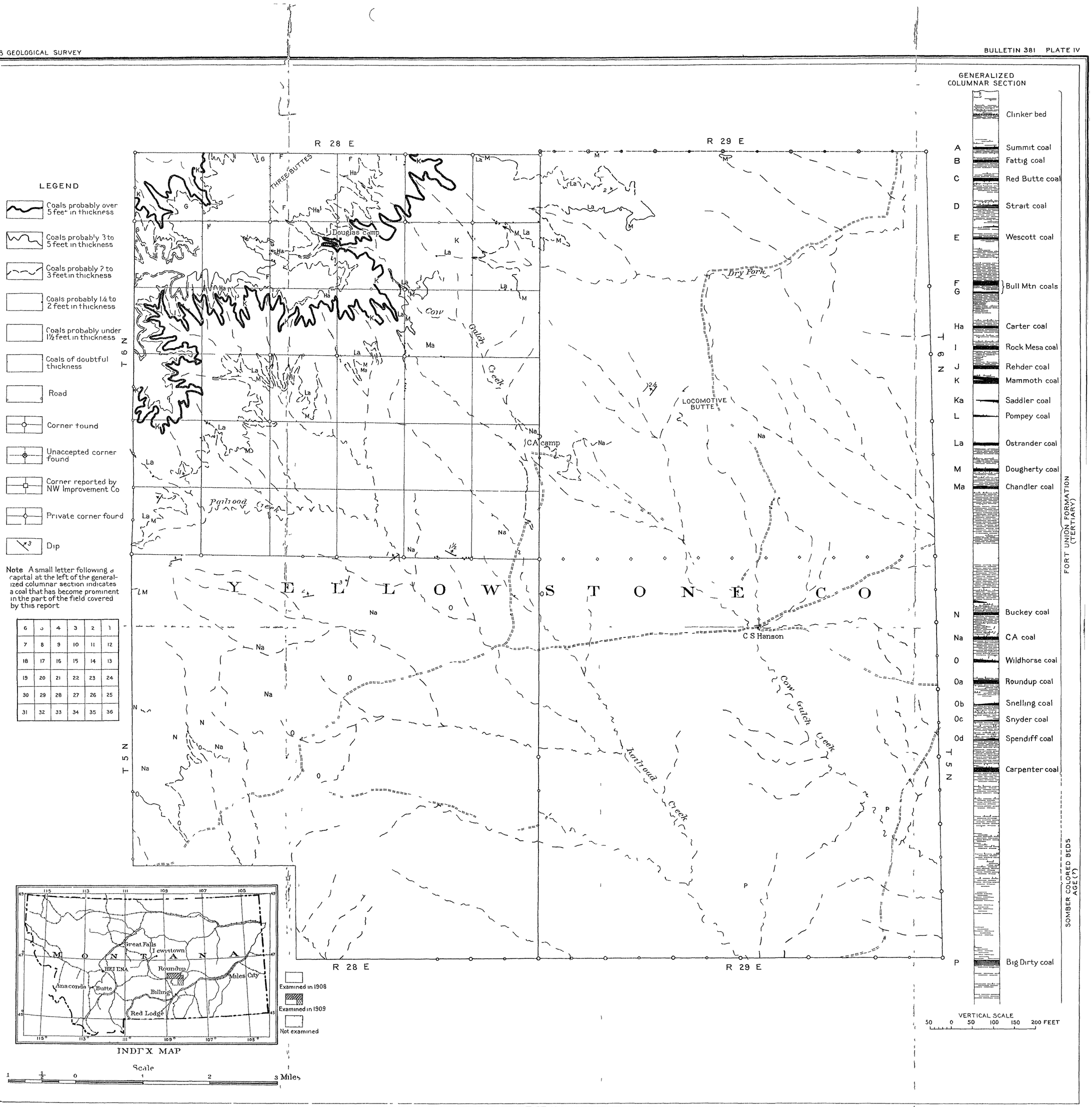
The Buckey coal occurs 60 feet above the "C. A." bed, and though prominent in the area examined in the previous year by Woolsey is of slight importance in that portion of the field mapped during 1908. The bed shows a workable thickness for a short distance along the western border of T. 5 N., R. 28 E.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

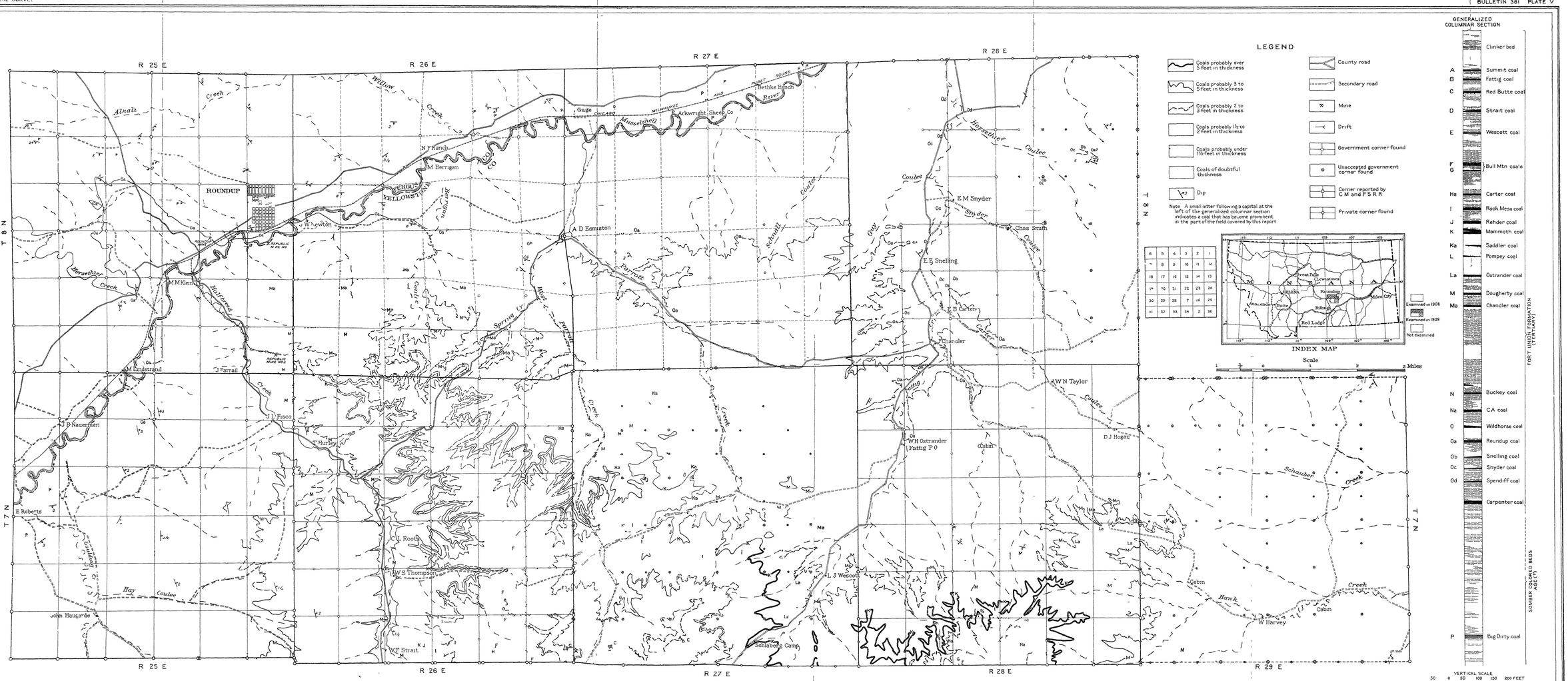
Between the Buckey and the Dougherty coal the rocks are generally barren of coal beds. The Chandler coal, 40 feet below the Dougherty, was found near Railroad Creek, Cow Gulch, and Fattig Creek. It is usually thin and of poor quality.

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

MAP OF SOUTHEASTERN PART OF BULL MOUNTAIN COAL FIELD, MONTANA

BY R W RICHARDS





MAP OF NORTHWESTERN PART OF BULL MOUNTAIN COAL FIELD, MONTANA

BY R W RICHARDS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CHARACTER.

PHYSICAL PROPERTIES.

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

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

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

CHEMICAL PROPERTIES.

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

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

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

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

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

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

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

Comparison of various Montana and Wyoming coals.

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

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

DEVELOPMENT.

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

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

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

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

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

THE MILK RIVER COAL FIELD, MONTANA.

By LEON J. PEPPERBERG.

INTRODUCTION.

Field work.—This paper is a preliminary statement[a] of the results of a detailed survey of a part of the Milk River coal field, Montana, made during the summer of 1908 by the writer with the assistance of V. H. Barnett. The object of this survey included not only the geologic and economic investigation of the area but primarily the classification of the public lands with respect to coal. Consequently the work was conducted with the view of ascertaining the extent of the coal areas and their relations to legal land subdivisions. In carrying on this work the geologic data were platted upon a base of recent topographic maps made by the United States Geological Survey on a scale of approximately 1 inch to the mile with a contour interval of 20 feet. This base covers the entire area examined, with the exception of a narrow strip about 1¼ miles wide along the southern part of T. 32 N., Rs. 15 to 21 E., inclusive.

Previous reports.—Very little has been written concerning the geology or coal of this region. The most important work published by previous investigators is that of T. W. Stanton and J. B. Hatcher.[b] Their report, which deals with the geology and paleontology of the Judith River formation, contains a review and bibliography of publications relating to this formation in Montana and Canada. Brief mention of the coal of this field is made in a report by J. P. Rowe[c] and the field is referred to in several reports of the inspector of coal mines of the State of Montana and in the "Mineral Resources of the United States."[d]

The glacial geology of the region has been briefly discussed by F. H. H. Calhoun,[e] and papers describing the prominent features of

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

[b] Geology and paleontology of the Judith River beds, with a chapter on fossil plants by F. H. Knowlton: Bull. U. S. Geol. Survey, No. 257, 1905.

[c] Montana coal and lignite deposits: Bull. Univ. Montana No. 37 (Geol. series No. 2), 1906, pp. 39–40.

[d] Mineral Resources U. S. for 1907, pt. 2, U. S. Geol. Survey, 1908, pp. 149–150.

[e] The Montana lobe of the Keewatin ice sheet: Prof. Paper U. S. Geol. Survey No. 50, 1906.

the Bearpaw Mountains with special reference to igneous rocks have been published by W. H. Weed and L. V. Pirsson.[a]

Location and extent.—The part of the Milk River coal field herein described is located in Chouteau County in north-central Montana. The greater portion lies in the Milk River drainage basin, but it also includes a strip in the extreme southwest corner which drains into Missouri River. The area examined embraces Tps. 32 to 34 N., Rs. 12 to 24 E., inclusive, along Milk River and the main line of the Great Northern Railway, and an irregular tract from the north boundary of T. 31 N. to the south boundary of T. 26 N., Rs. 10 to 14 E., inclusive, along the Montana Central division of the Great Northern Railway. The area as described includes over 2,000 square miles, but only that part which contains coal of importance is shown on the accompanying map (Pl. VI).

TOPOGRAPHY AND GEOGRAPHY.

The area under consideration is situated in the northwestern part of the Great Plains region. For the most part it is covered with a fair growth of grass and scattered patches of sagebrush. Trees are noticeably absent except along Milk River and its larger tributaries east of Havre, where cottonwood, willow, and underbrush grow close to the drainage ways. When viewed from the highlands the country has a rolling aspect, exhibiting no abrupt changes except where tributaries to the main river have eroded deep channels in passing from the higher land to the valley and where a few lava buttes south and southwest of Havre stand out prominently in comparison to the surrounding flat, treeless plains. In the extreme northeastern portion of the area the bench land has an altitude of 3,220 feet while the lowest point in the southeast corner is 2,320 feet above sea level. The average elevation of the area examined is 2,600 to 2,800 feet.

Almost the entire region under discussion is drained by Milk River, which enters the area in the northwest corner at an elevation of about 2,570 feet. It flows through a narrow, steep-walled valley in a southeasterly direction for about 14 miles and then makes an abrupt turn to the east and continues in this direction for about 24 miles. The course of the river from this point is almost due northeast for 4 miles, beyond which it flows in an east-southeast direction until it crosses the south boundary of the area at an elevation of 2,320 feet above the sea. Within the area examined Milk River flows circuitously about 114 miles in a distance of about 70 miles, forming numerous oxbows, cut-off lakes, and wide migrating meanders on its way. It has a fall of 230 feet, or approximately 2 feet to the mile. The valley of Milk River in the western part of the field is narrow and

[a] Am. Jour. Sci., 4th ser., vol. 1, 1896, pp. 283–301; vol. 2, 1896, pp. 188–199.

steep walled, some of the cliffs rising 200 feet above the water level. It has been pointed out by Calhoun[a] that Milk River now occupies the preglacial valley of the Missouri, which formerly flowed south of Havre and was joined by the preglacial Milk about 3 miles east of that city near Stringfellow's ranch. At this point the preglacial Missouri crossed the present course of Milk River in a northeasterly direction and the decrease in the width of the valley below Stringfellow's ranch is conspicuous, but at Yantic Milk River reenters the broad valley formerly occupied by the Missouri and follows the preglacial channel until it leaves the area under discussion. At Yantic the Milk River canyon, which has had an average width of less than a mile, spreads out abruptly to one 3 to 4 miles in width. The cliffs recede and become less abrupt, and the stream is small in comparison with the valley it occupies.

The tributaries of Milk River are for the most part intermittent streams, but the drainage ways contain local water pockets and a few springs which afford watering places for stock. As a rule this water is too alkaline for domestic purposes. The bench land is studded with numerous small intermittent lakes which occupy shallow depressions in the glacial drift. The water in these lakes, especially in the smaller ones, contains salts leached from the soil and is therefore alkaline.

The principal towns in the area are Havre, Chinook, Harlem, and Big Sandy. The first three are situated along the main line of the Great Northern Railway, which crosses the southern half of the field from east to west. Big Sandy is located in the southwestern part of the field, on the Montana Central division of the Great Northern Railway, which leaves the main line about 4 miles west of Havre and runs in a southwesterly direction to Great Falls and Helena.

GEOLOGY.

STRATIGRAPHY.

The sedimentary rocks outcropping in the part of the Milk River coal field under discussion consist mainly of sandstone and shale which belong to the Montana group of the Cretaceous system with the exception of a small infaulted area of Tertiary rocks about 6½ miles east of Big Sandy. These rocks are largely covered by glacial materials on the bench-land areas and by alluvial deposits in the larger valleys. In a few places they are cut by igneous intrusions or covered by lava flows.

[a] Op. cit., pp. 38–39.

The following formations, which are given in ascending order, outcrop in this field: Eagle sandstone, Claggett formation, Judith River formation, Bearpaw shale, and Fort Union formation.

Stratigraphy of the Milk River coal field, Montana.

System.	Group or formation.	Thickness.	Description.
		Feet.	
Quaternary			Alluvial deposits. Glacial drift.
Tertiary	Fort Union formation		Massive gray to buff sandstone and thin beds of gray shale, with lignite beds.
(Fault.)			
Cretaceous	Montana group:		
	Bearpaw shale	80–100	Leaden-gray shale, with thin beds of sandstone and large concretions.
	Judith River formation	480	Alternating beds of light-colored sandstone, shale, and lignite.
	Claggett formation	350	Dark gray shales, with thin beds of buff sandstone near top and bottom.
	Eagle sandstone	250+	Massive to calcareous white to cream-colored sandstone, locally cross bedded; at top dark-gray shale, with intercalated beds of gray to buff sandstone.

UPPER CRETACEOUS ROCKS (MONTANA GROUP).

EAGLE SANDSTONE.

The Eagle sandstone, which is the lowest formation in the Montana group, outcrops along Missouri River and several of its tributaries in the extreme southwestern portion of the field. The basal member of this formation is a massive, calcareous, white to cream-colored, persistent, usually hard, and locally cross-bedded sandstone about 100 feet thick. Wherever the base of the Eagle is exposed it constitutes a horizon marker that is easily recognized. In the top 30 feet of the sandstone are numerous concretionary hard lenses of sandstone, some of which are highly stained by iron. These harder parts resist the effect of weathering much better than the rest of the sandstone and stand out as prominent knobs or cap thin rounded or angular spires of the underlying softer material. In places the entire massive stratum forms a steep cliff several miles in length and about 100 feet in height.

The upper member of the Eagle sandstone, which has a thickness of about 150 feet, is easily separable from the lower by its marked lithologic and topographic differences. The sandstone strata in this part of the formation are thin and more friable than those in the lower member. Sandy shales and carbonaceous layers with streaks of coal predominate in the lower half, but the upper half is principally dark-gray shale with a few intercalated beds of gray to buff sandstone. The line between the two members of the Eagle is very pronounced. Overlying the massive white ledge of sandstone are a number of

coaly beds and carbonaceous shales which give this zone a dark color. The upper member, being much softer than the lower member, weathers into long, rounded slopes. Coal beds 6 to 8 inches in thickness were observed, but the greater part of the carbonaceous matter consists of black shale interbedded with fine laminæ of coal.

CLAGGETT FORMATION.

The Claggett formation, which consists largely of dark leaden-gray shales intercalated with thin beds of buff sandstone near the top and bottom, overlies the Eagle conformably. It is very similar lithologically to the Bearpaw shale, from which, without the aid of stratigraphic or paleontologic evidence, it is often distinguished with difficulty.

Gypsum flakes or crystals are scattered throughout this soft shale. Hard concretions of different sizes up to several feet in diameter are numerous, especially near the top. The concretions are calcareous and are usually traversed in all directions by cracks filled with amber-colored calcite or gypsum crystals. Invertebrates are found in the shale but more often in the calcareous concretions; however, they are not so abundant in this formation as in the Bearpaw shale. (See p. 84.) No coal occurs in this formation, but some thin carbonaceous shale was observed near the top. The Claggett in this field has an estimated thickness of 350 feet.

JUDITH RIVER FORMATION.

The Judith River formation overlies the Claggett conformably and is composed of alternating light-colored beds of sandstone and shale. It is almost entirely a fresh-water formation but some brackish-water beds are included at the top in the transition zone between the Judith River and the marine Bearpaw shale and at the base in the transition from the marine Claggett to the fresh-water Judith River formation. There is no persistent member in the entire formation which can be followed for any great distance. The ash-colored sandstone is locally cross-bedded and contains iron-stained concretionary bands. In some places the sandstone is hard and massive; in others it is soft and friable. The shales, sandstones, and coals of this formation are very lenticular and it is common to find a massive sandstone grading into a soft shale or a sandstone or shale grading into a carbonaceous shale or thin coal bed within a comparatively short distance horizontally. In the same manner a coal bed which consists of clean coal of workable thickness may pinch out altogether and be replaced by a sandstone at the next exposure half a mile away. A coal bed from 1 to 12 inches in thickness was observed in the base of the Judith River, but the coals of workable thickness occur within the upper 150 feet of the formation.

This formation outcrops extensively along Milk River northwest of Havre and near the mouth of Boxelder Creek in T. 32 N., R. 17 E., where intense erosion has carved it into typical badland forms. It has a total thickness of about 480 feet.

BEARPAW SHALE.

The Bearpaw shale overlies the Judith River formation conformably and consists of dark leaden-gray shale containing thin beds of sandstone and large concretions, many of which are highly fossiliferous. These round and oval bodies are fissured and the cracks are usually occupied by crystalline calcite. Selenite or gypsum flakes are scattered throughout the formation.

As previously stated, the Bearpaw and Claggett are very similar lithologically. Both are leaden gray in color, both contain similar concretionary masses and thin beds of sandstone and both weather into long, rounded slopes and form barren patches of loose weathered shale. The Bearpaw, which is represented by observed outcrops 80 to 100 feet in thickness in this field, has a known thickness of 350 to 900 feet in other parts of Montana.

TERTIARY SYSTEM (FORT UNION FORMATION).

Abundant fossil plants which are, according to F. H. Knowlton, of Fort Union age, were collected in sec. 18, T. 28 N., R. 14 E., about 6½ miles east of Big Sandy. These leaves occur above and below the coal beds in this district. The Fort Union outcrops in the western foothills of the Bearpaw Mountains, where it covers only a small area. From the few outcrops noted it was impossible to determine which part of the formation is present in this field, but it may possibly correspond to the upper yellow beds of the formation as developed in northeastern Montana and northwestern North Dakota.

Lithologically the Fort Union is notably different from the Judith River formation; it consists largely of massive strata of gray to buff sandstone, which are very persistent, and of thin beds of gray shale. These strata contain several beds of good coal which are discussed elsewhere in this paper. The position of this formation in the geologic column is several hundred feet above the Cretaceous formations already described, and its occurrence in this district is due to a fault having an estimated throw of about 2,000 feet.

GLACIAL AND ALLUVIAL DEPOSITS.

Among the features which should be fully described in any complete account of the region are several types of glacial and alluvial deposits, such as ground and recessional moraines, kames, eskers, drift, till, and river and lake deposits, which cover the greater part of the area. These features of recent glaciation and erosion can be only mentioned here.

IGNEOUS ROCKS.

In the area under consideration igneous rocks are comparatively rare, but a few prominent buttes are present in the vicinity of Havre and in the southwestern part of the field. The igneous rocks, which are of post-Eocene age, include both extrusive and intrusive types and have had little or no effect on the coal.

STRUCTURE.

As the area is largely covered by glacial and alluvial deposits and continuous exposures for great distances are lacking, the structure is very obscure. Except in a few places where the glacial cover is extremely thin, the only outcrops present in the field are along the lines of drainage where erosion has removed the glacial mantle. At these places the sedimentary rocks outcrop in small patches or long, narrow strips on either side of the coulées and along well-drained slopes. These rocks, which were originally approximately horizontal, have been subsequently disturbed by numerous faults and folds, which make the working out of the stratigraphy rather difficult. A vivid idea of the abundance of these disturbances is given by Hayden,[a] as follows:

> 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 faults of the Milk River field are too numerous to be described individually. They are in general closely associated with folds and for the most part are of the thrust type, although a few normal or tension faults were observed. The faulting is best developed in the regions where the folding has been greatest. The larger thrust faults were probably developed at about the same time as the folds with which they are associated, and with one or two exceptions they are in a general way parallel to the axis of the Bearpaw Mountains.

The disturbances mentioned have caused lateral and vertical offsets of the coal beds, in many places tilting them to high angles.

THE COAL.

GENERAL STATEMENT.

All the coals in the Milk River field, so far as studied, may be classed as a fair grade of subbituminous coal ("black lignite"). Most of the coal beds are lenticular in shape, showing a variation in thickness from a fraction of an inch to 9 feet at different points on the outcrop. These beds are noticeably thinner and of a lower

[a] Hayden, F. V., Proc. Acad. Nat. Sci. Philadelphia, 1857, p. 116.

grade in the eastern part of the field than in the western part, so that beds of considerable thickness and good quality in the vicinity of Havre contain little or no coal near Harlem. Generally there is one bed, in some localities two, and in others four beds, all of workable thickness. The greater part of the coal of workable thickness occurs in the upper part of the Judith River formation (Upper Cretaceous), from 10 to 150 feet below the base of the Bearpaw shale, the only exception being the coal east of Big Sandy, which is of Fort Union (Tertiary) age.

On account of the small number of mines and prospects in the area it was necessary to study the coal largely from the weathered outcrops of the beds and from the data thus obtained to infer the character of the coal. The method employed in pursuing this study may be outlined briefly as follows. A careful search was made in coulées and ravines over the whole area for outcrops of coal beds. All coals thus found were traced by foot traverse until they pinched out, were covered by glacial or alluvial material, or were cut out by faults. All mines and prospects visited and all coal outcrops traversed were platted upon a topographic base prepared by the United States Geological Survey and all the coal beds were measured. Samples for chemical analysis were taken from the principal beds at the mines and prospects throughout the area. The examination showed that the topographic maps were well tied to the land surveys, and the section corners were so well marked that no difficulty was experienced in locating a corner when it was desired to tie a coal crop or prospect to a known point. The extensive glacial and alluvial covering in this field or the slumping of talus obscures the outcrop of coal over large areas, making the continuous tracing of coal beds or formation boundaries impossible.

In many places the coal beds and carbonaceous shale have been burned along the outcrop and the adjacent rocks have been baked to a red material resembling brick or tile. Prospects driven through the burned areas where the covering is from 20 to 50 feet thick demonstrated that it extends from 30 to 70 feet from the present outcrop of the hardened clinker and ash, and that the good coal bed continues behind the burned crops. The map (Pl. VI) shows the location of the coal zone, mines, and prospects with relation to the section corners, and such other geologic data relating to the coal as the scale of publication permits.

DETAILED DESCRIPTIONS.

For convenience the parts of the Milk River coal field with which the present report is concerned will be discussed as separate units termed the Havre, Chinook, Harlem, and Big Sandy districts. The

boundaries of these districts have been arbitrarily chosen with reference only to the towns near which the greatest amount of mining is being carried on and from which coal shipments can be made.

HAVRE DISTRICT.

The Havre district is the best known in the Milk River field, on account of the local demand for the fuel and the fact that the largest coal mine in the area is located within its borders. This district as here treated embraces all of Tps. 32 to 34 N., Rs. 14 to 17 E., inclusive, and the northern tier of sections of T. 31 N., R. 17 E. Future work in this field will extend the boundaries of the Havre district both to the north and south of the area herein described. The coal of the district is as accessible as any other in the region and is easily reached by wagon roads which traverse the area in all directions. The sections given in the following pages show the thickness and contents of a few of the principal coal beds exposed at various localities throughout the field.

Locality 1:[a] The following section was measured in a prospect opened by Mr. Cowen in 1898 and worked during the winter of 1907 by Mr. Schean:

Section of coal bed in prospect in SE. ¼ NE. ¼ sec. 28, T. 33 N., R. 14 E. (No. 1).

	Ft.	in.
Shale, carbonaceous	2	3
Coal	3	
Bone and clay	1	5
Coal		4
Bone		3
Total coal	3	4

This bed was sampled at the breast of the workings about 75 feet from the mouth of the entry, where the coal showed little or no effect of slacking. The main coal has a bright black luster, is solid, and has a semiconchoidal fracture. On exposure to the air it loses moisture rapidly and checks or disintegrates into small irregular bits. The prospect is located about 30 feet southeast of a small fault which cuts the coal out to the northwest. Another small fault about 60 feet southeast of the opening limits the outcrop of the bed in that direction.

At the head of Supenau Coulee, in sec. 1, T. 33 N., R. 14 E., the coal zone of the Judith River formation is again exposed. Here the beds have a low dip to the northeast, which shows that the area to the north is underlain by the coal bed, while that south of the coal crop in the northern part of sec. 12, T. 33 N., R. 14 E., is probably not underlain by coal. On account of poor exposures no measurements were made of the coal at this place.

[a] Numbers like this correspond to those on Pl. VI.

Locality 2: The following section was measured on the south side of Redrock Coulee, where a bed of coal which lies almost flat and under thin cover outcrops for a short distance. This coal is badly weathered but shows good cubical joints, indicating that it would probably prove to be of good quality. Redrock Coulee derives its name from the red rocks along the burned coal crops in T. 33 N., R. 17 E.

Section of rocks exposed in SE. ¼ sec. 10, T. 34 N., R. 15 E. (No. 2).

	Ft.	in.
Glacial deposits	17	
Shale, carbonaceous	2	
Bone	1	
Coal	2	6

Locality 3: The following section was measured near an abandoned prospect in sec. 7, T. 33 N., R. 15 E. The bed dips slightly to the northeast and probably underlies the greater part of the area between this point and locality 2.

Section of coal in SE. ¼ sec. 7, T. 33 N., R. 15 E. (No. 3).

	Ft.	in.
Glacial drift	10	
Coal	1	4
Shale, carbonaceous	1	
Coal	1	6
Bone		8
Bone with coaly streaks	2	6
Total coal	2	10

Locality 4: The character of the bed in the southeastern part of T. 33 N., R. 15 E., is represented in the following section, which was measured at an abandoned prospect in sec. 25:

Section of coal bed at prospect in NW. ¼ sec. 25, T. 33 N., R. 15 E. (No. 4).

Shale, carbonaceous.	Ft.	in.
Bone	1	6
Shale, carbonaceous		3
Coal, clean	3	
Bone		3
Shale, soft gray		5
Coal, rather bony	1	4
Bone.		
Total coal	4	4

This zone continues in a southeast direction under the glacial drift and is next exposed in sec. 31, T. 33 N., R. 16 E., south of the Havre Fuel Company's mine. It will be described under locality 8.

Locality 5: The following section was measured in a prospect located in the southwestern part of T. 33 N., R. 15 E., where the coal

outcrops south of a thrust fault. This prospect, which was opened by H. Barrott, is worked by the room and pillar method. The main entry is about 250 feet long and follows the dip of the bed, which is about 8° NE. at this place.

Section at Barrott's prospect in SW. ¼ sec. 29, T. 33 N., R. 15 E. (No. 5.)

	Ft.	in.
Clay, shaly.		
Shale, carbonaceous	2	6
Coal		8
Bone		4
Shale, carbonaceous	4	
Coal		2
Bone		7
Coal	3	3
Total coal	4	1

The sample of coal which was taken from the 3-foot 3-inch bench of the above bed gave a calorific value of 8,944 British thermal units in the air-dried state.

Locality 6: The coal zone of the Judith River formation outcrops at various places in the bed of Coal Creek in the northern tier of sections of T. 33 N., R. 16 E. Here the beds, which dip about 3° NE., lie under very little cover and are badly weathered along the outcrop. The best exposure is at locality 6, in the SE. ¼ sec. 2, on the south bank of the creek. The following section represents the character of strata exposed at this point:

Section of rocks exposed in SE. ¼ sec. 2, T. 33 N., R. 16 E. (No. 6).

	Ft.	in.
Glacial drift	4	
Sandstone, clayey soft	3	
Shale, carbonaceous		2
Bone		4
Shale, sandy, carbonaceous	3	6
Coal		5
Bone		7
Coal	1	9
Clay, sandy, white		2
Coal	1	6
Shale, sandy, carbonaceous	1	8
Shale, drab	5	
Coal		11
Bone		4
Coal	1	2
Bone, with coaly streaks	1	9
Bone		4
Coal		11
Bone		5
Shale, black, carbonaceous.		
Total coal	6	8

Although the coal is badly weathered, it has well-developed cubical joints even at the surface, and by very little digging fresh coal of bright luster was uncovered, indicating that good coal exists within easy reach of the surface or within a short distance from the present outcrop. The coal extends beneath the glacial drift to the south, where it outcrops along the north side of a small coulee in secs. 28 and 29, T. 33 N., R. 16 E. At this place the coal contains numerous partings of bone and lies nearly flat under thin cover. Prospects have been driven at the head of the coulee in the N. ½ sec. 29, where the thickest bed contains three benches of coal 14, 16, and 17 inches thick, separated by 6 and 8 inches of bone. It is reported that these prospects were abandoned on account of the large amount of bone which could not be economically separated from the coal. From this point the bed swings to the southeast and then to the west, around the head of a coulée at the Alcott and Gussenhoven prospects.

Locality 7: The following section down the slope of the Alcott prospect shows the coal content of the beds measured:

Section down the slope of the Alcott prospect in NW. ¼ SW. ¼ sec. 29, T. 33 N., R. 16 E. (No. 7).

	Ft.	In.
Glacial drift.		
Shale, carbonaceous		8
Coal		4
Shale, carbonaceous		9
Shale, sandy	7	10
Shale, brown, carbonaceous		1½
Shale, black, carbonaceous		½
Bone, with coaly layers		4
Coal		10
Bone		3
Shale, with thin coaly layers		7
Shale, gray	3	
Shale, carbonaceous		3
Coal	1	2
Bone, with thin coaly layers		2
Shale, carbonaceous		5½
Clay, ash-colored	2	10
Shale, carbonaceous		3
Coal, with thin bone seams		5
Bone		¼
Coal		6
Bone		1½
Coal		8
Bone		10
Coal	2	2½
Bone, with thin coaly layers	1	2
Clay		4
Bone		4½
Bone, with thin coaly layers		10
Total coal	6	1½

The lower 5½ feet of the above section is being worked in this prospect. The 2-foot 2½-inch bench is clean coal of bright luster, with well-developed cubical joints and a calorific value of 9,729 British thermal units on the air-dried sample. The area between the Alcott prospect and the Havre Fuel Company's mine is underlain by this bed.

Locality 8: The following sections were measured at different points in the workings of the Havre Fuel Company's mine in the NW. ¼ sec. 31, T. 33 N., R. 16 E., and show the variations in the same bed within a comparatively short distance:

Sections of coal bed in Havre Fuel Company's mine, NW. ¼ sec. 31, T. 33 N., R. 16 E. (No. 8).

	Ft.	in.
Roof, coal	1±	
Coal		9
Bone		5
Coal	1	5
Bone		2
Coal		11
Bone		10
Coal		8–10
Floor, shale, black, carbonaceous.		
Total coal	4	9 to 4 11

	Ft.	in.
Roof, shale, with thin coaly layers	1	4
Bone		2
Coal		9
Bone, with thin coaly layers		10
Bone		6
Coal	2	6
Bone		6
Coal		4–8
Floor, shale, carbonaceous.		
Total coal	3	7 to 3 11

A number of other sections measured in this mine show the coal and bone to be variable throughout the workings. In several places the bed consists almost entirely of bone with thin seams of coal; in others the clean coal predominates and is from 25 to 34 inches thick. The mine is the largest in the Milk River field, having underground workings about 2 miles long, as shown on the mine maps of the company. The mine workings lie under about 72 feet of cover, and according to information received from the foreman there are two coal beds above the one that is now being worked; one, about 10 feet above the workings, has a thickness of 2 to 2½ feet, and the other, about 25 feet above the workings, has a thickness of 8 to 10 inches. Both beds probably contain bony and shaly streaks.

From the data given under localities 2, 3, 4, 6, 7, and 8 it is evident that the area between these points is probably underlain by beds of coal, some of which are possibly of workable thickness and fair quality.

Locality 9: The dip of the coal bed in the prospect where the following section was measured is about 10° S. 40° W. This high dip is due to several small faults in the immediate vicinity.

Section of coal bed in a prospect in the SW. ¼ sec. 29, T. 32 N., R. 16 E. (No. 9).

	Ft.	in.
Roof, shale, gray.		
Coal	1	10
Bone, with coaly streaks	2	4
Coal	2	2
Floor shale.		
Total coal	4	

Locality 10: The following section was measured in an abandoned prospect northwest of Brown's prospect, in sec. 21, T. 32 N., R. 17 E.

Section of coal bed in old prospect in the SE. ¼ NE. ¼ sec. 21, T. 32 N., R. 17 E. (No. 10).

	Ft.	in.
Shale, buff, sandy.		
Coal, clean	1	2
Bone		3
Coal, clean	3	4
Bone		2
Coal, clean		5
Total coal	4	11

At one place in this prospect 45 inches of clean coal was measured. At the Brown prospect, less than one-quarter mile southeast of locality 10, this bed of coal contains numerous partings of bone, showing that the coal is not persistently clean for even short distances along the outcrop.

Coal belonging to the same zone outcrops at various places along Boxelder Creek and at the heads of coulées in secs. 1, 9, 10, and 11, T. 32 N., R. 17 E. The section of the bed is, however, very changeable. The beds in the northern part of the township are thinner and contain more partings of bone than those at locality 10, and the same may be said of the area southeast of the point where the section was measured.

Locality 11: The following section was measured in the Clack prospect, in the NE. ¼ sec. 5, T. 31 N., R. 17 E.

Section of coal bed in Clack prospect, NE. ¼ sec. 5, T. 31 N., R. 17 E. (No. 11).

	Ft.	in.
Roof, coal	1±	
Coal	2	8
Bone	1	
Coal	1	6
Floor, bone.		
Total coal	4	2

In working the above bed the 1-foot bone is mined out, then the coal is loosened by firing shots first in the bottom and then in the top bench of coal. In this way large lumps are obtained. The coal is of good quality and represents the same zone as that exposed in the Staton mine about 1 mile east of this point.

Locality 12: The following section measured in the Staton mine shows the character of the bed, which probably underlies the larger part of the southern tier of sections in T. 32 N., R. 17 E., and the two northern tiers of sections in T. 31 N., R. 17 E.

Section of Staton coal bed in NE. ¼ sec. 4, T. 31 N., R. 17 E. (No. 12).

	Ft.	in.
Roof, coal	1±	
Coal	3	1
Bone		10
Coal	1	10½
Total coal	4	11½

The coal zone outcropping in Tps. 33 and 34 N., R. 17 E., consists of very poor carbonaceous shale and bone containing many thin, coaly layers. In several places this bituminous shale and bone has burned along the outcrop. No coals of notable thickness were observed in this part of the field.

CHINOOK DISTRICT.

The Chinook district joins the Havre district on the east and embraces Tps. 32 to 34 N., Rs. 18 to 20 E., inclusive. Only a part of the district has been examined, and further field work will extend the boundaries to the north and south. The coal is easily reached by wagon roads leading in all directions across the bench land from the towns and ranches.

Locality 13: The following section was measured on the West Fork of Milk River, 1 mile northwest of Reser's ranch.

Section in the NW. ¼ SW. ¼ sec. 2, T. 34 N., R. 18 E. (No. 13).

	Ft.	in.
Shale, brown, carbonaceous.		
Coal, with thin, bony layers	3	6
Shale, brown, carbonaceous	1	4
Bone, with thin, coaly layers	2	8
Coal		3
Bone, with thin, coaly layers	1	5
Covered.		
Total coal	3	9

This bed is exposed on the north side of West Fork of Milk River south of a fault line. The dip at the outcrop is about 60° S., decreasing rapidly away from the disturbed zone. The Judith River forma-

tion is overlain by the Bearpaw shale south of the outcrop, giving the coal a good cover. That the eastern part of T. 34 N., R. 18 E., is underlain by workable beds is indicated by outcrops of the Bearpaw shale, which overlies coal at localities 13 and 14. In the southern part of the township the coal is not well developed. Here the beds resemble those in T. 33 N., R. 17 E., of the Havre district and consist mostly of carbonaceous shale and bone with thin coal seams.

Locality 14: The following section shows the character of the coal exposed in the McLelland prospect:

Section at the McLelland prospect, NW. ¼ sec. 12, T. 33 N., R. 18 E. (No. 14).

	Ft.	in.
Bone, with thin coal lenses	1	
Coal, with thin, bony streaks	2	4
Bone		4
Coal		6
Bone		5
Total coal, about	2	10

From the McLelland prospect the coal is traceable southeastward for about 1½ miles, to a point where it again disappears beneath the glacial drift.

The greater part of T. 33 N., R. 18 E., is occupied by valley wash, and as the coal-bearing formation has been eroded the land is important only for agricultural purposes. In the northwestern part of T. 32 N., R. 18 E., the coal zone outcrops along a coulée, but no beds of importance were observed. The zone is again exposed along Clear Creek in the same township. The thickest coal measured along this creek is 2 feet 8 inches thick.

Locality 15: The following section was measured at the Burns prospect, about a mile east of Clear Creek, and shows the character of the coal which probably underlies the area between the two places.

Section at Burns prospect, NW. ¼ sec. 11, T. 32 N., R. 18 E. (No. 15).

Glacial drift.	Ft.	in.
Shale, carbonaceous	1	
Coal		4
Shale, sandy, carbonaceous	3	
Shale, carbonaceous	3	6
Bone		4
Coal	3	
Total coal	3	4

The structure in T. 34 N., R. 19 E., is complicated by numerous faults, large and small, and as the coal crops can not be traced for any great distance, the sections given represent purely local conditions.

However, it is reasonable to suppose that wherever the Bearpaw outcrops in this township the area is underlain by workable beds similar to those given under localities 16 and 17.

Locality 16: The following section was measured on the south bank of the West Fork of Milk River at the Leabo prospect, in sec. 29, T. 34 N., R. 19 E.

Section at Leabo prospect, SW. ¼ sec. 29, T. 34 N., R. 19 E. (No. 16).

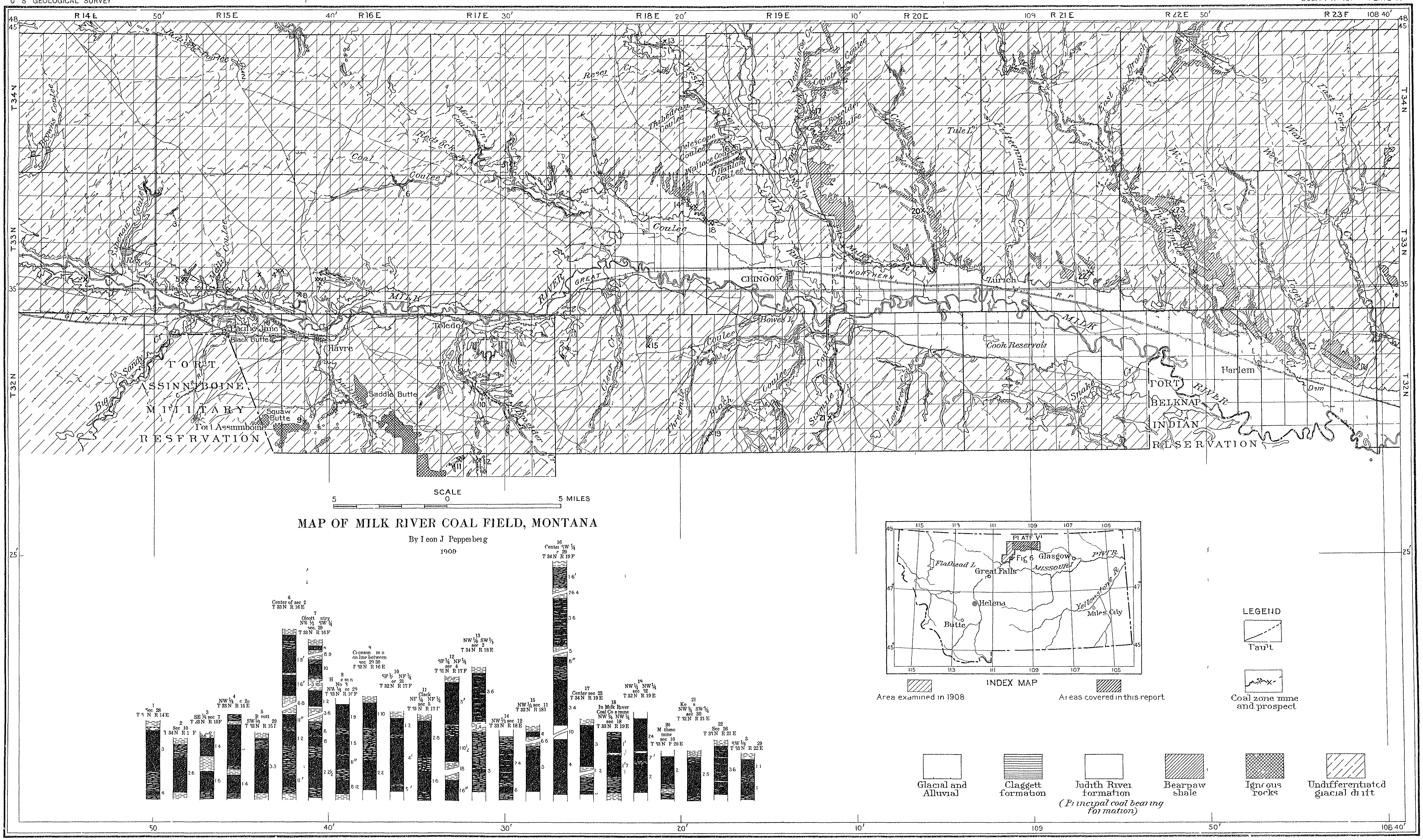
	Ft.	in.
Glacial drift	10	
Shale, carbonaceous	3	
Coal, rather bony	1	6
Shale, carbonaceous	1	4
Shale, sandy	9	
Shale and thin sandstone	16	
Coal, rather bony	3	6
Clay, sandy	5	
Coal		8
Bone	1	
Coal, same as in Leabo prospect	3	4
Covered	10	
Coal exposed in bed of West Fork, partly covered by water	4	
Total coal about	13	

The outcrop of this coal bed continues southeastward and then westward beneath the glacial cover and connects with the bed exposed at the Milk River Coal Company's mine (locality 18).

Locality 17: The character of the coal underlying the eastern half of T. 34 N., R. 19 E., is shown in the following section:

Section of rocks near center of sec. 23, T. 34 N., R. 19 E. (No. 17).

	Ft.	in.
Glacial drift	5	
Shale, carbonaceous	1	
Coal	3±	
Shale, carbonaceous	2	
Coal	3±	
Shale	6	
Shale with coaly bands	7	
Clay, sandy	2	
Shale, carbonaceous		2
Coal with thin bony streaks	1	3
Shale, carbonaceous	2	
Covered.		
Total coal	7	3±



MAP OF MILK RIVER COAL FIELD, MONTANA

By Leon J Pepperberg

1909

Locality 18: The following section measured in the Milk River Coal Company's mine shows the character of the bed worked at this place. Besides the bed worked by the company there are two beds containing from 2½ to 4 feet of coal and bone in the same locality. The bone content is variable.

Section of coal bed in Milk River Coal Company's mine, NW. ¼ NW. ¼ sec. 18, T. 33 N., R. 19 E. (No. 18).

Bone, with coal streaks:	Ft.	in.
Coal	1	
Clay		2
Coal	1	7
Bone	1	2
Coal[a]	2	6
Shale, carbonaceous.		
Total coal	5	1

The coal outcropping in the northeast quarter of T. 33 N., R. 19 E., has been disturbed by faults. In many places it has burned out. No good exposures were discovered, but there are probably coal beds from 2 to 3 feet thick.

Locality 19: The following section measured at the Tumbler prospect shows the character of the coal outcropping in T. 33 N., R. 19 E. The beds in this township have been distorted in many places by aults, consequently it is impossible to trace a single bed for any great distance, even where the rocks are well exposed.

Section of coal bed in the Tumbler prospect, NW. ¼ NW. ¼ sec. 32, T. 32 N., R. 19 E. (No. 19).

	Ft.	in.
Coal	2	4
Bone		1½
Coal		7½
Bone		3
Coal	2	
Total coal	4	11½

The coal beds outcropping in T. 34 N., R. 20 E., are unimportant and may be dismissed without further comment. It should be borne in mind, however, that workable beds, which do not outcrop within the township, may underlie it.

Locality 20: In the NE. ¼ SW. ¼ sec. 10, T. 33 N., R. 20 E., a coal bed is brought to the surface by a fault which has a northwest-southeast trend. A small prospect known as the Matheson mine is located on this coal on the west side of Coal Coulee southwest of the fault line. The following section was measured at the mouth of this prospect.

[a] This bench has been unintentionally omitted in the graphic section (No. 18, Pl. VI)

Section at Matheson prospect, NE. ¼ SW. ¼ sec. 10, T. 33 N., R. 20 E. (No. 20).

	Ft.	in.
Coal	1	2
Shale, carbonaceous		4
Shale, sandy carbonaceous	1	2
Coal	2	
Bone		4
Coal	1	
Bone		6
Clay, sandy		1
Coal	1	
Bone	1	
Shale, carbonaceous	2	
Total coal	5	2

This is the only important bed which outcrops in the township. The coal bed mapped in the southern part of the township consists of carbonaceous shale and a thin bed of dirty coal 1 to 1½ feet in thickness.

A dirty bed of coal coresponding to the one just described, but having a thickness of about 2 feet 9 inches, outcrops in the eastern part of T. 32 N., R. 20 E. This bed contains little clean coal, but consists of alternating layers of bone, carbonaceous shale and mineral charcoal, and thin coaly layers. The cover is thin, and the bed is badly weathered along the outcrop.

Locality 21: The Judith River formation outcrops in the southwestern part of T. 32 N., R. 20 E., and is overlain by the Bearpaw shale. The strata show evidence of faults. The only coal of importance within the township outcrops along the Sixmile Coulee. The following section measured in the Kerr mine shows the character of this bed:

Section in Kerr's mine, N W. ¼ SW. ¼ sec. 30, T. 32 N., R. 20 E. (No. 21).

	Ft.	in.
Roof, shale, black, carbonaceous.		
Coal		6
Coal, bony		5
Coal, good	2	5
Floor, bone.		
Total coal	2	11

From the foregoing discussion it is evident that the coal zone, which contains good workable coals in the Havre district and the western two-thirds of the Chinook district, becomes poorer as a source of thick coals toward the east. The beds in the eastern part of the Chinook district are thinner, contain more bone, and are less persistent than those in the western part of the area discussed.

HARLEM DISTRICT.

The Harlem district is the least important in the part of the Milk River field under consideration. It joins the Chinook district on the east and embraces Tps. 32 to 34 N., Rs. 21 to 23 E., inclusive. As in the Havre and Chinook districts, only a part of the Harlem district was examined during the summer of 1908, and future field work will extend the boundaries to the north and south of the area described here. The coals gradually become thinner and of poorer quality from west to east in this district, and with few exceptions the beds consist largely of bony coal under thin cover and consequently of low value as a fuel. Owing to the scarcity of wood in the district it has been necessary to work beds of coal which, in other localities, would be considered almost worthless at the present time. The coal in the area is easily accessible by wagon roads from Harlem and the ranches in the district.

The thickest coal observed in T. 34 N., R. 21 E., is only 8 inches thick, consequently the coals outcropping in this township may be dismissed without further comment.

Locality 22: At a small prospect in the NE. ¼ sec. 26, T. 33 N., R. 21 E., the following section was measured. The bed at this locality has a dip of 40° N. 60° E., due to a northwest-southeast fault.

Section of coal bed at prospect in NE. ¼ sec. 26, T. 33 N., R. 21 E. (No. 22).

	Ft.	In.
Shale, brown carbonaceous		4
Coal, with numerous partings of sandstone and bone	3	6
Shale, carbonaceous with thin coaly layers.		

The coal of the above bed is pockety; in some places the clean coal is over a foot in thickness but only for short distances, making it necessary to remove large quantities of rock to procure a small amount of good coal.

Locality 23: The following section measured in unsurveyed sec. 9, T. 33 N., R. 22 E., at an abandoned prospect, shows the character of the coal along Thirtymile Creek:

Section at prospect in SW. ¼ sec. 9, T. 33 N., R. 22 E. (No. 23).

	Ft.	In.
Bearpaw shale	68±	
Sandstone, soft, gray	20	
Shale	10	
Shale, sandy	3±	
Coal	1	1
Bone		5½
Coal	1	
Bone.		
Total coal	2	1

A sample taken from this bed gave a calorific value of 8,568 British thermal units on the air-dried coal, showing that the fuel is of low grade. However, part of this low efficiency is due to the large amount of ash caused by the numerous bony layers in the bed.

The strata exposed along Thirtymile Creek have been disturbed by faults, making mining on the east side rather uncertain. The dips on the west side are more constant and the coal is under thicker cover, being overlain by the Bearpaw shale.

A coal bed containing many partings and having a thickness of about 2 feet 9 inches has been prospected in the NW. ¼ sec. 27, T. 33 N., R. 22 E., and a bed of similar content was worked in the SE. ¼ sec. 30, T. 32 N., R. 22 E., during the winter of 1907–8. Coal from the last-named prospect sold for $7.50 a ton delivered at Harlem, a distance of about 8 miles. From this statement it is evident that these low-grade coals have some value at the present time, especially during severe winters.

BIG SANDY DISTRICT.

The sketch map (fig. 2) shows the location of the two principal mines in the Big Sandy district. They are situated in sec. 18,

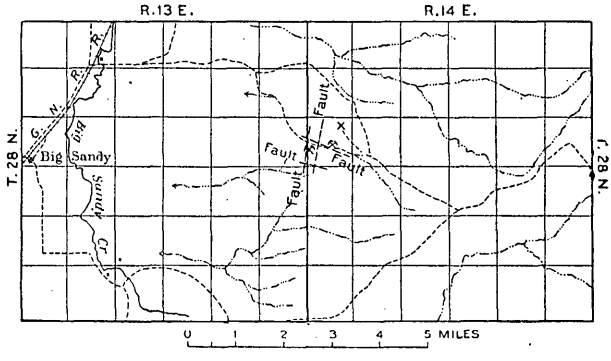


FIGURE 2.—Sketch map of Big Sandy district, Milk River coal field, Montana.

T. 28 N., R. 14 E., about 6½ miles east by a little north of the town of Big Sandy, and are easily reached by wagon road from the town and ranches in the vicinity. These mines were visited at the close of the field season of 1908, when the coal beds were measured and sampled. As no detailed mapping of formations of coal beds was attempted at that time, the boundaries of the district were not determined. As previously stated, the coals of this area are of Fort Union (Tertiary) age and consequently are younger than those of the Judith River formation already described, which they overlie stratigraphically.

The following section shows the character of the beds exposed at the Mackton Coal Company's mine:

Section at the Mackton Coal Company's mine, NW. ¼ SW. ¼ sec. 18, T. 28 N., R. 14 E.

	Ft.	in.
Sandstone.		
Shale, sandy	2	
Coal	4	
Sandstone, buff, massive, intercalated with sandy gray shale.	35±	
Shale, carbonaceous		1
Coal	2	5½
Bone, variable		2
Coal	1	3
Bone		7
Coal		6
Bone		4
Coal	3	11
Clay, gray.		
Total coal	12	1½

The following section was measured in the NW. ¼ SE. ¼ sec. 18, T. 28 N., R. 14 E., in the Mack mine. The bed is probably the same as the upper bed given in the preceding section.

Section of coal bed in Mack mine, NW. ¼ SE. ¼ sec. 18, T. 28 N., R. 14 E.

	Ft.	in.
Clay shale, gray	1	8
Shale, carbonaceous		2
Bone, variable		4
Coal		5
Bone with thin coaly streaks	2	4
Coal	4	6
Clay.		
Total coal	4	11

At the Mackton Coal Company's mine the strata dip about 40° E., indicating a north-south fault between this place and the Mack mine, where the strata lie practically flat. In the NE. ¼ sec. 18, T. 28 N., R. 14 E., a coal bed outcrops along a coulée and has been prospected in several places. The strata at this place also show evidence of faults. The Judith River formation in the vicinity of Big Sandy contains several very thin coals, but no bed of workable thickness was observed in this formation within the Big Sandy district.

CHARACTER OF THE COAL.

PHYSICAL PROPERTIES.

In studying the coals of the Milk River field an attempt was made to gather as many facts as possible concerning their physical properties, and the principal characteristics observed may be briefly summed up. The coal of the Havre, Chinook, and Harlem districts is in general pitch black to brownish black in color, the streak is dark brown the

luster bright and sometimes waxy. Two systems of joints are usually present and the coal commonly splits also along the bedding planes. The fracture of the solid coal is semiconchoidal or irregular. Fresh samples are usually brittle, but sometimes tough. The texture varies from dense to woody. Thin incrustations of gypsum flakes in the form of selenite crystals occur between the joint and bedding planes, especially on the weathered outcrop. Some mineral charcoal, fossil resin, and, rarely, iron pyrites were observed.

The coal of the Big Sandy district is hard and brittle. Its fracture is principally conchoidal. It has a bright black luster and two systems of joint planes, one of which is better developed than the other. These beds are more regular than the other coals of the Milk River field; that is, in the small area examined the sandstone, shale, and coal beds seem in general to be persistent rather than lenticular.

CHEMICAL CHARACTER.

The composition of the coal of the Milk River field is shown by the following analyses: The samples from which these analyses were made were collected in conformity with the regulations of the United States Geological Survey and the chemical work was done under the direction of F. M. Stanton at the Pittsburg laboratory.

Analyses of coal samples from the Milk River field, Montana.

Location	Havre district.								
	NE. ¼ sec. 28, T. 33 N., R. 14 E.	SW. ¼ sec. 29, T. 33 N., R. 15 E.	NE. ¼ sec. 26, T. 33 N., R. 15 E.	SW. ¼ sec. 29, T. 33 N., R. 16 E.	NW. ¼ sec. 31, T. 33 N., R. 16 E.	SE. ¼ sec. 30, T. 32 N., R. 16 E.	E. ½ sec. 21, T. 32 N., R. 17 E.	NE. ¼ sec. 5, T. 31 N., R. 17 E.	NE. ¼ sec. 4, T. 31 N., R. 17 E.
Laboratory sample No.	6549	6548	6475	6474	6479	6473	6477	6640	6478
Sample as received:									
Prox. Moisture	21.24	21.51	21.07	24.12	21.96	22.84	18.97	25.59	29.19
Prox. Volatile matter	31.44	29.28	30.00	26.58	23.80	29.31	27.05	27.96	26.67
Prox. Fixed carbon	36.44	35.55	38.12	38.97	43.90	34.61	35.43	39.18	37.40
Prox. Ash	10.88	13.66	10.81	10.33	10.34	13.24	18.55	7.27	6.74
Ult. Sulphur	.87	.73	.75	.69	.60	.80	1.48	.58	.67
Ult. Hydrogen	.....	.....	.....	.....	5.67	.....	.....	6.19	6.39
Ult. Carbon	.....	.....	.....	.....	47.98	.....	.....	49.08	46.04
Ult. Nitrogen	.....	.....	.....	.....	.99	.....	.....	1.03	.94
Ult. Oxygen	.....	.....	.....	.....	34.42	.....	.....	35.85	39.22
Calories	4,580	4,363	4,676	4,540	4,563	4,388	4,153	4,607	4,353
British thermal units	8,244	7,853	8,417	8,172	8,213	7,898	7,475	8,293	7,835
Loss of moisture on air drying	12.90	12.20	14.10	16.00	15.50	16.30	13.60	14.20	22.90
Air-dried sample:									
Prox. Moisture	9.58	10.60	8.11	9.67	7.64	7.81	6.21	13.27	8.16
Prox. Volatile matter	36.10	33.35	34.93	31.64	28.17	35.02	31.31	32.59	34.59
Prox. Fixed carbon	41.83	40.49	44.37	46.39	51.95	41.35	41.01	45.67	48.51
Prox. Ash	12.49	15.56	12.59	12.30	12.24	15.82	21.47	8.47	8.74
Ult. Sulphur	1.00	.83	.87	.82	.71	.95	1.71	.68	.87
Ult. Hydrogen	.....	.....	.....	.....	4.67	.....	.....	5.39	4.99
Ult. Carbon	.....	.....	.....	.....	56.78	.....	.....	57.20	59.72
Ult. Nitrogen	.....	.....	.....	.....	1.17	.....	.....	1.20	1.22
Ult. Oxygen	.....	.....	.....	.....	24.43	.....	.....	27.06	24.46
Calories	5,258	4,969	5,444	5,405	5,400	5,243	4,807	5,370	5,646
British thermal units	9,464	8,944	9,799	9,729	9,720	9,437	8,653	9,666	10,163

Analyses of coal samples from the Milk River field, Montana—Continued.

Location	Chinook district.					Harlem district.	Big Sandy district.	
	SW. ¼ sec. 29, T. 34 N., R. 19 E.	NW. ¼ sec. 18, T. 33 N., R. 19 E.	NW. ¼ sec. 32, T. 32 N., R. 19 E.	SW. ¼ sec. 30, T. 32 N., R. 20 E.	SW. ¼ sec. 10, T. 33 N., R. 20 E.	SW. ¼ sec. 9, T. 33 N., R. 22 E.	SW. ¼ sec. 18, T. 28 N., R. 14 E.	SE. ¼ sec. 18, T. 28 N., R. 14 E.
Laboratory sample No.	6381	6316	6318	6317	6380	6315	6550	6609
Sample as received:								
Prox. Moisture	26.67	22.89	21.44	20.48	23.27	30.00	12.07	14.86
Prox. Volatile matter	26.41	28.76	26.59	28.81	29.87	40.10	34.71	34.58
Prox. Fixed carbon	40.02	39.32	41.14	39.27	33.12	18.00	41.68	44.20
Prox. Ash	6.90	9.03	10.83	11.44	13.74	11.90	11.54	6.36
Ult. Sulphur	.68	.56	.64	.81	.72	1.08	.80	.46
Ult. Hydrogen	6.09	.....	5.73	.....	5.80	5.53	5.30	5.41
Ult. Carbon	49.23	.....	50.43	.....	44.90	40.39	55.85	58.56
Ult. Nitrogen	.91	.....	1.09	.....	.89	.80	.71	.85
Ult. Oxygen	36.19	.....	31.28	.....	33.95	40.30	25.80	28.36
Calories	4,690	4,685	4,808	.....	4,332	3,841	5,332	5,521
British thermal units	8,442	8,433	8,654	.....	7,798	6,914	9,598	9,938
Loss of moisture on air drying.	18.50	12.00	11.80	10.30	14.90	19.30	5.50	5.60
Air-dried sample:								
Prox. Moisture	10.02	12.38	10.93	11.35	9.83	13.26	6.95	9.81
Prox. Volatile matter	32.41	32.68	30.15	32.12	35.10	49.69	36.73	36.63
Prox. Fixed carbon	49.10	44.68	46.64	43.78	38.92	22.30	44.11	46.82
Prox. Ash	8.47	10.26	12.28	12.75	16.15	14.75	12.21	6.74
Ult. Sulphur	.83	.64	.73	.90	.85	1.34	.85	.49
Ult. Hydrogen	4.94	.....	5.01	.....	4.86	4.20	4.96	5.07
Ult. Carbon	60.41	.....	57.18	.....	52.76	50.05	59.10	62.03
Ult. Nitrogen	1.12	.....	1.24	.....	1.05	.99	.75	.90
Ult. Oxygen	24.23	.....	23.56	.....	24.33	28.67	22.13	24.77
Calories	5,755	5,324	5,451	.....	5,090	4,760	5,642	5,848
British thermal units	10,359	9,583	9,821	.....	9,162	8,568	10,156	10,526

A study of the analyses of coals from the Havre, Chinook, and Harlem districts shows that the Judith River coals of this field are comparatively low in sulphur and high in moisture and ash, though in some samples the amount of ash is only medium. The heating value of these coals, ranging from 8,568 to 10,359 British thermal units on air-dried samples, and their poor keeping quality indicate that they should be classed as subbituminous coals. The coals burn with a medium-long, orange-colored flame which is smoky under ordinary circumstances. The ash is fine and has a gray color.

The Fort Union coal from the Big Sandy district contains a lower percentage of moisture than those from the other districts, and consequently stocks to better advantage, as it tends to slack more slowly than coal containing high amounts of moisture. The amount of ash varies from medium to high, and the heating value from 10,156 to 10,526 British thermal units on air-dried samples. The coal is therefore subbituminous, but close to the bituminous grade.

The low heating value, the low specific gravity (about 1.3), the high percentage of volatile matter, and the low percentage of fixed carbon show the coals to be of value for gas-producer purposes and domestic and boiler use.

Two things are essential to insure the most economical results with fuel of this class when used under boilers. First, as the coal disintegrates rapidly on losing the large percentage of moisture which it contains, it is necessary to use a fine grate similar to the herringbone type in order to minimize the loss of coal passing through the grate bars. Second, a suitably high draft is necessary to insure perfect combustion.

QUANTITY OF COAL AVAILABLE.

It has been pointed out in the foregoing pages that the greater part of the field with which this report is concerned is covered by glacial and alluvial deposits and that the complex structure is greatly obscured by this covering. Consequently, at the present time it is difficult to estimate even approximately the total quantity of coal available in the region. Future demands for this grade of fuel may encourage detailed prospecting with the diamond drill, which will give the data necessary for estimating the tonnage of available coal.

CONDITIONS OF MINING AND TRANSPORTATION.

The largest and best-equipped mine in the field is that operated by the Havre Fuel Company, which has installed one of the most modern surface plants in the State. The cars are hauled in the workings of the mine by mules to the foot of the incline, where they are attached to a cable and drawn to the surface by steam power. From this place they are hauled by a 10-ton Baldwin Westinghouse electric locomotive to the tipple, about a mile southeast of the mine. Here they are weighed and automatically dumped, and the coal is loaded into box cars on a spur of the Great Northern Railway which has been built across Milk River from the main line of the railroad at Havre. The only other mine in the field having a steam surface plant is that of the Mackton Coal Company. At this mine the cars are brought to the surface by a steam hoist, dumped into a chute, and conveyed to bins, from which wagons are loaded. Coal from the Staton mine is hauled to Havre partly by wagon and partly by traction engine. A railroad line has been surveyed connecting this property with the main line of the Great Northern Railway at Havre, but as yet no grading has been done. The coal from the other mines in the field is transported by wagon.

The mines in the field employing the largest number of men are those of the Havre Fuel Company, 4 to 30; the Mackton Coal Company, 4 to 16; and the Staton Coal Company, 4 to 10. The other mines and prospects in the area employ from 1 to 3 men each.

The roof and floor in most of the mines and prospects in the field are soft sandstone or carbonaceous shale, making it necessary in

most places to leave coal in the roof to keep the entries from caving in. Extensive timbering will be necessary when mining is done on a large scale, and this will add to the cost of producing coal, as there is no timber in the field suitable for stulls, lagging, or props.

FUTURE DEVELOPMENT.

As the coal of the Milk River field is high in moisture and slacks rapidly on exposure, it can not be shipped great distances in uncovered cars. The rapid disintegration of the coal when burned, together with its low specific gravity, make it a poor railroad fuel with engine grates of the present pattern and the strong draft of the locomotive, as much of the finely-divided coal would be lost through the grate bars and the stack. Consequently the future development of the area will depend largely on an increase in the population of Milk River valley. If the several large reclamation projects which are proposed in this general region are completed, the population will greatly increase and there will be a greater local demand for the fuel.

A few carload shipments have been made to Seattle and Spokane, Wash., and to Helena, Great Falls, and Conrad, Mont., but the greater part of production, which was 24,847 tons[a] in 1907, is consumed locally.

[a] Mineral Resources U. S. for 1907, pt. 2, U. S. Geol. Survey, 1908, p. 50.

NOTES ON THE COALS OF THE CUSTER NATIONAL FOREST, MONTANA.

By CARROLL H. WEGEMANN.

INTRODUCTION.

General situation.—The Custer National Forest, comprising an area of approximately 950 square miles, lies to the eastward of Tongue River in southeastern Montana, a little north of the Montana-Wyoming line. Its coal field is a part of the broad area of coal-bearing rocks of Eocene age, which extends from North Dakota across Montana far into Wyoming.

In the spring of 1908 it was the writer's privilege to accompany a small party from the Forest Service engaged in the examination of timber in this region. In working from the camps it was impracticable to trace individual coal beds from township to township over the area. Beds were traced in separated localities as time allowed, and for correlation recourse was had to detailed stratigraphic sections. Although data of this nature are sometimes misleading, the information gathered in the four weeks spent on the work was sufficient to warrant the classification of four townships in the northern part of the forest.

Relation to other fields.—The yellow beds of the Fort Union formation are the only rocks exposed within the area. They lie practically flat. To the north they are continuous with the rocks of the Miles City coal field;[a] to the south with the rocks of the Sheridan field of Wyoming.[b]

Routes of travel.—The post-office of Ashland, the home of the forest supervisor, is situated at the junction of Otter Creek with Tongue River and is reached by daily stage from Forsyth, 65 miles away. There is also a main road up Tongue River from Miles City which runs through to Sheridan, Wyo. Stacey post-office, on the northeast border of the forest, is reached by a stage road up Tongue River and Pumpkin Creek from Miles City. There is a good road up Otter Creek, and wagon roads follow most of the larger tributaries of the above-mentioned streams.

[a] Collier, A. J., and Smith, C. D., The Miles City coal field, Montana: Bull. U. S. Geol. Survey No. 341, 1909, pp. 36–61.

[b] Taff, J. A., The Sheridan coal field, Wyoming: Bull. U. S. Geol. Survey No. 341, 1909, pp. 123–150.

TOPOGRAPHY.

The topography may be discussed under three main heads, the lowlands, the badlands, and the uplands. Terraces occur along Tongue River, but they are of small extent.

The lowlands consist of the present river flood plains. They constitute the lands available for irrigation and are very fertile, alfalfa and oats being the principal crops.

Badlands are not as typically developed in the yellow beds of the Fort Union formation, which show little variation in texture and hardness, as in the alternating hard and soft rocks of the somber-colored beds which underlie them. They are present, however, in this area along certain streams—as, for example, Pumpkin Creek and its tributaries. Here they form a transition zone between the uplands, which are but little affected by erosion, and the river flats, which have been completely leveled. They represent, in fact, the maturely developed topography of the region, sharp ridges and deep canyon-like valleys alternating with one another in such rapid succession that travel across the drainage lines is often difficult.

The uplands rise in abrupt escarpments from the lower levels of the badlands or in places directly from the river flats. Their existence is due to the heavy beds of baked sandstone and shale formed by the burning of the coals of the region. These "slags" that cap or rim the uplands effectually retard the down-cutting of the streams which drain them and so protect the uplands from degradation. When the slag cap is once dissected and the soft rocks below are exposed to the conditions of erosion in an arid climate, badlands are formed, provided the main streams have sufficient gradient for rapid cutting and other heavy slag beds do not interrupt the work. Each heavy bed of slag determines an upland area. These may rise one above another in a series of benches to the high divides between the streams. Some of these benches are gently rolling, forming excellent grazing land, and in some places being suitable for "dry farming," or the raising of crops without irrigation. Many of the ridges rise 200 to 300 feet above the valley floors. The total thickness of rocks exposed from Tongue River to the crest of the divide is 1,200 feet.

Drainage.—The portion of the forest examined is drained by Tongue River and two of its larger tributaries, Otter and Pumpkin creeks. Tongue River, which follows the western border, rises in the Bighorn Mountains of Wyoming and flows northeastward to join the Yellowstone at Miles City, Mont. The Custer Forest is situated about halfway along its course. Otter Creek rises a little south of the forest and flows northward across it to unite with Tongue River at Ashland. Pumpkin Creek rises on the eastern border of the forest and flows northeastward parallel to Tongue River for a considerable distance; then turning northwesterly it joins the main stream about 12 miles above its mouth.

GEOLOGY.

Stratigraphy.—As has been stated, the only rocks exposed within the area are the yellow beds of the Fort Union formation, of early Eocene age. In the Miles City district the underlying dark shales of the somber-colored beds are also exposed, and the contact of the two may be traced as one rides up Tongue River. At a point a little below Coleman's ranch, about 10 miles north of Ashland, the somber-colored beds disappear beneath the river. The beds of the Fort Union formation are for the most part white and cream-colored shales and sandstones which present but slight variation in texture and color. At intervals occur thin beds of impure limestone which, being harder than the adjacent rocks, stand out in small ledges. Here and there thin beds of gray shale and of brown carbonaceous shale may be observed, but the beds most easily recognized in the section are the subbituminous coals and the slags formed by their burning. In fact, the coal beds furnish about the only means by which different portions of the section may be recognized.

About 400 feet above the base of the Fort Union formation appears a series of gray sandstones and shales approximately 100 feet in thickness. It contains numerous thin beds of ferruginous limestone which weather brown and red. The resemblance of this part of the Fort Union to the typical somber beds is striking. Whether or not these rocks are constant in character over any considerable area it is impossible to say. Their occurrence is probably of no great importance, simply showing that during the deposition of the Fort Union formation conditions recurred similar to those which prevailed while the somber-colored beds were being deposited.

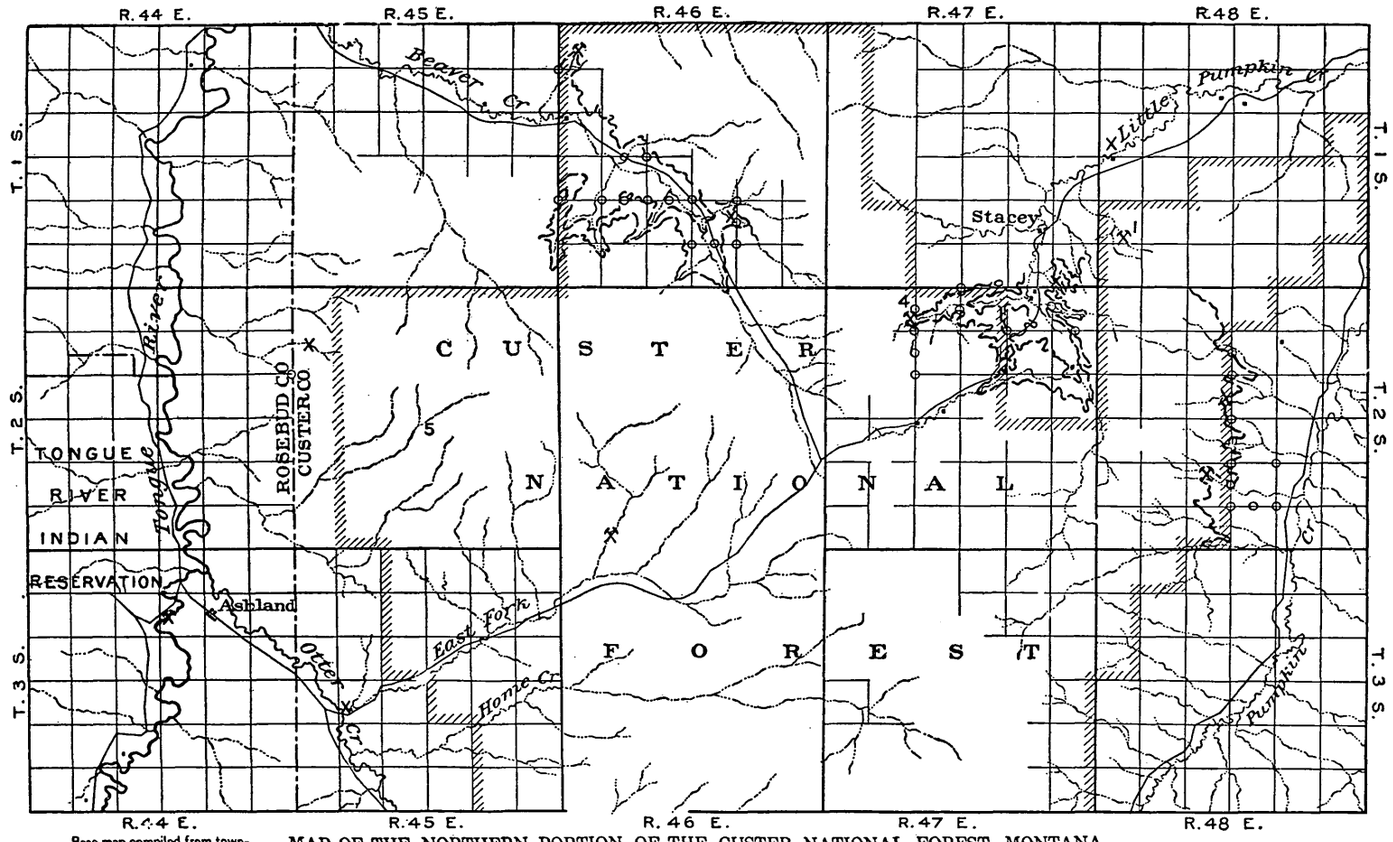
All these strata are of fresh-water origin. Many of the thin limestone layers contain fossil leaves, and in the dark shales just mentioned there are several thin beds rich in gastropod shells.

Structure.—So far as could be determined the rocks within the area are horizontal, the dips being too slight to be detected with the instruments employed.

COAL.

GENERAL DESCRIPTION.

Coal beds ranging from a few inches to many feet in thickness occur throughout the stratigraphic section in this region. They seem to be fairly constant in thickness and quality over considerable areas, but too much reliance should not be placed on this continuity, for shale seams appear in many places, rendering a coal valueless which at another locality is workable. Coal beds run out into bone or black shale or disappear altogether. On the other hand, if several exposures of good coal are found on the same bed at intervals of a mile or two, the bed appearing to be fairly constant in thickness and



MAP OF THE NORTHERN PORTION OF THE CUSTER NATIONAL FOREST, MONTANA

Showing distribution of coal in three townships and the locations of prospects and mines

By Carroll H. Wegemann

Scale

5 0 5 Miles

LEGEND

Coal outcrop located or inferred

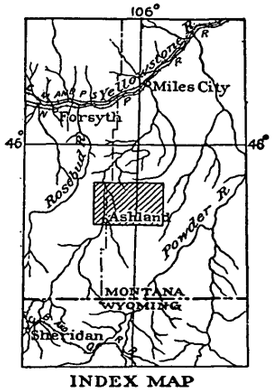
Coal mine

Coal prospect

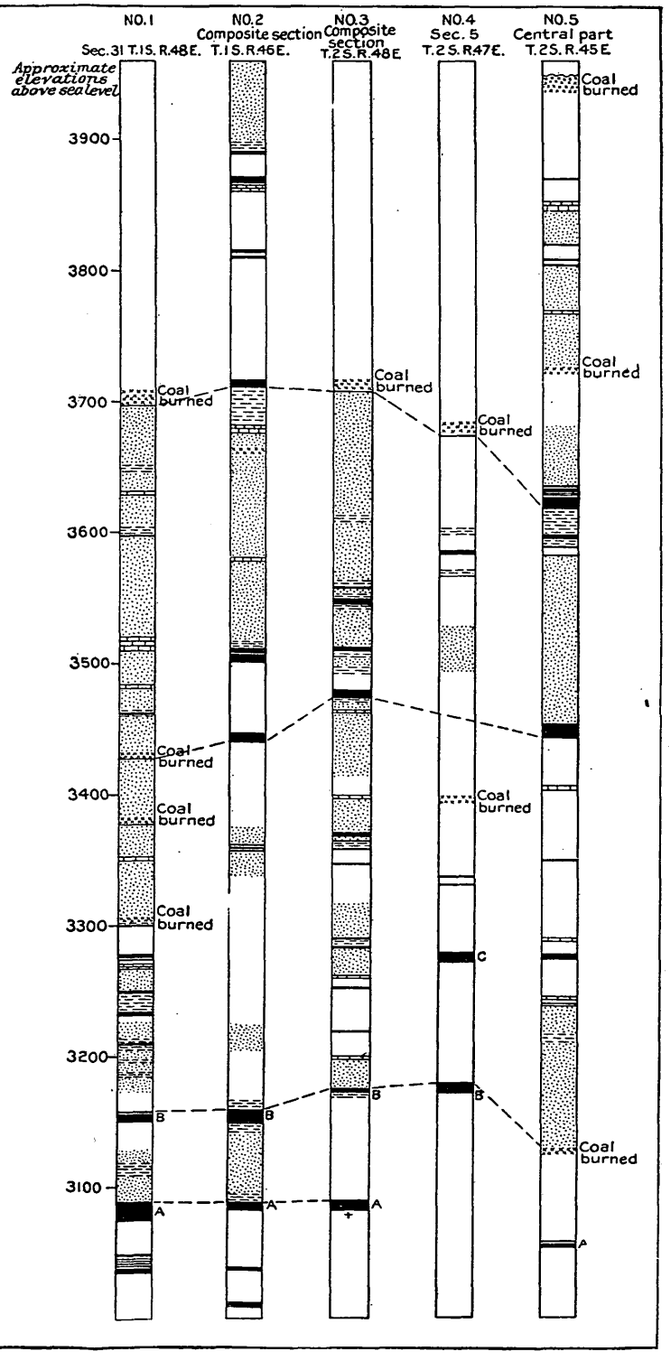
Land survey corner

Wagon roads

Numbers indicate locations of stratigraphic sections



INDEX MAP



MAP OF NORTHERN PART OF CUSTER NATIONAL FOREST, MONTANA.

With stratigraphic sections. By C. H. Wegemann.

quality, it is very probable that the coal is good between the exposures, although it may be completely concealed.

Silicified logs were noted in many of the coal beds. Some of these logs appear as slabs representing but about one-third of the original trunk, the upper side being flat and the lower conforming to the shape of the original log. In some places the logs when partly decayed were undoubtedly crushed and flattened by the load above them, but it is possible that in others as the log lay in the bog the upper portion turned to coal while the lower under different conditions was silicified.

The coal of this field is somewhat darker than the Miles City lignite described by Collier. When first mined it has a brownish cast, but soon blackens on exposure. The grain of the original wood is for the most part well preserved, yet there are seams between the woody layers which have lost all woody structure. In them the coal is black and shiny with conchoidal fracture.

That the coal is subbituminous rather than lignite may be questioned. It lies near the border line between the two. On the whole, it resembles more the subbituminous coals of the Sheridan field than the lignites which occur east of Miles City, being darker than the latter and containing a greater amount of material in which no woody structure is apparent. The Sheridan coals run as high as 10,000 British thermal units in calorific value; the Miles City lignite runs about 8,200 British thermal units. No samples for analysis were obtained from the Custer Forest, yet an idea of the probable calorific value of the coal may be formed from the values in these adjoining fields.

DEVELOPMENT.

Mining development has made but slight progress in the Custer Forest. Coal is so plentiful that almost every ranch has its own bank, where the coal is obtained by stripping the surface and mining from the open face of the bed. No drift or shaft was seen by the writer, and until a railroad runs up the Tongue River valley the demand for coal must be but local.

DETAILED DESCRIPTIONS.

In the following descriptions the area is taken up by townships, beginning at the northeast corner of the field examined and passing from east to west.

T. 1 S., R. 48 E.—Two beds of good coal with an interval of about 60 feet between them are exposed along a coulée in the southwest corner of this township (Pl. VII, No. 1). The lower bed, which is 14 feet in thickness, has been worked to a moderate extent. The upper bed is about 7 feet thick. It has not been prospected at this locality,

but about a mile to the southwest it has been mined. Both beds, like most of the coal of this region, have burned widely, forming marked "slag" horizons.

North of the Charles Daly ranch in section 18 coal is exposed in a hillside. The bed is at present so obscured by slumping that a measurement could not be obtained. It is stated, however, that this coal is of considerable thickness and was formerly mined. It is by barometer 110 feet below the 14-foot bed in the southwest corner of the township.

The coal outcrops in this township were not mapped. The coal area is probably confined, however, to the southwestern portion, as the beds described have been removed by erosion from the northern part of the township and the presence of lower workable coals is uncertain.

T. 1 S., R. 47 E.—Coal is mined for use at Stacey post-office in section 36 of this township, where about 7 feet of good coal is exposed. The bed probably corresponds to the highest of the three beds in the township to the east (Pl. VII, No. 1B). No coal outcrops were traced, but it is probable that the greater portion of the township is underlain by workable coal.

T. 1 S., R. 46 E.—The high divide between Beaver Creek and Liscom Creek runs across this township from northwest to southeast. Several coal beds are exposed on the higher slopes of this divide, but they underlie comparatively small areas. The important coals for the classification of the township are two in number. North of the Kelsey ranch on Beaver Creek, in sec. 6, T. 1 S., R. 46 E., over 7 feet of coal is exposed in a bank opened by Mr. Kelsey (Pl. VII, No. 2A). The coal is of rather inferior quality, containing specks of clay and small particles of pyrite. Its outcrop is indicated on the map. Sixty feet above this coal is a slag which may be traced southeastward up Beaver Creek to an exposure of coal in the NE. ¼ sec. 27 (Pl. VII, No. 2B). This bed is 11 feet 4 inches in thickness and apparently of good quality. This coal is by barometer 335 feet above Tongue River at the mouth of Beaver Creek. It is probably the same bed as that which is burning about 3 miles north of the Kelsey ranch across the divide, where along a coulée about 20 feet of coal is exposed, but the bed is separated into two benches by 2 feet of brown shale. It is possible that the coal which is here on fire corresponds to one of the two beds which have been described as burning 6 miles northeast of Ashland.

Two other coals occur, one 50, the other 75 feet below the Kelsey bed (Pl. VII, No. 2). The lower is 3 feet 4 inches in thickness in the SW. ¼ sec. 7. No lower coal beds of value were observed above the somber-colored beds in passing down Beaver Creek to Tongue River.

Liscom Creek within the limits of the township has not cut down to the horizon of the Kelsey coal, so that the whole township, except that portion along Beaver Creek indicated on the map, is probably underlain by workable coal.

T. 2 S., R. 48 E.—Several coal beds outcrop along the slopes of the divide which occupies the western portion of this township, but the principal coal of the area is the heavy bed indicated on the map. In the NW. ¼ sec. 28 this bed outcrops at several points along a coulée. A pit opened for mining exposes 7½ feet of clean coal without reaching the bottom of the bed (Pl. VII, No. 3A). In the SE. ¼ sec. 16 the same coal is exposed, but no other exposures of this bed were found within the township, the outcrop being traced by the heavy slag or clinker formed by the burning of the coal. The valley of Pumpkin Creek may be underlain by the bed of coal outcropping in section 18 of the township to the north. This bed is by barometer about 100 feet below the coal here mapped. There is no assurance of its presence in this township, however.

T. 2 S., R. 47 E.—The Otter Creek-Pumpkin Creek divide, which reaches an elevation of nearly 4,000 feet above sea level, runs across the southwestern portion of this township. This divide contains several coal beds which are in general burned along the outcrop, but which probably contain much workable coal. Time was not taken to map these upper beds, as it was considered that the classification of the land would depend on the lower beds in the township. Of these there are two outcropping in the valley of Little Pumpkin Creek, in the northeastern portion of the township. A good exposure of the upper bed occurs in the SE. ¼ sec. 5. The bed is over 7 feet in thickness and the coal is said to be of excellent quality, burning with but little ash (Pl. VII, No. 4C).

A rather poor exposure of the lower coal occurs in the SW. ¼ sec. 35 of the township north of this. About 6 feet of coal were measured here (Pl. VII, No. 4B). Across the divide to the northeast coal which is considered to be this same bed has been mined to a small extent in an open bank. Here the coal is 7 feet in thickness. The outcrops of these two beds were traced in the mapping by means of the slag formed by the burning of the coal along the outcrop.

About 1 mile northeast of the exposure last described a bed 60 feet lower in the section has been worked for local use, and contains 14 feet of good coal. (See T. 1 S., R. 48 E.)

T. 2 S., R. 46 E.—This township occupies an area of considerable elevation between Beaver Creek and East Fork. No coal outcrops were traced here, but the whole area is believed to be underlain by workable coals which outcrop at lower levels in adjoining townships.

In the SW. ¼ sec. 32 about 7½ feet of good coal is exposed in the bed of a coulée and is mined for local use. This coal is by barometer about 400 feet above Ashland.

T. 2 S., R. 45 E.—About 6 miles northeast of Ashland, in sec. 7, T. 2 S., R. 45 E., is a considerable area in which two beds of coal are at present on fire. The beds are about 60 feet apart, the lower being 265 feet above Ashland. Neither of these beds is exposed, but to judge by the amount of settling of the surface over the burned area they are of considerable thickness.

T. 3 S., R. 45 E.—Near the Pete Daly ranch, at the mouth of the East Fork of Otter Creek, 4 miles southeast of Ashland, 38 inches of coal is exposed in the creek bed. The base of the coal is covered. It is probable that this is the same bed as that exposed on Tongue River near Ashland.

T. 3 S., R. 44 E.—In sec. 10, T. 3 S., R. 44 E., 1 mile west of Ashland, a coal bed 5 feet 7 inches in thickness outcrops just above the level of Tongue River. The coal is of good quality and has been mined for local use. Six miles down Tongue River from this point, at the mouth of Culberts Coulee, a careful examination of the river bluff failed to show any coal over 2 feet in thickness at about this horizon. Whether this bed is thinning toward the north or whether it is simply obscured by the slumping of the soft shales is uncertain.

If the writer's correlations prove to be correct, five workable coal beds occur within the first 400 feet of strata above Ashland. Two higher coals were measured, one 10 feet in thickness 700 feet above Ashland, the other 11 feet in thickness 650 feet above Ashland. These are found only on the high divides and extend over comparatively little country. Several heavy slags also were noted, the coals of which were not found. No mine openings were found on the two highest beds. This is not because they are inferior in quality to the lower beds, but because, occurring only in the higher hills, they are more difficult of access.