

COAL AND LIGNITE.

THE WILLISTON LIGNITE FIELD, WILLIAMS COUNTY, NORTH DAKOTA.

By FRANK A. HERALD.

INTRODUCTION.

LOCATION AND EXTENT OF FIELD.

The Williston lignite field (Pl. X, p. 156) lies north of Missouri River in the northwestern corner of North Dakota. It is in the southern part of Williams County and embraces approximately 650 square miles. This field includes a relatively small portion of the Fort Union coal region, which comprises parts of Montana, North and South Dakota, and a portion of Saskatchewan, Canada. The area considered in this report is bounded on the south by Missouri River, on the west by the Montana-North Dakota State line, on the north by the fourteenth standard parallel, and on the east by the range line between Rs. 99 and 100 W., together with T. 157 N., R. 100 W., to the north and T. 154 N., R. 99 W., to the east.

ACCESSIBILITY.

The main line of the Great Northern Railway crosses the southern part of the Williston lignite field, and Missouri River near by also affords a means of transportation except when it is frozen over during the winter. At present no lignite is shipped by water because there is no regular line of boats, and because in the summer when the river is navigable there is very little demand for the lignite. However, when there is a demand for the lignite in territory accessible over the water route the river will furnish a very economical means of transportation. At present only the southern part of the field has railroad facilities, but branch lines could be built to almost any part of the area without great difficulty. A route over which a road could be cheaply constructed is along the valley of Muddy Creek. Surveys have been made along this valley for a branch of the Great Northern Railway from Williston, but construction has not been undertaken. This line would pass through a territory containing an abundance of lignite well situated for mining. Wagon roads are easily constructed and maintained in excellent condition.

FIELD WORK.

The Williston lignite field is not a separate basin but is a part of the great lignite-bearing province of North Dakota, South Dakota, and Montana; therefore its boundaries as here defined are not natural limits but mark the area examined by the writer and his assistants during the summer of 1911. (See map, Pl. X, p. 156.)

A detailed survey of the field was made necessary by acts of Congress which provide for the examination and classification of the public land. The land in the Williston field has been classified, and the report here presented describes the lignite.

The field work consisted mainly of a careful examination of the surface for exposures of lignite and the accurate locations of such exposures by use of the planetable, telescopic alidade, and stadia rod. All locations were made with regard to land corners, which are in general well marked and properly located. The dip of the beds was determined chiefly from altitudes based on United States Geological Survey bench marks and carried by a system of vertical angles with nearly all planetable traverses. A considerable part of the field is covered by glacial débris which conceals the lignite and prevents an accurate location of the limits of the beds. No lines of outcrop could be traced in these areas, but it was possible to locate the approximate position of the outcrop in many places. Contours were sketched at the approximate altitude of the lignite beds and, after the exposures were examined and their position and altitude determined, the inferred location of the covered outcrop was sketched from the topography as recorded by the contours. In addition to the data collected by the surface examination much information was obtained from well records and from an examination of mines. Probably the best records are those of holes drilled in various parts of the field by the United States Reclamation Service to determine the depth and thickness of the beds of lignite, but well drillers and residents in the field also gave considerable data. In general these records are less reliable than those kept by the Government because usually well drillers have neither instruments for accurate measurements nor experience in determining accurately the thickness and character of strata. The records of the Reclamation Service are presented on subsequent pages, but information furnished by residents and well drillers is withheld because most of it was confidential.

ACKNOWLEDGMENTS.

The writer was assisted in the surveying by E. K. Soper, Rowe Hohman, A. C. Munger, C. C. Clark, and C. W. Hamilton. To each member of the party he is deeply indebted for the unusual interest taken in the work and most efficient service rendered.

Mr. G. B. Morgan, mineral surveyor of the United States General Land Office, rendered valuable assistance through personal inter-

views in the field and also furnished maps and notes that he had compiled during his service in the Williston land district.

Thanks are due also to various officials of the United States Reclamation Service for their hearty cooperation and assistance. Through the kindness of Mr. E. C. Bebb the writer obtained copies of unpublished topographic maps of that part of the field along Missouri River and Muddy Creek valleys. Logs of drill holes made by the Reclamation Service in various parts of the field were furnished by Messrs. R. H. Fifield and A. Young. Mr. J. M. Fine gave valuable information relative to the use of lignite in the power plant near Williston. Data concerning the United States Reclamation Service mine and also other mines, prospects, and drill holes in the vicinity of this mine were furnished by Mr. William Hutchinson.

Acknowledgment is due also to a large number of residents in the field who have facilitated the work through information given and courtesies extended.

TOPOGRAPHY.

The surface of the field is a slightly undulating grass-covered plain which, when viewed as a whole, is moderately depressed in the valley of Muddy Creek and abruptly terminated to the south by rather steep slopes or cliffs between the upland surface and the Missouri River Valley. The Missouri flows through a moderately broad flood plain bounded by bluffs, which are very steep in the eastern part of the field but gradually decrease in height and steepness to the west. At some places the bluffs are abrupt, but more generally they are comparatively low and sloping. In the vicinity of Williston they swing to the north and merge into the gentle grassy slopes along Muddy Creek. In general, the drainage is thorough, but in the northern part of the field ponds and lakes indicate undeveloped drainage. The drainage of the field is to Missouri River, partly through several small streams which flow directly to the river but chiefly through Muddy Creek and its tributaries. In general, the lower courses of the streams are marked by sharply cut valleys of considerable depth, whereas their upper parts flow through very broad valleys which merge into long gentle slopes extending to the divides. The general features of the drainage are shown on the map (Pl. X, p. 156).

GEOLOGY.

STRATIGRAPHY.

The lignite-bearing rocks of the Williston field belong to the Fort Union formation, which is the lowest formation exposed in the field. Though this is economically the most important formation, two others—glacial débris and alluvium—cover nearly all of the field. Each formation is described separately below.

FORT UNION FORMATION.

The Fort Union formation (of Eocene age) consists mainly of shale and soft sandstone, with every degree of gradation from one to the other. This gradation occurs not only from one bed to another but also along the same bed. Some beds consist of shale at one place but become sandy and lose their shale characteristics until the bed merges into sandy shale, then shaly sandstone, and in some places all of the shale disappears and the bed is pure sandstone. In a similar manner at some places there is transition from one stratum to the next above or below except where beds of lignite occur. Such transition is gradual in most places, and hence, without continuous exposures, correlation of beds is always difficult to make and frequently unreliable.

The shale of the Fort Union is predominantly gray and the sandstone is light yellow, but as the beds vary in composition they also vary in color. However, most of the exposures present a somber aspect because the gray shale predominates. Except for sandstone concretions and lenses of indurated sandstone the strata are soft and yield readily to erosion.

As shown by the generalized section (Pl. X), beds of lignite are distributed throughout the formation. They are much more persistent than the beds of shale and sandstone, but even they grade laterally into carbonaceous shale, which in turn at some places grades into shale or sandstone that does not show a trace of lignite. Because these beds are not continuous it is impossible to correlate them throughout the field, but it is possible to determine the stratigraphic position of the most persistent beds. Their positions are shown in the generalized section in Plate X, but it should not be assumed that all of the beds shown there underlie any particular tract or that the section includes all of the beds that may be found in the area. However, it is probable that beds with about the thickness shown occur at the positions indicated.

The Eocene age of the formation is well known from the work of other geologists, but their conclusion was confirmed by three collections of fossils made in the field. Two collections of fossil plants were made within the field and identified by F. H. Knowlton, and a collection of invertebrate fossils was made from a place just beyond the western boundary of the field (location 103, Pl. X) and determined by T. W. Stanton.

Mr. Knowlton's report is as follows:

Collection No. 13.—SE. $\frac{1}{4}$ sec. 4, T. 153 N., R. 102 W.	Collection No. 14.—NW. $\frac{1}{4}$ sec. 27, T. 154 N., R. 102 W.
<i>Onoclea sensibilis</i> Linné.	<i>Onoclea sensibilis</i> Linné.
<i>Leguminosites arachiooides</i> Lesquereux.	<i>Sapindus affinis</i> Lesquereux.
<i>Populus cuneata</i> Newberry.	<i>Celastrus pterospermoides</i> Ward.
<i>Populus amblyrhyncha</i> Ward.	Fragments of several leaves.
<i>Viburnum newberryanum</i> Ward.	Age, Fort Union.
Age, Fort Union.	

Mr. Stanton reports the invertebrates as follows:

Collection No. 7444.—Sec. 24, T. 28 N., R. 59 E., Montana.

<i>Unio priscus</i> Meek and Hayden.	<i>Limnæa</i> (<i>Pleurolimnæa</i>) <i>tenuicostata</i> Meek and Hayden.
<i>Viviparus trochiformis</i> Meek and Hayden.	<i>Micropyrgus minutulus</i> Meek and Hayden.
<i>Viviparus leai</i> Meek and Hayden.	
<i>Goniobasis nebrascensis</i> Meek and Hayden.	Age, Fort Union.

The Fort Union formation underlies the entire field beneath a thin mantle of glacial débris or alluvium, through which it appears in small areas only. It outcrops over a considerable area in the southeastern part of the field and is moderately well exposed in the southwestern part, but in the northern part the strata are generally covered. Well records and isolated exposures show that the formation is not deeply buried at any place, but the overlying rocks are distributed so generally and evenly over the field that the formation is concealed except in small areas.

GLACIAL DRIFT.

Glacial drift covers the field, except the valleys and steep slopes adjacent to them. It forms a mantle over the uplands and more gentle slopes extending to the alluvium-filled valleys, but it is absent on the more abrupt slopes, where perhaps it has been removed by erosion. The drift ranges in thickness from a thin veneer to a maximum of about 75 feet, but throughout the field in general its thickness is most commonly between 10 and 30 feet. It consists of a heterogeneous mixture of clay, sand, gravel, and boulders mostly foreign to this region, but it seems probable that some of the finer constituents were derived from the Fort Union rocks lying below and have been transported comparatively short distances. The coarse material consists of boulders of a great variety of igneous and metamorphic rocks and some sandstone and fossiliferous limestone. Such rocks are not known to occur in place in this region, but are common to the northeast; hence it is assumed that they were transported by the glaciers from some place in Canada and were left where they are now found when the ice melted.

ALLUVIUM.

Missouri River and Muddy Creek valleys are filled with alluvium. The thickness of this filling is not well known, but a vertical exposure of the river bank near Trenton shows 54 feet of alluvium. It is probable that the maximum thickness in the field is but little greater.

STRUCTURE.

Though exposures are not abundant enough to make it possible to trace any particular stratum for a great distance, or to determine accurately the dip of the beds, the rocks are exposed enough to show that the beds are almost horizontal. Minor variations from the horizontal occur at places in the field, but the dips are so slight that the apparent variation from the horizontal is believed to be due either to minor undulations or to cross bedding. The strata in the Culbertson field to the west¹ have a slight eastward dip, and a similar condition exists in the Fort Berthold Indian Reservation, which lies to the east of the Williston field, but the data obtained for this report do not show that the slight eastward dip is continuous across the field here described. The exposures show that if the beds do not lie horizontal the general dip is very slight and locally counteracted by gentle undulations. The local structure is exhibited in mine workings where the dip is so gentle that many of the entries are drained by gravity, whereas from the others water has to be pumped.

THE LIGNITE.**DISTRIBUTION.**

As stated in the discussion of geology, the lignite occurs at various stratigraphic horizons in the Fort Union formation, which underlies the entire area, though it is concealed at most place either by glacial débris or by alluvium. As the Fort Union is so persistently lignite bearing, it is believed that the entire field is underlain by a large quantity of lignite. Probably the quantity varies in different parts of the field, but there is little doubt that beds of lignite more than 2 feet thick underlie the entire field at a depth less than 500 feet. The distribution of the lignite in the strata is believed to be as represented in the generalized columnar section on Plate X. The only continuous exposures are in the southern part of the field, where the beds show a variation in thickness, but more or less lignite is everywhere present. The greatest number of beds exposed at any one place in the field is in T. 154 N., R. 100 W., where four thick beds and several thin ones occur; the least number is in T. 153 N., R. 103 W., where only three

¹ Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: Bull. U. S. Geol. Survey No. 471, 1912, pp. 319-358.

beds are exposed. The amount of variation is shown by the stratigraphic sections accompanying the various township descriptions in the latter part of this report. It seems probable that the conditions in T. 153 N., R. 103 W., where very little lignite has been found, are local and do not prevail over any considerable part of the field. However, a large part of the field is covered and no definite information can be obtained, so that comparisons are uncertain. In the northern part of the field especially the few small exposures have been made by the inhabitants to secure their fuel supply and show little more than the lignite bed. Though the data are not sufficient to form a good basis to closely estimate the quantity of lignite in the field, they do show that there is an abundance.

CHARACTER OF THE LIGNITE.

PHYSICAL PROPERTIES.

The lignite of this field is dark brown to brownish black in color, tough, and markedly woody in structure, and breaks with an irregular fracture. It slacks rapidly on exposure to the air and sunlight, especially when subjected to much handling or to long hauls. After short exposure to the atmosphere it checks and breaks into small fragments. On further exposure it breaks down into fine black or very dark brown sootlike powder, but small fragments that retain the woody structure are commonly intermingled with the powder. This feature is especially observable along dry, weathered outcrops. The powdered lignite has been brought to the surface by gophers and badgers at many places where the outcrop is concealed by glacial drift. In this way the animals have served to indicate the location of a lignite bed which otherwise would have been undetected.

Intermingled with the lignite are various impurities, chiefly clay and sand, but pyrite, marcasite, and gypsum in minor quantities. There is every gradation from pure lignite to pure clay or sand. Pyrite and marcasite occur mainly as nodules disseminated through the bed, but in places in layers. The nodules vary in size from mere grains up to lumps 2 or 3 inches in diameter. Marcasite is the most common iron sulphide. Incrustations of gypsum in the form of satin spar and selenite crystals occur between the joint and bedding planes, especially on the weathered outcrop.

CHEMICAL ANALYSES.

Four samples of lignite were collected by the writer in the manner prescribed by the United States Geological Survey from freshly exposed surfaces in working mines and sent to the Pittsburgh laboratory of the Bureau of Mines for analysis. The results of these analyses are shown in the table on pages 100-101, together with analyses of samples collected in this field previously by other persons.

In comparing the analyses of samples previously collected with those collected by the writer, it should be noted that the volatile matter in the writer's samples was determined by the "modified" method, which involves about four minutes' gradual heating preliminary to the regular determinations. The result gives a higher percentage of volatile matter and a relatively lower percentage of fixed carbon, because in the older method the sudden application of extreme heat causes spluttering and mechanically drives off fixed carbon, especially in lignite. This condition is recognized at the chemical laboratory and hence a somewhat modified method has been introduced to determine the volatile matter. The differences in analyses made by the two methods are, however, too small to be of consequence except in making close comparisons.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form is not well suited for comparison, because the quantity of moisture in the sample as it comes from the mine is governed largely by the quantity of water in the mine, and consequently analyses of the same coal expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted to general comparisons, because it more nearly represents the fuel as it is delivered to the consumer than any other form of analysis. Analyses of the same type made on weathered coal and on fresh coal do not form a proper basis of comparison for the two samples, because on exposure to atmosphere lignite loses 5 to 10 per cent of its moisture, and the remaining moisture seems to become fixed, so that it is not readily driven off in the process of air-drying in the chemical laboratory. The analyses of an air-dried weathered sample or a car sample therefore should not be compared with the analysis of an air-dried unweathered sample that was carefully taken and sealed in the mine. The quantity of moisture left in the sample after air drying is commonly an indication of its weathering that is not evident in the mine. Generally the analysis of an air-dried entirely unweathered sample of North Dakota lignite shows 10 to 16 per cent of moisture. A greater amount of moisture in this analysis may indicate that the sample was more or less weathered and that a part of the moisture that would ordinarily be given off had become fixed before the sample was subjected to the air-drying process in the chemical laboratory. Analysis C represents the theoretical condition of the coal after all the moisture has been eliminated, and analysis D represents the coal after all moisture and ash have been theoretically removed. This is supposed to represent the true coal substance, free from the most significant impurities. Forms C and D are

obtained from the others by calculation. They should not be used in comparison, for they represent theoretical conditions that never exist.

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

Partial analyses of five lignite samples from this field have been published by the North Dakota Geological Survey.¹ The percentages of fixed carbon, volatile matter, ash, and moisture of two samples of lignite collected in the vicinity of Williston published by the United States Geological Survey in 1905² are not reprinted in this report because they were made in other laboratories and by methods slightly different from those now used.

¹ First Blen. Rept. North Dakota Geol. Survey, 1900, pp. 63-64.

² Water-Supply Paper U. S. Geol. Survey No. 117, 1905, p. 18.

Analyses of lignite samples from the Williston lignite field, North Dakota.

[Made by the United States Geological Survey and the Bureau of Mines. F. M. Stanton and A. C. Fieldner, chemists in charge.]

Laboratory No.	Name of mine.	Location.				Page.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.				Heating value.		
		Quarter.	Sec.	T. N.	R. W.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
a 1416	Mine of Cedar Coulee Coal Co.	34	154	100	24.1	A B C D	36.8 16.7 44.5 48.4	28.1 37.1 47.4 51.6	30.0 39.5 47.4 51.6	5.09 6.71 8.05 8.83	0.48 .63 7.76 4.89	6.93 5.61 4.49 4.89	41.87 55.16 66.23 72.03	0.69 .91 1.09 1.19	44.94 30.98 19.38 21.06	4,000 5,275 6,330 6,885	7,200 9,490 11,390 12,390
1730	Miller Mine (Cedar Coulee).	34	154	100	121-122	33.1	A B C D	41.1 12.0 46.2 50.8	27.2 40.6 44.7 49.2	26.3 39.4 9.1 1.34	5.4 8.0 9.1 1.22	.72 1.08 1.22 1.34	3,605 5,385 6,120 6,755	6,480 9,690 11,020 12,120
a,b 2365	Mine at mouth of Cedar Coulee.	.....	34	154	100	.....	17.3	A B C D	36.1 22.8 45.8 49.8	29.3 35.4 46.3 50.2	29.6 35.7 46.3 50.2	5.04 6.10 7.90 1.00	.59 .71 .92 4.40	6.60 5.66 65.77 71.39	42.00 50.78 1.14 21.97	.73 .88 1.24 21.97	45.04 35.87 20.22 6,920	4,070 4,920 6,375 12,450
a 4276	Mine of Cedar Coulee Coal Co.	34	154	100	31.7	A B C D	38.9 10.6 41.8 45.9	25.5 37.4 49.4 54.1	30.2 44.1 8.82	5.39 7.89 7.948 .71 .79 .86	6.89 4.93 4.21 4.61	39.34 57.60 64.41 70.64	.68 .99 1.11 1.22	47.22 27.88 20.66 22.67	3,745 5,480 6,130 6,725	6,740 9,870 11,030 12,100
b 5469	Black Diamond mine.....	SE.	33	154	100	122	12.7	A B C D	38.9 30.0 53.6 57.4	32.7 37.5 39.8 42.6	24.3 27.9 6.6	4.0 4.6 6.6.....	.27 .31 .44 .47	.....	.....	.....	3,710 4,250 6,070 6,500	6,680 7,650 10,930 11,700
5470	Mine of United States Reclamation Service.	NE.	7	154	100	121-124	12.0	A B C D	36.6 28.0 52.0 56.2	32.9 37.4 40.5 43.8	25.7 29.2 7.5	4.8 5.4 7.5.....	.48 .55 .76 .82	.....	.....	.....	3,790 4,310 5,980 6,460	6,820 7,750 10,760 11,630
7600	Black Diamond mine.....	SE.	33	154	100	122	35.8	A B C D	42.3 10.2 42.0 45.7	24.2 37.7 49.8 54.3	28.8 44.7 8.2	4.7 7.4 6.1.....	.35 .55 .61 .66	.....	.....	.....	3,485 5,425 6,040 6,575	6,270 9,770 10,870 11,840
12411	Geltz mine (operated by H. L. Duncan).	NW.	27	154	102	129	34.7	A B C D	42.7 12.3 44.9 50.9	25.7 39.4 43.2 49.1	24.8 37.9 11.9 2.74	6.8 10.4 11.9 2.74	1.38 2.11 2.41 2.74	.....	.....	.....	3,370 5,155 5,880 6,675	6,060 9,280 10,580 12,010

12533	Mine of United States Reclamation Service.	NE.	7	154	100	121, 124	33.2	A	43.9	c 24.9	25.4	5.8	.49	3,300	5,940
					B	16.0	37.2	38.1	8.7	.73	.....	.....	.....	.....	.....	4,940	8,890
					C	.....	44.3	45.3	10.4	.87	.....	.....	.....	.....	.....	5,875	10,580
					D	.....	49.5	50.5	.....	.97	.....	.....	.....	.....	.....	6,555	11,800
12587	Mine of John Bruegger	SE.	3	154	100	122, 124	33.2.	A	41.5	c 27.0	27.2	4.3	.30	3,580	6,440
					B	12.5	40.4	40.7	6.4	.45	.....	.....	.....	.....	.....	5,355	9,640
					C	.....	46.1	46.5	7.4	.51	.....	.....	.....	.....	.....	6,120	11,010
					D	.....	49.8	50.2	.....	.55	.....	.....	.....	.....	.....	6,605	11,890
12588	Mine of R. M. Powell.....	SE.	33	154	100	124	34.7	A	42.9	c 26.8	25.0	5.3	.71	3,460	6,230
					B	12.6	41.1	38.2	8.1	1.09	.....	.....	.....	.....	.....	5,300	9,540
					C	.....	47.0	43.7	9.3	1.24	.....	.....	.....	.....	.....	6,065	10,920
					D	.....	51.8	48.2	.....	1.37	.....	.....	.....	.....	.....	6,685	12,030

a Car sample.

b Sample probably weathered.

^c Volatile matter determined by the "modified" method.

Laboratory No. 1416.—This analysis was made from run of mine car sample shipped in 1904, by H. A. Storrs, engineer United States Reclamation Service, to the coal-testing plant at St. Louis, and is an ultimate analysis of a sample taken from the car on its arrival at the testing plant. The producer-gas test of this sample showed it to be a good gas-producer fuel. The mine from which the sample was taken was located in sec. 34, T. 154 N., R. 100 W., but has since been abandoned.

Laboratory No. 1730.—Sample collected in regular manner by M. R. Campbell in 1905 from the mine from which sample No. 1416 was obtained. Only lower 6 feet of 12-foot bed was sampled, as only that part was being mined. This mine has been abandoned and has all caved in since the sample was taken.

Laboratory No. 2365.—Run of mine car sample shipped in 1905 by H. A. Storrs to the coal-testing plant in St. Louis. Producer-gas test No. 72 shows this to be a good gas-producer fuel.¹ The location recorded when this sample was taken is indefinite. It was probably taken in secs. 33 or 34, T. 154 N., R. 100 W., or sec. 4, T. 153 N., R. 100 W.

Laboratory No. 4276.—Run of mine car sample sent to the St. Louis testing plant by H. A. Storrs in 1905. The analysis indicates that this sample was not weathered, although the records show that it was a car sample. It was probably taken from the car soon after its arrival in St. Louis, and properly sealed and sent to the laboratory. The mine from which it was taken has been abandoned.

Laboratory Nos. 5469 and 5470.—Samples collected in regular manner by John W. Groves, October 9, 1907. Sample No. 5469 was taken in the main entry of the Black Diamond mine in the SE. $\frac{1}{4}$ sec. 33, T. 154 N., R. 100 W., and sample No. 5470 was taken about 250 feet east of the mouth of the main entry in the United States Reclamation Service mine in the NE. $\frac{1}{4}$ sec. 7, T. 154 N., R. 100 W. Both of these analyses indicate that the samples were weathered. The bed in the United States Reclamation Service mine was observed by the writer to be weathered for a considerable distance back from the outcrop. The character of the lignite in the Black Diamond and United States Reclamation Service mines is believed to be more fairly represented by analyses Nos. 7600 and 12533, respectively.

Laboratory No. 7600.—Sample from the Black Diamond mine in the SE. $\frac{1}{4}$ sec. 33, T. 154 N., R. 100 W., collected in regular manner by Karl M. Way, April 6, 1909. Sample taken in room 3, off first west entry off first south entry.

Laboratory No. 12411.—Sample from Geltz mine in the NW. $\frac{1}{4}$ sec. 27, T. 154 N., R. 100 W., collected in regular manner by Frank A. Herald, June 30, 1911. Sample taken at end of main entry, about 150 feet from mine mouth. There is only 32 feet of cover over the bed where the sample was taken and the mine is dry, but the analysis indicates that the sample was unweathered. At the place where the sample was taken the bed has a total thickness of 5 feet 6 inches, including a 5-inch shale parting 1 foot 9 inches above the bottom. As shown by the section on Plate IX the bed is thicker near the mine mouth.

Laboratory No. 12533.—Sample from the United States Reclamation Service mine in the NE. $\frac{1}{4}$ sec. 7, T. 154 N., R. 100 W., collected in regular manner by Frank A. Herald, August 16, 1911. Sample taken in William Sprangler room, 1,225 feet east of mine mouth. There is about 96 feet of cover over the bed where the sample was taken. The mine was dry. The lignite bed is 10 feet 3 inches thick at the place, but only the lower 8 feet was sampled, as that was all that was exposed in this room. Steaming tests and analyses of 15 samples from this mine were made at the United States Reclamation Service power plant in October, 1908.²

Laboratory No. 12587.—Sample from the John Bruegger mine, collected in regular manner by Frank A. Herald, September 5, 1911. Sample taken 50 feet west of main

¹ Bull. U. S. Geol. Survey No. 290, 1905, p. 137; and Bull. U. S. Bureau of Mines No. 13, 1911, pp. 174 and 175.

² Randall, D. T., and Kreisinger, Henry, North Dakota lignites as a fuel for power-plant boilers: Bull. U. S. Bureau of Mines No. 2, 1910.

entry, 1,225 feet northwest from mine mouth. There is about 125 feet of cover over the bed where the sample was taken. The mine was wet and constant pumping was necessary to keep it from being flooded. The total thickness of the bed at the place where the sample was obtained is 11 feet, including a 4-inch shale parting 22 inches from bottom. The sample was taken from only 5 feet 6 inches of the bed above the parting, as neither the top nor the bottom of the bed was exposed at that place.

Laboratory No. 12588.—Sample from the mine of R. M. Powell in the SE. $\frac{1}{4}$ sec. 33, T. 154 N., R. 100 W., collected in regular manner by Frank A. Herald, September 6, 1911. Sample taken about 50 feet north of main entry, about 900 feet northeast of mine mouth. There is about 80 feet of cover over the bed where the sample was taken. The mine was dry. The total thickness of the bed is 10 feet, but only the lower 6 feet 6 inches was included in the sample, as the upper part of the bed was not exposed where the sample was taken.

DEVELOPMENT.

At the time of the writer's visit there were three comparatively large mines in the eastern part of the field and strip pits at many other places which are locally called mines. The large mines are operated chiefly to supply fuel to Williston and to small towns along the railroad and to near-by farming communities. Strip pits are operated by farmers to secure fuel for themselves and neighbors. In the description by townships each mine is noted.

Of the plants using lignite one is unique, that of the United States Reclamation Service, which uses lignite at the mines northeast of Williston for the generation of electricity that is conveyed over cable lines to Buford, where electrically operated pumps are located. These pumps lift water from Missouri River to the canals of an extensive irrigation system, which waters a large section of the Missouri River valley. This plant, including the mine, is in operation during the irrigation season only, but it furnishes the basis of an important industry. Lignite seems well adapted to this work, and it can be cheaply mined. It is hauled in pit cars from the mine to a small crusher above bunkers which empty into the engine room. Some of the furnaces are fed by hand, but others are stoked automatically; the fuel is handled well either way.

Underground development is rendered unusually expensive by the absence of suitable timber for mines. The county is practically timberless except along the Missouri River valley, where scattered areas are covered by a dense growth of small timber, but very little is large enough for mine work. The absence of timber is especially unfortunate in this field, because the strata overlying the lignite are soft, commonly shale or soft shaly sandstone, and require a large amount of timber in the mines.

Where the lignite beds are thick only the lower part is mined at first, leaving 2 or 3 feet at the top to support the roof. Then after certain areas are entirely worked out the pillars are drawn and the lignite left in the roof is recovered. This method of mining reduces the amount

of timber required, but the main entries must be well timbered. Practically all timber used in the development of this field must be shipped from the Rocky Mountains on the west or the timber-covered areas on the east.

USES OF LIGNITE.

In the Williston field lignite is used chiefly as a household fuel, but also to some extent under stationary boilers. As a domestic fuel it is satisfactory when properly used; but the novice generally meets perplexing difficulties and is likely to underestimate its value. The most satisfactory results are obtained in ordinary cooking or heating stoves when the firebox is well filled with lignite that has been broken into small chunks and dried.

Lignite has been thoroughly tested under power-plant boilers and found to be satisfactory when properly handled. Systematic tests were made at the United States Reclamation Service power plant in October, 1908, to determine the efficiency of the fuel and to learn the best methods of firing. These tests showed that the lignite is satisfactory for making steam when boilers and fireboxes are properly constructed and the fires are correctly fed and controlled. The results of these tests are set forth in Bulletin No. 2 of the Bureau of Mines.

Great possibilities exist in the conversion of lignite into producer gas. Though producer-gas plants are numerous in Europe and are becoming common in this country, as yet they are not wholly beyond the experimental stage. They have, however, been perfected sufficiently to prove their superiority in many points over ordinary steam boilers. There is no producer plant in the Williston field, but coal was shipped from the mine of the Cedar Coulee Coal Co. to be tested at the fuel-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition in St. Louis in 1904. The results of the tests are as follows:¹

Of scarcely less importance are the results obtained in the use of lignite in the gas-producer plant. It has been shown that a gas of higher quality can be obtained from lignite than from high-grade bituminous coals, and that 1 ton of lignite used in a gas-producer plant will yield as much power as the best Pennsylvania or West Virginia coals used under boilers. It appears in fact as coals decline in value when measured by their steam-raising power, they increase in value comparatively as a fuel for the gas producer. The brown lignites on which tests were made at the coal-testing plant were from North Dakota and Texas, and the unexpectedly high power-producing qualities developed by them in the gas producer and gas engine give promise of large future developments in these and other States in the Far West, where extensive but almost untouched beds of lignite are known to exist.

Some briquetting tests have been made with North Dakota lignite and have proved that the fuel can be treated successfully in that way. Tests at the Pittsburgh laboratory of the Bureau of Mines indicate

¹ Report on the operations of the coal-testing plant of the United States Geological Survey at the Louisiana Purchase Exposition, St. Louis, Mo., 1904: Prof. Paper U. S. Geol. Survey No. 48, 1906, pt. 1, p. 30.

that lignite from the Williston field can be economically briquetted.¹ Lignite from this field has been briquetted successfully at the North Dakota Mining and Experiment Station at Hebron, N. Dak.² The Pittsburgh tests were made with high pressure without binder, whereas the others were made with lower pressure and binder. As both methods gave favorable results, experimenters believe that the lignite can be successfully briquetted on a commercial basis both with and without binders. When briquetted the lignite can compete with higher-grade coal, as the briquets withstand weathering and do not crumble badly when handled. The process of briquetting removes 75 per cent of the water in the lignite, thus decreasing the weight about 30 per cent, and considerably increasing the heating value, by saving the heat otherwise needed to remove the moisture. Excessive moisture not only wastes heat during combustion but is also an important factor in freight charges, approximately one-third of the weight of most lignites being water. Briquetting, therefore, is especially useful because it increases the heat value and decreases the cost of transportation. In the tests mentioned above the heat value of the briquets made without binder was about 50 per cent greater than that of the raw material, and the briquets made at the Hebron experimental substation by a different process involving more thorough drying and the addition of binders showed a heat value about 70 per cent greater than the raw lignite.

A plant which would combine the producer-gas and briquetting features has been proposed by E. J. Babcock, director of the Mining Experimental Station of North Dakota.³ This process consists of "first, the removal of moisture; second, the expulsion and saving of the volatile gas; and, third, the binding together of the concentrated residue into a strong, durable, and satisfactory briquetted product." The process was tested by careful experiments at the Hebron substation and both the gas and briquets were highly satisfactory. The experiments indicate that this method of utilizing the lignite of this region would be highly profitable wherever there is sufficient market for power.

The future installation of briquet and gas-producer plants in this field seems probable. The rapid change in methods and machinery for such plants, as well as the large initial cost, doubtless everywhere delay the immediate introduction of producer-gas machinery. The installation of such plants will of course go along with the introduction of manufacturing industries to utilize the power developed. At present there is no general demand for power plants in the region and

¹ Wright, C. L., Briquetting tests of lignite at Pittsburgh, Pa., 1908-9: Bull. Bureau of Mines, No. 14, 1911.

² Babcock, E. J., Investigations of lignite coal relative to the production of gas and briquets: Rept. School of Mines and Experimental Station of North Dakota, 1911.

³ Babcock, E. J., Investigations of lignite coal to the production of gas and briquets: Rept. School of Mines and Experimental Station of North Dakota, 1911.

therefore it is not expected that even the most economical plants will be erected.

As this field is in the midst of a large lignite-bearing area, the establishment of manufacturing industries and briquetting plants to supply outside markets depends largely on development here ahead of competing points. This field is connected with areas outside the lignite basin by two routes of transportation—the Great Northern Railway and Missouri River—but both routes traverse country for a long distance about equally rich in lignite. The region nearer the edge of the basin has the advantage of shorter haul to outside markets. The principal development of this field for many years at least will be to supply local demand.

ESTIMATED TONNAGE.

Data are not available for an accurate estimate of the amount of lignite in this field, because a large portion of the area is covered by glacial drift which conceals the lignite-bearing formation. Only a few exposures show a considerable thickness of the strata which underlie the area and the lignite content in these exposures differs widely. The data furnished by natural exposures is supplemented by logs of wells and drill holes in several parts of the field, but these are too few and are not of sufficient depth to afford a basis for an accurate estimate.

If only beds greater than 25 inches in thickness and lying at a depth less than 500 feet are considered, and the amount of lignite in an acre-foot is regarded as 1,800 tons, the total tonnage of lignite in the field is 12,918,000,000 short tons. These figures are believed to be conservative but must be regarded as only a general approximation. There are, of course, lignite beds at greater depth and many beds of less thickness, but these are not considered in making this estimate.

DESCRIPTIONS BY TOWNSHIPS.

The following detailed descriptions treat of the lignite exposures and the general geology of the townships in this field. The preceding portion of this report contains a discussion of the field as a whole. A person who desires a knowledge of the lignite resources of any particular township should read both the detailed description and also the preceding general discussion. In the following descriptions each tier of townships is taken in regular order, beginning at the northeast corner of the field and going from east to west.

T. 157 N., R. 100 W.

Practically the whole surface of T. 157 N., R. 100 W., is covered by a mantle of glacial drift, which conceals lignite beds except in small areas in secs. 6, 19, and 36. The glacial drift is uncommonly thin in parts of secs. 5, 6, and 7 and is absent over certain small areas

in sec. 6. At the strip pit in sec. 19 (location No. 2¹) the thickness of the drift mantle varies from 12 to 25 feet. This exposure probably shows the average condition over the township, though the glacial material is doubtless considerably thicker in some places.

Location 1 in sec. 6 is a small strip pit, which was so badly caved at the time of examination that a section could not be measured. From the appearance of the pit the lignite bed at this place was estimated to be 5 feet or more in thickness.

Location 2 in sec. 19 is a strip pit which has furnished lignite for local use for several years. At the time of examination the workings were badly caved and the drainage was obstructed so that a complete section of the lignite bed could not be measured. The exposure showed 5 feet of lignite above water. A. W. Paterson, who lives in the SE. $\frac{1}{4}$ sec. 19, reported that the lignite bed has a total thickness of 6 feet. Several large springs flow from the lignite bed in the workings at this strip pit.

Considerable mining has been done at location 3 in sec. 36, but at the time of examination the hillside had slumped so extensively that the lignite could not be measured without excavation. It was reported by the son of Charles Holse, who has a lease on the mine, that the lignite bed is 9 feet 6 inches thick and that the bottom is slightly below the level of the near-by branch of Sandy Creek. He reported also that since the first opening 13 entries, some of them over 200 feet long, have been made in the bed at this place. Several large springs flow from the hillside, apparently from the upper part of the lignite bed. The water probably aids in the preservation of the lignite, but such a large flow adds considerably to the difficulty of mining, especially as the bottom of the bed is below the level of the near-by stream.

T. 156 N., R. 100 W.

The whole area of T. 156 N., R. 100 W., is covered with glacial drift. Glacial topography is especially evident in the west-central part, but the entire surface shows the effects of the action of a continental ice sheet. At its maximum the mantle of drift is probably 65 to 80 feet thick, but the average in the township is probably less than 25 feet. The lignite-bearing Fort Union formation underlies the entire area and thick beds of lignite are probably everywhere within 500 feet of the surface.

At location 4 in sec. 33 a thickness of 2 feet 6 inches of lignite is exposed, but the bottom of the bed was not reached. Glacial drift lies in immediate contact with the top of the lignite bed, which is at an elevation of 2,000 feet above sea level. This exposure indicates that under normal conditions the bed is more than 30 inches thick, but no data are at hand to show the total thickness. Location 5 in sec.

¹Numbers refer to locations on the map, Pl. X, and many of them also to sections with corresponding numbers on Pl. IX.

33 is a small prospect on a bed about 30 feet higher than that at location 4. A thickness of 2 feet 9 inches of lignite is exposed at this place, but this is not all the bed, for the top has evidently been removed by glaciation. At location 6 a spring flowing about 100 gallons a minute probably comes from the same bed of lignite.

A section measured in a strip pit at location 7 in sec. 31 is shown on Plate IX. The pit is about 15 by 30 feet and extends across the range line. Exposures at locations 11, 12, and 13 in the township to the west are believed to represent the same bed. The inferred location of the outcrop of this bed in secs. 19, 30, and 31 is indicated on the map.

T. 156 N., R. 101 W.

With the exception of small areas on nearly vertical banks along Otter Tail and Cow creeks, this township is entirely covered by glacial drift, probably nowhere exceeding 80 feet in thickness and generally from 15 to 30 feet thick. The entire township is underlain by the lignite-bearing Fort Union formation and it is probable that thick beds of lignite are everywhere comparatively near the surface. Although this township is generally covered by glacial drift, some exposures of lignite were found and are indicated on the map.

At location 8 in sec. 10 a strip pit goes down to the lignite from the surface back of the outcrop. The pit from which the lignite has been removed is about 20 feet square, but a space 25 by 50 feet has been cleared. The exposures indicate a very slight westward dip. The pit contained water, so the full thickness of the bed could not be determined with certainty, but probably it is very little thicker than indicated by the section on Plate IX. The lower part of the same bed outcrops at location 9 in sec. 11, but its upper part has been removed by glaciation.

Section at location 9 in sec. 11, T. 156 N., R. 101 W.

	Ft.	In.
Glacial drift.....	4	3
Lignite.....	1	3
Shale, gray.....	18	
Lignite.....	1	10
Shale, gray.....	6	
	25	7

The lower bed in the section given above is not known to be exposed elsewhere.

The Miller mine in the north-central part of sec. 24 has furnished lignite for local use for several years. A section of the bed at this mine is shown on Plate IX. Lignite has been mined extensively by stripping and from two short entries. At the time the mine was examined A. C. Miller, the owner, was planning to open a drift mine on an extensive scale.

The section measured at location 10 in sec. 24 and represented on Plate IX was obtained by digging into the hillside where fragments of lignite had been brought to the surface by gophers. The outcrop of the bed was readily followed for some distance by blossom due to the digging of gophers and badgers and is indicated on the map by a solid line.

The exact point where section No. 7 was measured is a few feet in the township to the east, but the strip pit, which is 15 by 30 feet, extends across the range line into this township. Two other openings, hardly more than prospects, which lie to the west at distances of 75 and 100 yards, were caved at the time of examination.

A section measured at location 11 in sec. 36 is represented on Plate IX. Because of water in the pit the section was not measured to the bottom of the bed. At this place there is a small strip pit about 10 by 20 feet long. The top of the lignite bed is 4 to 5 feet above the water level in Cow Creek. The same bed has been prospected at three or four places near by, but the prospect holes have caved so that sections could not be measured without considerable excavation.

At location 12 in sec. 35 a spring flows about 35 gallons of water a minute. Although only about a foot of lignite is exposed, the spring may come from a thick bed of lignite, the same as that exposed at locations 13, 11, and 7. The spring is 4 feet above the level of Cow Creek, which is about 25 feet away.

A strip pit about 20 feet wide by 40 feet long affords an exposure of lignite at location 13 near the east line of sec. 34. The section, which is shown on Plate IX, was not measured to the bottom of the bed because of water in the pit. The bottom of the bed is below the water level in Cow Creek, which is only a few feet distant. About 30 feet southeast from the place where the section was measured is a similar pit.

The bluffs along Cow Creek are generally low, rounded, and covered by glacial drift, but at location 14 in sec. 34 an exceptionally high and steep bluff affords the most extensive exposure along Cow Creek.

The following section was measured at that point:

Section at location 14 in sec. 34, T. 156 N., R. 101 W.

	Ft.	in.
Glacial drift.....	8	
Slumped glacial drift.....	18	
Shale, gray.....	7	
Sandstone, soft, gray, argillaceous.....	15	
Shale, gray.....	10	
Lignite.....	7	
Shale, gray.....	3	6
Lignite.....	10	
Shale, gray.....	4	
Lignite (Pl. IX, section 14).....	6	10
Shale, gray.....	25	
Cow Creek.	98	9

Lignite has been taken from the bed near the bottom of the section given above at two small strip pits on the hillside. The same bed has been worked at the Lampman mine about three-fourths of a mile to the northwest.

The Lampman mine in sec. 28 has furnished lignite for local use for several years. It is said to be the property of H. R. Lampman, of Williston. Lignite has been taken from this mine by stripping only, but this method has been carried almost to the limit of profit because the workings now extend back to the bank where the cover is so thick that it costs almost as much to remove it as the lignite is worth. The exposure at this place shows the following section:

Section at Lampman mine in sec. 28, T. 156 N., R. 101 W.

	Ft. in.
Glacial drift.....	3
Shale, gray.....	8
Lignite.....	8
Shale, gray.....	8
Lignite.....	10
Shale, gray.....	3
Lignite (see Pl. IX).....	6 6+
	30

A complete section of the main lignite bed was not obtained because water covered the lower part. Mr. Blair, who lives near by, reported that the bed ranges in thickness from 7 to 11 feet where it has been exposed in the pit. The above section extends slightly below the water level in Cow Creek about 15 feet away.

A section measured in a small prospect at location 15 in sec. 18 is shown in Plate IX. The bottom of the bed is 2 feet above the water level in Cow Creek about 10 feet away.

T. 156 N., R. 102 W.

The whole area of T. 156 N., R. 102 W., is covered by a mantle of glacial drift, probably not exceeding 75 feet and generally about 20 feet thick. The lignite-bearing Fort Union rocks lie immediately beneath the drift. The only surface exposures of lignite in the township are along Cow Creek in secs. 13 and 14. The three exposures there noted seem to be on the same bed, and if they are the structure is anticlinal. The elevation above sea level of the top of the lignite at location 17 is 2,092 feet, at the Big Four mine 2,097 feet, and at location 16 2,080 feet. At location 17 the bed strikes S. 65° W. and dips 5° W., but at the Big Four mine and at location 16 no dip was observed. Lignite was reported to have been found about 19 feet below the level of the creek at the bottom of a well about one-eighth of a mile east of location 16. These four occurrences are thought to represent the same bed and hence the outcrop was inferred as indicated on Plate X.

The section at location 16 in sec. 13 was measured at a small strip pit from which only a few wagonloads of lignite had been taken. The section was not measured to the bottom of the lignite bed because of water in the pit.

Section at location 16 in sec. 13, T. 156 N., R. 102 W.

	Ft. in.
Glacial drift.....	2
Shale, buff.....	2
Lignite.....	4
Shale, buff and yellow.....	5
Shale, brown, carbonaceous.....	1 8
Shale, buff.....	1 1
Lignite (Pl. IX, section 16).....	4 2+
	<hr/> 16 3

The Big Four mine in sec. 14 is a drift mine with two openings about 40 feet apart. Two sections of the lignite bed measured at points about 50 feet apart are shown on Plate IX. Section A was measured at the mouth of the main entry, and section B about 10 feet back in the entry to the west. The lignite outcrop is just high enough above the creek and far enough from it to make the mine readily accessible by wagon. This mine was not being operated at the time of the writer's visit, but it is reported to be operated regularly during the winter months. The main entry is fairly well timbered, but the opening to the west has no timbers and has caved to a point within 30 feet of the mouth. A steel track in the main entry leads to a dumping bin at the face of the mine. An air shaft is situated about 125 feet south of the mouth of the main entry.

Location 17 is at a small strip pit which had probably not been opened for more than a year previous to the writer's examination. Only a few wagonloads of lignite had been taken out. The pit is on the bank of Cow Creek and the bottom of the lignite is slightly below the water level in the creek. A section measured at this pit is represented graphically on Plate IX.

T. 156 N., R. 103 W.

All the surface of T. 156 N., R. 103 W., is covered by glacial drift probably not exceeding 75 feet and generally 20 to 30 feet thick. The lignite-bearing Fort Union rocks lie immediately beneath the drift. A very careful examination failed to reveal any surface exposures of lignite. However, lignite is reported to have been found in nearly all the wells in the township. Doubtless the entire township is underlain by thick beds of lignite comparatively near the surface.

T. 156 N., R. 104 W. (FRACTIONAL).

The whole area of fractional T. 156 N., R. 104 W., is covered by a mantle of glacial drift, probably not exceeding 75 feet and generally

10 to 25 feet thick. The lignite-bearing Fort Union rocks lie immediately beneath the drift. A very careful examination failed to reveal any surface exposures of lignite. In the northern part of sec. 24, the southern part of secs. 14 and 15, and the northern part of secs. 22 and 23 some clinker was observed on knolls over which lies only a light scattering of glacial débris. However, the remnant of the lignite bed represented by this clinker underlies a comparatively small portion of the township, probably being limited to a part of secs. 14 and 15. The whole township, however, is believed to be underlain by lignite beds lower in the Fort Union formation.

T. 155 N., R. 100 W.

The glacial mantle covering T. 155 N., R. 100 W., is thin at places on the low, gentle slope that bounds Muddy Creek valley. In some places the lignite beds are exposed and in others the covering is so thin that gophers and badgers have brought fragments of the lignite to the surface.

In sec. 4 at location 18 a section of part of the lignite was measured in an old strip pit, but the bottom of the bed could not be reached on account of water. The exposure showed 2 feet of lignite overlain immediately by glacial drift. A farmer who lives near by reported that the lignite bed is 7 feet thick. The area stripped is about 25 feet wide and 100 feet long.

At location 19 in sec. 3 a 35-inch bed of lignite is exposed in a small prospect hole. The evidence for the correlation of the beds in this vicinity is very meager, but the writer believes that this bed is stratigraphically lower than any other exposed in the township and that it may be the bed exposed at location 4 in the township to the north. The stratigraphic distance between this bed and the lowest lignite at the Wagenman mine is probably less than 25 feet.

The Wagenman mine in sec. 10 is a strip pit 200 feet wide by 300 feet long, or rather a series of strip pits that have furnished lignite for local use for several years. The workings had nearly all caved and were partly filled with water at the time of examination. Two sections are as follows:

Sections at the Wagenman mine in sec. 10, T. 155 N., R. 100 W.

Section measured at south end of mine.		Section measured at north end of mine.
Glacial drift.	Ft. in.	Glacial drift.
Lignite.....	1 8	Lignite.....
Shale, carbonaceous.....	5	Shale.....
Lignite.....	6	Lignite.....
Shale.....	2	Shale.....
Lignite.....	11	
Shale.....	3	
Lignite.....	2 11+	
Bottom not exposed.	9 7+	

The lignite in the upper part of the section which was measured on the north side of the workings probably corresponds to that at the bottom of the section which was measured on the south side, but the exact relation could not be determined. Mr. Morgan reports more than 6 feet of lignite in the lower part of the section.

Lignite blossom, due to workings of gophers and badgers, indicated the approximate location of the outcrop of a bed of lignite in secs. 21, 22, and 28, but no place was found in these sections where the lignite could be uncovered without much digging. The blossom, which occurs at altitudes ranging from 2,025 to 2,030 feet, was regarded as coming from the same bed as that exposed at the Wagenman mine and was used as a basis for the location of the inferred outcrop as indicated on the map (Pl. X).

The party making this examination was unexpectedly directed to drop the work in this field, to take up very urgent work elsewhere, before the survey of this township was complete. A traverse along Stony Creek valley was planned, but not made. However, Mr. Morgan has furnished data regarding the lignite in this valley. There are two drift mines in the valley, neither of which was operated at the time of examination. Mr. Morgan reports 6 to 8 feet of lignite in the Pioneer mine, which is near the southeast corner of sec. 23, and 5 to 6 feet in the Yell mine, which is near the center of the SW. $\frac{1}{4}$ sec. 35. From information furnished by Mr. Morgan in regard to the elevations and sections of lignite at the Pioneer and Yell mines the writer believes that these mines, the Wagenman mine, the strip pit at location 18, and the blossom in secs. 21, 22, and 28, are all on the same bed. This bed is believed to be the same as that extensively mapped in the township to the south and also in the northern part of T. 153 N., R. 100 W.

T. 155 N., R. 101 W.

Although T. 155 N., R. 101 W., is covered generally by glacial drift, some exposures of lignite were found. These exposures are indicated on the map (Pl. X) and are described below.

At location 20, near the southeast corner of sec. 15, a strip pit has been worked for several years. At the time of examination this pit was caved and partly filled with water, so that a complete section could not be obtained. The exposure above water showed 2 feet 6 inches of lignite with glacial drift immediately overlying the bed.

Lignite has been extensively mined by strip pits from the lower of the two beds along Camp Creek in sec. 16. At the time of examination the pits were so badly caved that measurements could be obtained only with great difficulty. Water was standing in nearly all the pits.

Location 21 is at a strip pit about 40 feet wide by 100 feet long. A section of a part of the bed measured at this place is shown on

Plate IX. The same bed is exposed at a small strip pit on the south side of the coulee at location 22. The exposure at this place shows 3 feet 4 inches of lignite, but the section was not measured to the bottom of the bed because of water in the pit. At a similar strip pit about halfway between locations 21 and 22 a thickness of 3 feet of lignite is exposed above water.

A complete section of the bed was measured in a small strip pit at location 23. Location 24, which is on the opposite bank of Camp Creek, about 400 feet from location 23, is at a strip pit about 40 feet wide by 200 feet long. This pit was so badly caved that the bed could not be measured, but it is probable that its thickness is about the same as at location 23. A slight dip southeast is evident throughout the exposures mentioned above, but it is probable that this dip is local and does not indicate the general dip of the beds throughout the field.

The upper bed mapped in sec. 16 is exposed only at location 25, on the north side of the coulee just opposite the strip pit at location 22. The top of the lignite bed at that place is 22 feet higher than the top of the bed in the strip pit. A section measured at location 25 is represented graphically on Plate IX.

Two beds of lignite were mapped in sec. 36. The lower bed is exposed in strip pits at locations 26 and 27 and at the Goode mine. The strip pit at location 26 is about 15 feet wide by 40 feet long; it was badly caved and partly filled with water at the time of the examination. The exposures above water showed 2 feet 4 inches of lignite overlain by glacial drift. At location 27 the pit is about 30 feet wide by 50 feet long and in similar condition to that at location 26. The exposure at this place shows 3 feet of lignite covered by glacial drift. The total thickness of the bed at these places is doubtless considerably greater than the part exposed. About 600 feet northwest of location 27 is an old caved mine, which seems to have been a drift beneath the hill. A big spring flows from the lignite bed in the pit at location 27, and springs and seeps mark the location of the outcrop of the bed for the greater part of the distance across sec. 36.

The Goode mine has been extensively operated for several years, but no work had been done there for several months previous to the writer's visit. At that time 9 feet of lignite was exposed, but this is not a complete section of the bed. Mr. Morgan reports that in general throughout the mine the bed is 12 feet thick but at some places it reaches a maximum of 14 feet. The writer went into the mine far enough to see that the main entry goes back at least 75 feet and that in this distance there are two side entries. The mine is not timbered except for a few feet at the mouth of the main entry. From 2 to 3 feet of lignite is left for roof.

The upper bed mapped in sec. 36 is exposed at locations 28, 29, 30, 31, and 32. The exposure at location 28 represents only the lower part of the bed, the upper part having been removed by glaciation. The results of glacial action are evident also at location 29, a strip pit 25 by 40 feet, which is 50 feet east of location 28. The exposure at location 29 includes part of the strata exposed at location 28 and also lower beds. A correlating stratum in the two sections is indicated by asterisks.

Sections at locations 28 and 29 in sec. 36, T. 155 N., R. 101 W.

Location 28.	Ft.	in.	Location 29.	Ft.	in.
Glacial drift.....	7		Soil.....	8	
Lignite.....	2	10	Glacial drift.....	1	3
*Shale, brown.....	1	1	Lignite, slacked ¹	9	
Lignite.....	1+		Glacial drift.....	8	
	11		Lignite.....	7	
			Shale, brown.....	2	
			Lignite.....	1	
			*Shale, brown.....	1	
			Lignite.....	2	
			Shale, gray.....	1	8
			Lignite.....	1+	
				7	1

A very old strip pit about 15 by 30 feet in size at location 29 indicates that the bed at the bottom of the section at that place is probably 2 or 3 feet thick. An attempt was made to extend the section to include all of the bed, but water came in so fast that the attempt was abandoned as impracticable.

At location 30 an old drift mine has been almost closed by glacial drift that has slumped down from above. About 2 feet of water was standing in the entry, which extends back at least 25 feet from the outcrop. The exposure showed 5 feet 2 inches of lignite, but this is not the full thickness of the bed, because the section does not extend to the bottom and the top has probably been removed by glaciation. Glacial drift, consisting of a heterogeneous mixture of boulders and clays, lies immediately over the lignite and serves as roof. Lignite has been stripped around the face of this drift from an area about 30 by 175 feet in size.

Location 31 is at a strip pit 10 by 20 feet in size. The exposure at this place shows 4 feet 6 inches of lignite overlain by glacial drift. The section was not extended to the bottom of the bed because a spring flows from the lignite bed and fills a portion of the pit.

Location 32 is at a pit which had evidently been opened several years before this examination was made. It was so badly caved that

¹ This slacked lignite has evidently been transported by glacial action and is probably from the same bed as the 7 inches of lignite below.

a section of the bed could not be measured. Mr. Morgan reports that the lignite is 6 feet thick at this place. Lignite has been stripped from an area about 75 by 100 feet in size and in some places as much as 12 feet of cover has been removed. An exceptionally good spring, both in quantity and quality of water, comes from the lignite bed.

The inferred location in sec. 31 of the outcrop of a bed of lignite that is exposed in the township to the south is indicated on the map (Pl. X), though the bed in this section is covered by glacial drift.

The United States Reclamation Service gives the following log of a drill hole in the SE. $\frac{1}{4}$ sec. 36, but the exact location in this quarter section was not reported. If the boring were made in the extreme northwest corner of the quarter section, then the bed of lignite found near the surface is probably the lower bed whose outcrop is indicated on the map; otherwise it is a still lower bed.

Log of United States Reclamation Service drill hole No. 1A in the SE. $\frac{1}{4}$ sec. 36, T. 155 N., R. 101 W.

	Ft. in.
Loam, sandy.....	5
Lignite.....	4 5
Clay.....	15 9 $\frac{1}{2}$
"Sulphur" ball.....	9 $\frac{1}{2}$
Clay, blue.....	28
Lignite.....	7
Clay, blue.....	4 5
Lignite.....	7
Clay.....	5
Lignite.....	7
Clay.....	1 5
	<hr/>
	62

T. 155 N., R. 102 W.

Location 33 in sec. 36, T. 155 N., R. 102 W., is at a strip pit 25 feet wide by 50 feet long, known locally as the Bartholomew mine. At the time of examination this pit was badly caved and partly filled with water. The following section was measured:

Section at location 33 in sec. 36, T. 155 N., R. 102 W.

	Ft. in.
Glacial drift.....	12
Lignite, slackened.....	9
Shale, brown.....	6
Lignite, slackened.....	1 1
Shale, gray.....	8
	<hr/>
	15

The workings indicate that the main bed of lignite is below the measured section. W. F. Garretson, who lives in sec. 28 of this township, reported a 5-foot bed of lignite at this place.

A shaft mine near the southeast corner of sec. 28 is owned and operated by W. F. Garretson, who furnished the following information about the mine. Mr. Garretson reported the following section exposed in the shaft and workings of the mine.

Section in Garretson mine in sec. 28, T. 155 N., R. 102 W.

	Minimum.	Maximum.
	Ft. in.	Feet.
Glacial drift.....	14	14
Shale and sandstone.....	30	30
Lignite.....	12	12
Shale.....	1	1
Lignite (mined).....	5	9½
Shale.....	8	8
Lignite.....	8	16
Shale.....		
	77 1	90½

Mining has been limited to the bed indicated. Several borings have been made from the bottom of these workings, in none of which has the lowest bed been found to be less than 8 feet thick. Mr. Garretson was unable to state whether the maximum measurement on this bed was 12 or 16 feet. The 12-foot bed of lignite above the bed mined is left to support the roof, which is so firm that no timbers are required in the mine. The shaft, which is 10 or 12 feet square, extends only to the bottom of the bed mined. The lignite is hoisted by horsepower. The mine was opened in December, 1907, and has been operated during the winter months since that time, except during the winter of 1910-11. It has not been operated on an extensive scale, the maximum daily output being about 20 tons, and the total output since the mine was opened is from 2,000 to 3,000 tons.

T. 155 N., R. 103 W.

The whole surface of T. 155 N., R. 103 W., is covered by glacial drift, so the lignite-bearing rocks are not exposed. The lignite-bearing Fort Union formation underlies the entire area, and it is probable that thick beds of lignite are everywhere near the surface.

The outcrop of a lignite bed in the southwest part of sec. 31 is indicated by blossom which has been brought up through the glacial drift by gophers. A good spring about 500 feet east of the range line also bears evidence of the same bed of lignite. Both the spring and the blossom are believed to come from the same bed of lignite that was extensively mapped in the townships to the west and southwest.

T. 155 N., R. 104 W. (FRACTIONAL).

Although fractional T. 155 N., R. 104 W., is generally covered by glacial drift, it contains some exposures of lignite. Most of these,

however, have been made by the inhabitants in securing their fuel supply.

The lowest bed exposed in the township was measured at locations 34, 35, 36, 37, and 38. This bed is mapped extensively in the township to the south. A bed 35 feet higher stratigraphically was measured at locations 39 and 40, and a still higher bed at the Barnes mine in sec. 12. At location 41 in sec. 35 a lignite bed is exposed at a slightly higher altitude than the Barnes mine. It is probable that this bed is stratigraphically above the Barnes bed, but the evidence as to their relative stratigraphic positions is not conclusive. There are doubtless other beds of lignite in this township, but so far as known they do not show at the surface.

Location 34 is at a strip pit about 40 feet wide by 100 feet long, known as the Miller mine. A section of the lignite bed at this place is shown on Plate IX. Location 35 is at a small strip pit so badly caved that a complete section could not be measured. About 30 inches of lignite were exposed.

Lignite has been extensively mined from a strip pit at location 36, where the area stripped is about 50 by 100 feet. A section of the lignite bed at this place is shown on Plate IX.

Measurements at location 37 were not carried to the bottom of the bed because of water in the pit. The top of the bed at that place is about 12 feet above the water in Little Muddy Creek, but the water that issues from the bed is not drained off. Lignite has been stripped along the creek bank for a distance of about 1,000 feet, but only for a small width—12 feet or less.

The bed seems to dip under the stream a short distance north of the exposure just mentioned, but reappears again slightly above the level of the creek at location 38. The latter exposure seems to be in a local fold, for an exposure in the creek bank about 800 feet east shows no signs of the bed. The exposure at location 38 is in a prospect hole 6 feet square and about 10 feet deep. The section represented on Plate IX continues to water, which is at or near the water level in the creek.

A bed 35 feet higher stratigraphically than the one at location 38 outcrops in small natural exposures at locations 39 and 40. At location 39 the bed is 2 feet 6 inches thick and at location 40 it is 1 foot 11 inches thick.

Lignite has been extensively mined at the Barnes mine in sec. 12. Previous to this examination mining had been carried on by stripping, but plans were being made to open a drift and operate on an extensive scale. This mine was opened in July, 1910, by Rolly Barnes and has been operated by him intermittently since that time. For a short time previous to the examination the mine had not been operated,

and caving had partly obstructed the drainage, so that a complete section could not be measured. As indicated by the section on Plate IX, the exposure showed 6 feet 3 inches of lignite. Mr. Hiram Walker, who has done most of the work in the mine for Mr. Barnes, reports that the bed is split into two benches by 6 inches of shale, the upper bench being 7 to 8 feet thick and the lower about a foot thick. The workings at this place extend over an area about 40 feet wide by 300 feet long.

The lignite bed measured at location 41 in sec. 35 is under very little cover where mapped. It underlies only the higher hills in that part of the township. The section shown on Plate IX was measured at a small natural exposure.

T. 154 N., R. 99 W.

The principal lignite beds of T. 154 N., R. 99 W., are not exposed within its boundaries. The strata that outcrop in the township to the west and that carry so many beds of lignite underlie this area.

The lowest bed of lignite that outcrops in this township has been extensively mined at the Sidpe mine in sec. 6. At this mine a series of strip pits extends along the outcrop for about 500 feet, ranging in width from 10 to 100 feet. No work was being done at the time the mine was examined, and so much water was standing in the pits that a complete section of the lignite bed could not be measured, but farmers living in the vicinity report the thickness to be 8 or 9 feet. At this place a bed 14 feet higher shows only 10 inches of lignite, overlain by glacial drift. It seems probable, however, that this exposure represents all or nearly all the thickness of the bed. At the south end of the mine the upper part of the lignite bed has been removed by glaciation, and glacial drift is in immediate contact with the lignite. The exposure at this place shows a peculiar intermingling with the lignite of a gelatinous hydrocarbon, probably due to a part of the bed having been put in colloidal solution through the action of percolating alkaline waters and later brought to its present condition by hydration. Where exposed to the direct heat of the sun the substance has a pitchlike appearance. It is especially abundant under and in immediate contact with the glacial covering, but it was observed also where the glacial covering is separated from the lignite by 3 or 4 feet of shale.

A bed about 30 feet stratigraphically higher than the bed at the Sidpe mine has been opened in sec. 31 of the township to the north, at location 42, by a strip pit about 10 feet wide and 150 feet long. Exposures at locations 43, 44, 45, 46, and 47 are believed to represent the same bed that has been mined at location 42. Location 44 is at a small strip pit which shows the full thickness of the bed. The ex-

posures at locations 43, 45, 46, and 47 show sections of only part of the bed, the top having been removed by glaciation. The thickness of the lignite at location 43 is 11 inches; at location 45, 1 foot 3 inches; at location 46, 2 feet 11 inches; at location 47, 1 foot 2 inches. The inferred line of outcrop, as shown on Plate X, was sketched on the basis of these exposures and springs and of blossoms that had been brought up by gophers and badgers.

At location 48 in sec. 18 a bed of lignite outcrops about 65 feet stratigraphically above the bed exposed at location 47. This bed is not of great value because it underlies only a small area and is not under thick cover. At the exposure at location 48 glacial drift is in immediate contact with the lignite and it is probable that a portion of the bed has been planed off by glacial action.

At location 49, in sec. 14, 20 inches of lignite is exposed in a spring. The total thickness of the bed could not be determined. A well near by is reported to have gone through a 3-foot bed of lignite at about this altitude. It seems probable therefore that the total thickness of the bed is approximately 3 feet.

At location 50, in sec. 14, a 10-inch bed of lignite is exposed at an altitude about 8 feet higher than that at location 49. No other exposure of this bed was observed.

Clinker and lignite blossom were observed at several places in the township. Clinker was noted in secs. 19, 29, and 30, but it is on the hilltops, and the bed from which it came is probably all burned out.

T. 154 N., R. 100 W.

As T. 154 N., R. 100 W., contains an unusual amount of lignite, a detailed report will be published separately. Though the essential facts are given below, both the scope of this report and the scale of the map are inadequate to present the data fully.

Four beds of lignite were mapped throughout the greater part of this township. In addition to these persistent beds, several thin beds are also represented and other lenticular beds between 2 and 3 feet thick occur. For convenience in description the four beds are referred to as beds A, B, C, and D, the lowest of the four being A and the highest D.

Bed A is exposed at only a few places. Mr. William Hutchinson, foreman of the United States Reclamation Service mine, reported that he had prospected this bed at several places in secs. 7 and 18 and that at these places it varies in thickness from 4 to 8 feet. An exposure of what seems to be the same bed at location 59 shows 5 feet 1 inch of lignite. The exposure at that place shows 8 inches of bone and a 9-inch bed of lignite below bed A.

Section at location 59, in sec. 28, T. 154 N., R. 100 W.

	Ft. in.
Glacial drift.	
Shale, gray.....	48
Lignite (bed C).....	7 2
Shale, gray.....	57
Lignite (bed B).....	2 9
Shale, gray.....	13
Lignite (bed A).....	5 1
Shale, gray.....	24
Bone.....	8
Shale, gray.....	18
Lignite.....	9
Shale, gray.....	5
	181 5

The thickness of bed A at locations 60 and 61 is shown on Plate IX. At three exposures in Cedar Coulee the thickness of the bed is 3 feet 10 inches, 3 feet 1 inch, and 2 feet 4 inches, respectively. This bed is considerably thicker in the northern part of the township than it is at the southern boundary.

Generally bed B is stratigraphically about 35 feet above bed A, but the distance ranges from a minimum of 13 feet to a maximum of about 50 feet. Bed B has been extensively worked at the United States Reclamation Service mine, where it is 10 feet to 10 feet 6 inches thick. At the Brown mine, in sec. 7, and at location 52 it is 9 feet 6 inches thick, as shown on Plate IX. At location 51, where this bed is only 6 feet thick, it is considerably below its normal thickness for that part of the township. Besides the mines mentioned above, the Standard, Snyder, and Sharp mines have operated on this bed. The Standard mine was abandoned at the time the field examination was made, but it was learned through reports of people living in the vicinity that this mine is laid out on a good plan for mining on a large scale. Mr. E. F. Lovejoy reports that the lignite bed in this mine is 11 or 12 feet thick. At the Snyder mine the bed is 8 feet thick. At the Sharp mine 7 feet of lignite are exposed, but this does not include the full thickness of the bed. At a strip pit at location 57 the bed is 6 feet thick. The thickness of the bed near the southeast corner of sec. 21 is shown by sec. 56. South of Crazy Mans Coulee this bed is much thinner than it is to the north. At location 59 it is only 2 feet 9 inches thick, a quarter of a mile northeast of this location it is 3 feet 2 inches thick, and a quarter of a mile south it is 3 feet 3 inches thick. Its thickness at locations 60 and 61 is shown on Plate IX. Exposures in Cedar Coulee show it to be slightly thicker than at location 61. It thickens eastward to the place where the coulee rises above its level, a short distance west of

the old Miller mine, where it is 3 feet 6 inches thick. Like bed A, bed B is thinner in the southern part of the township than it is in the northern part.

Throughout most of its exposures bed C is about 40 feet stratigraphically above bed B, but at some places it is as much as 60 feet higher and at others only 20 feet. It is a thick bed throughout all the exposures and does not decrease from north to south as the other beds do. Sections 50, 52, and 53 on Plate IX show the character of this bed on the west side of Stony Creek. This bed has been extensively mined at the Bruegger mine. A section representative of the bed in this mine is shown on Plate IX. At location 55 in sec. 22 the bed is 7 feet thick. The thinnest complete section was measured at location 58. At location 59 and at a small drift mine 500 feet southwest the bed is 7 feet 2 inches thick. At the Dahl mine, which has long been abandoned, the bed is 6 feet 6 inches thick. The Jackson mine and the old Black Diamond mine are on the same bed, but sections were not measured at either of them. At the Powell mine, where the bed is 10 feet thick, extensive operations were in progress on bed C at the time of the examination. A quarter of a mile east of the Powell mine this bed is 9 feet thick and is 7 feet 1 inch thick at its thinnest exposure in Cedar Coulee, in sec. 34, about 800 feet east of the west line. A short distance farther up the coulee, at an old drift mine, the bed is 9 feet thick. An incomplete exposure at the old Miller mine showed 8 feet 4 inches of lignite, but it is reported that the bed is 12 feet thick at this place. At all of its exposures in this township bed C is a thick and continuous bed.

Generally bed D is about 85 feet stratigraphically above bed C, but the distance varies somewhat. Bed D consists of two benches separated by 2 to 10 feet of shale. In the south part of the township the parting ranges from 2 to 4 feet thick, and consists of gray shale, whereas to the north the shale parting is thinner and contains thin seams of lignite and carbonaceous shale. Representative sections of the bed are shown on Plate IX as Nos. 54, 61, and 62. The following section includes this bed near the bottom:

Section at location 63 in sec. 35, T. 154 N., R. 100 W.

	Ft. in.
Glacial drift.....	7
Shale, gray.....	5
Sandstone, soft, yellow.....	18
Lignite.....	4
Shale, gray.....	5
Lignite.....	1 2
Shale, brown, carbonaceous.....	3
Shale, gray, carbonaceous.....	12
Lignite.....	3
Shale, gray.....	25
Shale, brown, carbonaceous.....	5
Lignite.....	2 7

	Ft.	in.
Shale, brown, carbonaceous.....		3
Shale, gray.....	15	6
Lignite.....	1	2
Shale, brown, carbonaceous.....		2
Shale, gray.....	22	
Shale, brown, carbonaceous.....		4
Lignite.....	1	5
Shale, gray.....	1	1
Shale, brown, carbonaceous.....		1
Shale, gray.....	6	6
Shale, brown, carbonaceous.....	6	11
Lignite.....		11
Sandstone, soft, yellow.....		8
Shale, gray, with thin lignite beds.....	10	
Shale, brown, carbonaceous.....		1
Lignite.....	1	8
Shale, brown, carbonaceous.....		1
Shale, gray.....		5
Lignite.....	2	3
Shale, gray, carbonaceous.....		2
Lignite.....	2	6
Shale, brown, carbonaceous.....		5
Lignite.....	4	10
Shale, gray.....	17	
	181	9

The Lovejoy mine in sec. 11 is believed to be on the upper bench of bed D. At this mine the two benches are more widely separated than they are in the south part of the township and the lower bench is only partly exposed. All the following section below the top of the bed worked at the Lovejoy mine is believed to represent bed D. The parting shown in the section is typical for this part of the township.

Section at Lovejoy mine in sec. 11, T. 154 N., R. 100 W.

	Ft.	in.
Shale, gray.....		10
Lignite.....		
Shale, gray.....	27	
Lignite.....		3
Shale, brown, carbonaceous.....	2	6
Covered.....	10	
Shale, gray.....	14	
Shale, brown, carbonaceous.....		10
Shale, gray.....	3	4
Lignite (Lovejoy mine).....	6	7
Shale, gray.....	6	
Lignite.....	1	3
Shale, gray.....	3	4
Lignite.....	5	
Shale, carbonaceous.....		2
Lignite.....	2	1
	78	7

The Donnelly mine in sec. 12 is believed to be on the same bed as the Lovejoy mine. At that mine there is 5 feet of lignite separated near the middle by a 3-inch shale parting.

The outcrops of higher beds of lignite exposed at several places in this township are indicated on the map (Pl. X). These beds are between 2 and 3 feet thick, except one, which is slightly thinner.

The strata in this township dip very gently to the north, but locally the beds are included in minor undulations, which, however, are so slight that they will not materially affect mining.

Three large mines—the United States Reclamation Service, Bruegger, and Powell mines—were in operation in this township at the time of the examination. Samples were collected from these mines and their analyses with others from the same area are given on pages 12-13 of this report.

For more complete data the reader is referred to a forthcoming separate publication on this township.

T. 154 N., R. 101 W.

Although T. 154 N., R. 101 W., is generally covered by glacial drift and alluvium, several exposures of lignite were observed within its boundaries along Sand Creek. From these localities the inhabitants have obtained their fuel supply.

The lowest bed outcropping in the township was measured at location 64, where the following section is exposed in a prospect in the hillside:

Section at location 64 in sec. 16, T. 154 N., R. 101 W.

	Ft. in.
Glacial drift.	
Shale, gray.....	2
Lignite.....	3
Shale, gray.....	1
Shale, carbonaceous.....	9
Lignite.....	1
Shale, carbonaceous.....	2
Shale, gray.....	6
To level of Sand Creek.	20
	25
	11

A prospect at location 65 shows the following section:

Section at location 65 in sec. 16, T. 154 N., R. 100 W.

	Ft. in.
Glacial drift.....	10
Shale, brown.....	5
Lignite.....	1
Shale, gray.....	4
Lignite.....	4
Shale, gray.....	1
Shale, brown, carbonaceous.....	8
Lignite.....	11
Shale.	19

As there is a difference of 22 feet in the altitude of the 14-inch beds in the two sections, it is probable that the beds at location 65 are stratigraphically higher than those at location 64.

The next higher bed is exposed at several places. An inferred line of outcrop connecting the various exposures is given on the map (Pl. X). At location 66 in sec. 16, in an abandoned drift, a thickness of 1 foot 10 inches of lignite overlain by glacial drift indicates that the upper part of the bed has been removed by glacial action. At location 67, which is a somewhat better exposure, a timbered entry goes back about 40 feet from the outcrop. The bed has been opened at two prospects between locations 66 and 67, but these were so badly caved that sections could not be measured. Considerable lignite has been taken from a strip pit 75 feet wide by 200 feet long on this bed at location 68, where the bed is 4 feet 9 inches thick, overlain by 30 feet of glacial drift. Location 69, in the central part of sec. 8, is at an old mine which was so badly caved at the time of examination that little could be learned of its character or extent nor could a section of the lignite bed be obtained. The Eby mine, near the southwest corner of sec. 5, seems to have been operated for several years, but at the time of examination it was abandoned and was so badly caved that a complete section of the lignite bed could not be measured. Mr. Morgan reports that the lignite bed is 8 feet thick in this mine. The following section is exposed in the low bluff at the face of the mine:

Section at Eby mine near southwest corner of sec. 5, T. 154 N., R. 101 W.

	Ft. in.
Glacial drift.	.....
Sandstone, soft, grayish yellow, argillaceous.....	6
Shale, gray.....	4
Sandstone, soft, grayish yellow, argillaceous.....	12
Shale, gray.....	1 3
Lignite.....	6
Covered to Sand Creek.	<hr/> 29 3

The same bed has been worked at four strip pits in the eastern part of sec. 6 (locations 70 and 71, Pl. X). The dimensions in feet of the pits, in order from east to west, are 50 by 100 (location 70), 20 by 75, 20 by 40, 30 by 100 (location 71).

The next higher bed of lignite which is exposed in this township is about 50 feet stratigraphically above the bed last discussed. It has been worked at the Head mine in sec. 7, where an entry 200 feet long has been made. This mine was not in operation at the time of examination and was so badly caved at the mouth of the entry that a section of the lignite bed could not be measured. Mr. G. L. Head reports that the bed is uniformly 10 feet thick throughout the mine. There

is a track laid in the mine and a fairly good tipple at the mouth. About 300 feet east of the Head mine the same bed of lignite has been worked in a strip pit 25 by 150 feet, which seems to have been abandoned. The pit was so badly caved and filled with water that a section of the lignite bed could not be obtained. A strip pit at location 72 in the central part of sec. 7 was in similar condition. At location 73 in sec. 6 a prospect goes back about 10 feet from the outcrop, beneath a covering of 7 feet of glacial drift which lies in contact with the lignite bed. At location 74 the same bed has been opened by a small prospect near the top of a bluff, where the strata are partly exposed. The following section was measured at this place:

Section at location 74 in sec. 6, T. 154 N., R. 101 W.

	Ft. in.
Glacial drift to top of bluff.....	15
Shale, gray.....	3
Lignite.....	1
Shale, brown, hard.....	6
Lignite.....	4
Shale, brown.....	5
Lignite.....	4 10
Shale, brown.....	5
Lignite.....	1 3
Shale, brown.....	7
Shale, gray.....	1
Covered by vegetation.....	25
Shale, gray.....	5
Sandstone, soft, grayish yellow, argillaceous.....	9
Covered by vegetation to top of lower lignite bed (estimated)....	8
	74 5

Location 75 in sec. 6 is at an old abandoned mine that was so badly caved at the time of examination that little could be learned of the character or extent of the mine nor could a section of the lignite bed be measured. About 1,000 feet south of this old mine is a small strip pit which also was in such bad condition that a section could not be measured.

Springs flow from practically every lignite exposure in this township and the locations of the concealed beds are commonly indicated by seeps.

The strata dip gently southeast, as shown by the altitudes of the lignite beds at the various exposures.

The United States Reclamation Service reported the following logs of core drill holes in this township:

Logs of United States Reclamation Service drill holes in T. 154 N., R. 101 W.

Drill hole in SW. $\frac{1}{4}$ sec. 24.		Drill hole No. 6 in SE. $\frac{1}{4}$ sec. 31.	
	Ft. in.		Ft. in.
Gumbo.....	7 2	Sand.....	40
Clay.....	10 5	Drill hole No. 1 in SE. $\frac{1}{4}$ sec. 31.	
Sand.....	5 5		Ft. in.
Gravel.....	10 1	Loam, sandy.....	2
Sand.....	7	Sand and gravel.....	11
Gravel and sand.....	2 4	Sand.....	10 4
Gravel and sand.....	4	Lignite.....	2 8
Indications of lignite at bottom.	40	Clay.....	9
		Sulphur balls.....	1
Drill hole No. 3 A in SE. $\frac{1}{4}$ sec. 31.			36
	Ft. in.	Drill hole No. 2 in SE. $\frac{1}{4}$ sec. 31.	
Gravel.....	12		Ft. in.
Lignite.....	1	Clay, sandy.....	7
Clay, sandy.....	9	Sand.....	4
Hard rock.....	1	Clay and gravel.....	12
Sulphur balls.....	1	Clay and gravel.....	8
Sand, fine.....	20	Clay, white.....	4
Sandstone, soft.....	5 7	Sandstone, soft.....	10
Lignite.....	3	Clay.....	6
Sandstone, soft.....	10 2	Lignite.....	6
Sand, fine.....	5	Clay, sandy.....	9
Sulphur balls.....	2		55
Sandstone, soft.....	6	Drill hole No. 3 in SE. $\frac{1}{4}$ sec. 31.	
Clay, soft, blue.....	7		Ft. in.
Lignite.....	1	Clay.....	12
Clay, blue.....	19	Sand.....	28
Lignite.....	2	Clay.....	2
Slate.....	20	Sand.....	5
	122		47

The location of these drill holes is given only to the quarter section, but this is not exact enough for a reliable interpretation. For instance, the log of the hole in the SE. $\frac{1}{4}$ sec. 24 represents all alluvium or all glacial drift, depending on whether it was sunk in the river flat in the southeast part of the quarter section or above the flat on the bench on which the main part of the town of Williston is located. Holes Nos. 1 and 2 in the SE. $\frac{1}{4}$ sec. 31 were probably sunk northwest of the low bluff along the river, as was also hole No. 3A in the southwest quarter of the same section. Holes Nos. 3 and 6 seem to have been sunk in the river valley and probably include alluvium only. The logs show very little lignite, the thickest bed being 2 feet 8 inches thick 23 feet 4 inches below the surface in hole No. 1. Hole No. 3A shows a 2-foot bed 100 feet below the surface and three thinner beds at less depth. Exposures of lignite shown on the map and reports of lignite in wells in the vicinity indicate that this scarcity of lignite is only local.

T. 154 N., R. 102 W.

The surface of T. 154 N., R. 102 W., is covered generally by glacial drift, but there are a few small natural exposures of the underlying Fort Union rocks along Painted Woods Creek in the south part of the township. Lignite is shown at several places along this creek in both natural exposures and in openings made by inhabitants of the vicinity in securing their fuel supply.

The lowest bed outcropping in the township was measured at four places in secs. 27 and 34. A natural exposure at location 77 in sec. 27 shows 4 feet 4 inches of lignite about 6 feet above the level of the creek. As shown by the section on Plate IX, the lignite is overlain by glacial drift, but it seems probable that very little if any of the bed has been removed by glacial action, as the bed is much thinner at other exposures near by. At an exposure in the bluff below location 82 this bed is only 11 inches thick. A caved prospect on this bed near location 81 indicates that it is present at this place, but the lignite bed was entirely covered by caved material at the time of examination. At location 76 this bed is 2 feet thick but contains a high percentage of impurities. It is exposed about 40 feet stratigraphically below the higher bed in the strip pit at location 79, where a 14-inch parting of gray shale splits it into two thin benches, the upper 4 inches and the lower 8 inches thick. The lignite in both benches is impure. The single bed of lignite shown in the exposure between the beds mapped at this place has a thickness of only 4 inches. The lowest bed of lignite mapped in the township is very irregular in thickness as shown by the sections exposed in the township to the south. Except at location 77 this bed does not seem to be of economic value in this township, but a short distance to the south, as shown by secs. 149 and 150, it is good.

The next higher bed ranges between 20 and 40 feet stratigraphically above the one last discussed. It has been exposed at locations 78, 79, 80, 81, 82, 83, 84, 85, 86, and at the Geltz mine. Location 78 is a small strip pit that was so badly caved at the time of the field examination that a section could not be measured. Location 79 is at a strip pit measuring about 20 by 40 feet, which shows the following exposure:

Section at location 79 in sec. 34, T. 154 N., R. 102 W.

	Ft. in.
Shale, yellowish gray.....	30
Lignite.....	2
Shale, yellow.....	5
Lignite.....	4
Shale, gray.....	2
Lignite.....	2
Shale, gray.....	4
Lignite.....	2
Shale, gray.....	6
Lignite.....	3
Shale, gray.....	1
Lignite.....	9
Shale, brown.....	6
Total lignite.....	4 11

Location 80 is at a large pit which has been stripped on the hillside and a drift run on the lignite bed. At the time of the examination the pit and drift were so badly caved that a complete section could not be obtained, but it was seen that the lignite is at least 4 feet in thickness. A caved prospect at location 81 shows that the bed has been opened at that place, but the lignite was entirely covered by caved material at the time of examination. At location 82 a natural exposure shows 4 feet of lignite, but probably the top of the bed has been removed by glacial action, for the drift lies in contact with the bed and the top of the lignite where exposed is irregular. A prospect at location 83 was caved at the time of examination, but a farmer who lives near by reported that between 4 and 5 feet of good lignite is present at this place. A section measured at the mouth of a caved and abandoned drift at location 84 is shown on Plate IX. The drift was caved a few feet from the mouth, so its full length could not be determined, but evidently there has been no extensive mining at this place.

The Geltz mine, which consists of a drift 150 feet long, is the only mine in this township. The drift was opened in the fall of 1910 and has been worked since intermittently, mainly during the winter. Most of the mining in the last-opened drift has been done by H. L. Duncan, who pays royalty to Mr. Geltz, owner of the mine. The small output is sold to the inhabitants of the immediate vicinity at \$1.50 a ton. A sample for analysis was taken at the end of the drift and sent to the Pittsburgh laboratory of the Bureau of Mines. The analysis is given on page 12. At the place where the sample was taken the lignite is apparently unweathered, though it was probably slightly affected. The mine is dry and there is about 30 feet of cover over the bed where the sample was taken. The analysis indicates good lignite with a calorific value higher than that of most lignites. A collection of fossil leaves was made from the shale overlying the lignite near the mouth of the mine and a list of the species is given on page 7.

Mining has been done in strip pits and short drifts at locations 85 and 86 by Mr. Joyce, owner of the land. A section of the main bed at location 85 is shown on Plate IX and the section exposed at location 86 is as follows:

Section at location 86 in sec. 21, T. 154 N., R. 102 W.

	Ft.	in.
Shale, yellowish gray.....	30	
Sandstone, soft, grayish yellow.....	15	
Lignite.....	2	9
Shale, gray.....	5	
Lignite.....	3	
Shale, gray.....	6	
Lignite.....	2	6+
Water concealing bottom of the bed.		

A complete section could not be obtained, but Mr. Joyce reports that the bed at the bottom of the section at location 86 has the same thickness as that at location 85. The upper bed of lignite, however, is 2 feet 9 inches thick at location 86 and only 10 inches thick at location 85.

A lignite bed has been opened by a prospect at location 87, but this was so badly caved at the time of the examination that no section could be measured.

Location 88 is at a strip pit 20 feet wide by 200 feet long in which a bed of lignite 5 feet 7 inches thick is exposed. The strip pit has been operated for five or six years and is locally known as the McCoy or the Adams mine. Lignite has been selling at this mine for \$1.50 a ton. The outcrop of this bed could not be traced on either side of the exposure at the strip pit because of the covering of glacial drift. As indicated by the altitudes on the map (Pl. X), this bed is about 125 feet higher stratigraphically than the upper bed mapped along Painted Woods Creek to the east.

Considerable lignite has been taken from a strip pit at location 89, where the bed is only 2 feet 2 inches thick, as shown by the section on Plate IX. A farmer who said that he had mined at location 90 for three winters reports 5 feet of lignite in the bed at that place, but at the time of the field examination the pit was so badly caved that a section could not be measured.

A marsh area in the south part of the SW. $\frac{1}{4}$ sec. 6 and the north part of the NW. $\frac{1}{4}$ sec. 7 contains several big springs that seem to come from a lignite bed.

The United States Reclamation Service reports the following logs of three drill holes in this township:

Logs of United States Reclamation Service drill holes in T. 154 N., R. 102 W.

Drill hole in NW. $\frac{1}{4}$ sec. 36.	Ft. in.	Drill hole in NW. $\frac{1}{4}$ sec. 36.	Ft. in.
Clay and gravel.....	8	Cobblestones and clay.....	6 11
Clay, sandy.....	12	Clay, sandy, and coarse gravel...	3 7
Clay, soft.....	36	Sand, fine; traces of lignite.....	4 6
Lignite.....	1	Clay, gray, and coarse gravel....	1 5
Clay and sand.....	5	Gravel, coarse.....	7 11
Lignite.....	1	Gravel, coarse, and cobblestone..	3 1
Sandstone.....	5	Clay, white, and gravel.....	2
Clay, sandy.....	17	Gravel, coarse; traces of lignite...	4 10
Lignite.....	1 7	Clay, yellow, and fine sand.....	8 11
Sandstone, hard.....	2 5	Gravel, coarse.....	2 11
Gravel and sand.....	6	Clay, yellow, and fine sand.....	9 2
Clay, blue.....	7 7	Gravel, coarse.....	4 1
Lignite.....	1	Gravel, coarse, and yellow clay...	2 1
Soft mud.....	5	Gravel, coarse, and cobblestone..	2 5
Lignite.....	7	Clay, yellow, and fine sand.....	7 11
Clay, blue.....	5 5	Lignite.....	1
Lignite.....	10		
Clay, blue.....	8 2		70

Drill hole in NE. $\frac{1}{4}$ sec. 1.	Feet.	Drill hole in NE. $\frac{1}{4}$ sec. 1—Continued.	Feet.
Gravel and clay.....	18	Mud seam.....	1
Gravel and sand.....	8	Lignite.....	2
Clay, yellow.....	8	Clay, yellow.....	7
Lignite.....	1		45

These logs show very little lignite, the thickest bed being 2 feet thick 36 feet below the surface in the drill hole in the NE. $\frac{1}{4}$ sec. 1. If this hole had been continued to a slightly greater depth it probably would have gone through the upper thick bed mapped in sec. 6 of the township to the east, and if continued about 50 feet deeper the lower thick bed probably would have been found. The holes in sec. 36 were sunk to a greater depth but did not go through any beds sufficiently thick to be of value. Holes in the section to the east show a similar absence of lignite. Exposures of lignite shown on the map and reports of lignite in wells in the vicinity indicate that this absence of lignite is local. It is believed, however, that thick beds of lignite underlie this barren surface area at less depth than 500 feet.

T. 154 N., R. 103 W.

The glacial mantle over T. 154 N., R. 103 W., covers the Fort Union rocks so that the outcrop of the lignite beds is in general concealed. The only natural exposure of lignite observed is in the northwest corner of sec. 25. At that place there is 15 inches of slacked lignite. The bottom of the bed seems to be in place, but the top has probably been removed by glacial action. The inferred location in sec. 34 of the outcrop of a lignite bed that is exposed in the township to the south is indicated on the map. Lignite was reported in wells at several places in this township, but as these reports were confidential they are withheld from publication. The entire township is doubtless underlain by thick beds of lignite at a depth less than 500 feet.

T. 154 N., R. 104 W. (FRACTIONAL).

Although T. 154 N., R. 104 W., is generally covered by glacial drift, some exposures of lignite were observed as indicated on the map (Pl. X). The bed mapped most extensively in this township was measured at locations 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, and 102. The sections are either given on Plate IX or included in the following discussion. Throughout the greater part of the distance along the outcrop the bed is covered, but fragments of lignite brought up at several places by gophers and badgers helped materially in tracing the outcrop.

The Postal mine, location 91, is a drift which was started on a clinker bed. It was reported that plans were made for operating this mine on an extensive scale, but the lignite was so badly weathered

that the mine was abandoned after the drift had gone about 200 feet back from the outcrop. About 300 feet southeast of the Postal mine is another abandoned drift mine, which extends back about 75 feet from the outcrop. This mine was so badly caved that a complete section could not be measured, but at least 30 inches of lignite was exposed. It is probable that the thickness of the bed is about the same as at the Postal mine. The same bed has been opened by prospects at locations 92 and 93, and a third place about 250 feet southeast of 93, but very little lignite has been taken from these prospects. An exposure at location 94 shows 1 foot 8 inches of lignite overlain by glacial drift, but this evidently represents only a portion of the bed. Fragments of lignite brought up by gophers and badgers are conspicuous along the line of outcrop southward in secs. 2 and 3. The lignite bed is near the surface under the whole of this township, though it is not probable that there is any lignite of commercial value in the southern halves of secs. 2 and 3. As shown by the section on Plate IX this bed is 6 feet 10 inches thick at a strip pit at location 95 in Montana, slightly beyond the boundary of this township. At location 96, in sec. 12, the section exposed at the time of examination showed 2 feet 2 inches of lignite above a 3-inch shale parting and at least 4 inches of lignite below, but a complete section could not be obtained because water filled the pit. As shown by the section on Plate IX the parting does not appear in the bed at a natural exposure at location 97. At location 98 the portion of the bed exposed is overlain immediately by glacial drift. It is probable that about a foot of lignite has been removed from the top of the bed. At location 99 the bed is 5 feet 4 inches thick with a 3-inch parting near the top and at location 100 it is 4 feet 3 inches thick, but only a short distance south, at location 101, it measures 5 feet 6 inches thick. The Dakota mine at location 101 is a series of strip pits 10 to 30 feet wide extending about 1,000 feet along the outcrop. The same bed of lignite outcrops at a natural exposure at location 102 in Montana, slightly beyond the boundary of this township. A lignite bed about 80 feet lower than that at location 102 was measured at location 103, where lignite has been taken from four or five small pits. The section exposed at the strip pit is as follows:

Section at location 103, sec. 24, T. 28 N., R. 59 E., Montana.

	Ft. in.
Shale, gray and brown.....	7
Lignite.....	10
Shale, gray (containing fossil shells).....	4
Lignite.....	4
Shale, gray (containing fossil shells).....	3
Lignite.....	2
Shale, gray.....	4

This bed has been worked in each of the four or five strip pits. A list of the species of fossil shells collected at this locality is given on page 7.

Location 104 is at a natural exposure of a bed of lignite 1 foot 9 inches thick that is believed to be stratigraphically higher than the bed at location 103 and lower than that at location 102.

A lignite bed about 150 feet higher stratigraphically than that mined at the Dakota mine, location 101, is exposed in sec. 23 at locations 105 and 106. Sections measured at these places are shown on Plate IX. At location 107 there is 22 inches of lignite beneath 1 foot of soil. The slopes at and near the level of these exposures are so heavily covered by glacial drift and grass that the bed could be traced for only a short distance.

In sec. 34 some bare slopes show two thin beds of lignite. The lower bed is 22 inches thick at locations 109 and 110 and 25 inches at location 108; the upper bed is 19 inches thick at location 111 and 26 inches at location 112. The upper bed contains a 2-inch shale parting 8 inches above the bottom at both places measured. The bench above the parting is 16 inches thick at location 111 and 9 inches thick at location 112. The upper bed is near the top of the divide and probably underlies only a small area in secs. 34 and 35. These beds are 55 feet apart, the intervening strata being shale and soft sandstone. Exposures below the lower bed show about 20 feet of gray shale. Near location 112 there is a cover of 40 feet, mainly of soft yellow sandstone, above the upper bed. The rocks are not absolutely bare, but evidently there are no considerable beds of lignite in the 40 feet of strata immediately above the bed exposed at location 112.

A lignite bed, the inferred outcrop of which crosses the southwest part of sec. 34, is exposed just beyond the southern boundary of the township and doubtless underlies a considerable portion of the south part of this township comparatively near the surface. Where exposed in the south part of sec. 3, T. 153 N., R. 104 W., it is 4 feet 10 inches thick.

The various beds mapped throughout the northern part of the township dip gently a little south of east. The general eastward dip is interrupted by local undulations of minor importance. In the vicinity of locations 100 and 101 a pronounced local dip, approximately S. 25 E., is shown by the altitudes on the map.

T. 153 N., R. 100 W.

As shown by the map (Pl. X), only a part of T. 153 N., R. 100 W., was examined. The party making the examination was unexpectedly ordered to drop the work here and begin investigations elsewhere before the examination of the township was finished.

The Fort Union formation is extensively exposed in a high bluff in secs. 4, 9, and 16, and well exposed along Clark Coulee in secs. 2, 3, 10, 11, 14, and 15. The upland area is covered by a mantle of glacial drift and the river valley by alluvium. That part of the Fort Union which is exposed in the examined portion of this township contains many beds of lignite. The following section probably represents the average character of the exposed part of the Fort Union formation.

Section at location 119 in sec. 9, T. 153 N., R. 100 W.

	Ft.	In.
Glacial drift, thin.		
Shale, yellow, sandy.....	20	
Lignite.....	1	8
Shale.....	2	3
Lignite (119 D, Pl. IX).....	4	8
Shale, yellowish gray.....	16	6
Lignite, impure.....		4
Sandstone, soft, yellow, argillaceous.....	22	
Shale, carbonaceous.....	1	2
Shale, yellow, sandy.....	30	
Lignite (119 C, Pl. IX).....		8
Shale, yellowish gray.....	19	
Lignite (119 B, Pl. IX).....	2	9
Shale, yellowish gray.....	18	
Shale, carbonaceous.....		10
Lignite	1	10
Shale, yellowish gray.....	20	
Shale, carbonaceous.....		10
Shale, gray.....	7	6
Lignite (119 A, Pl. IX).....	2	4
Shale, yellow.....	15	6
Lignite.....	1	10
Shale, brown, containing iron concretions.....	10	
Shale, carbonaceous.....		2
Shale, yellow.....	16	6
Shale, carbonaceous.....		1
Lignite		2
Shale, gray.....	2	2
Lignite.....		10
Shale, yellow.....	20	6
Lignite.....		10
Shale, yellowish gray, sandy.....	26	
Shale, carbonaceous.....		2
Shale, brown.....	1	4
Lignite.....		2
Shale, brown.....	1	8
Lignite	1	1
Shale, carbonaceous.....		3
Sandstone, soft, gray, argillaceous.....	16	
Sandstone, hard, gray.....	2	6
Sandstone, soft, gray, argillaceous.....	1	
To level of water in Missouri River.		5

The strata below the 8-foot bed of lignite (119 C, Pl. IX) contain more beds of lignite in the township to the north than where this section was measured, whereas the same strata as exposed in sec. 16 of this township contain fewer beds than represented by the above section; hence it seems probable that this section represents the average condition of these strata in the township. A section extending somewhat higher stratigraphically, measured at location 115 in sec. 4, is as follows. Bed 115 C at the bottom of the following section is the same as bed 119 C in the section given above:

Section compiled from measurements at locations 113 and 115 in sec. 4, T. 153 N., R. 100 W.

	Ft. in.
Glacial boulders.	
Sandstone, soft, yellow.....	10
Lignite.....	2
Sandstone, soft, yellow.....	22
Lignite.....	1
Shale, carbonaceous.....	8
Lignite.....	2
Shale, carbonaceous.....	6
Shale, yellowish gray, arenaceous.....	8
Shale, carbonaceous.....	5
Sandstone, soft, yellow.....	12
Shale, brown, carbonaceous, fissile.....	3 6
Lignite.....	3
Shale, brown, carbonaceous.....	8
Lignite.....	2
Shale, brown, carbonaceous.....	6
Shale, gray.....	10
Lignite.....	10
Shale, gray.....	10
Lignite.....	1 10
Shale, grayish brown.....	1 6
Lignite.....	2
Shale, brown.....	2
Lignite (115 D, Pl. IX).....	4
Shale, gray.....	20
Lignite.....	6
Shale, gray, with several thin ledges of iron sandstone and many iron sandstone concretions.....	58
Lignite (113 C and 115 C, Pl. IX).....	8 2
Shale, gray.....	16
Lignite, impure.....	1 8
Shale, gray.....	19
Lignite, impure (113 B, Pl. IX).....	2 8
Shale, carbonaceous.....	6
Shale, gray.....	6
Total.....	217 4
Total good lignite.....	19 1

As shown by this section, which fairly represents the general character of the strata in the township, there are four beds of lignite more than 2 feet thick and also many thinner beds. Of the several beds only the two most important were mapped throughout the

examined portion of the township. Several sections of them are shown on Plate IX. The beds of greater thickness than 2 feet are treated in the following discussion.

The lowest bed more than 2 feet thick is exposed at location 119, where the only section of it was measured. As shown in the section given above, its thickness at that place is 2 feet 4 inches. The outcrop of the next higher bed (bed B) was mapped in secs. 4, 9, and 16, and sections of the bed were measured at locations 113, 119, 122, and 123. This bed is of considerable importance in the township to the north, but here it is generally thin and impure. As shown in the preceding section (113 B), this bed consists of 2 feet 8 inches of impure lignite at location 113. The exposure at location 119 shows the bed to be 2 feet 9 inches thick and almost free from impurities, but south of this place the percentage of impurities is much higher and the bed is thinner. At locations 122 and 123, where the bed is 20 and 14 inches thick, respectively, the lignite is very impure. As this bed is not of sufficient thickness in the southern examined portion of the township to be of economic value, the outcrop along Clark Coulee was not traced. Thin beds of lignite are distributed throughout the strata in this part of the township. Most of these beds are less than 15 inches thick, but one near the northeast corner of sec. 15 is 20 inches thick.

Bed C, which is the thickest and most uniform bed exposed in the area, was measured at locations 113, 115, 118, 119, 121, 124, 125, 126, 127, 128, 129, 132, 139, 140, and 141. Graphic sections representing the thickness of the bed at all of these places are shown in Plate IX. Location 140 is at a strip pit about 25 by 100 feet in size, from which lignite has been taken for local use. An incomplete exposure at this place shows 7 feet 7 inches of lignite, but the measurement could not be extended because of water in the pit. Lignite has been mined from this bed at location 118, where there is an old caved drift mine, which was reported to have been operated by Peter Visina. The sections measured at locations 128 and 129 do not represent the entire thickness of the bed, for at these exposures the lower part of the bed has been burned. The amount consumed is considerable, as shown by the bed of ashes 14 or 15 inches thick. At location 129 glacial drift is in contact with the lignite, but it seems probable that the ice sheet has removed little, if any, from the top of the bed. The bed has burned along the outcrop at several places in the township, but at no place does the burning seem to have extended far back from the outcrop. Lignite was burning in this bed near locations 129 and 132 at the time of examination.

Bed D, which ranges from 65 to 85 feet stratigraphically above bed C, is exposed extensively in this township and also in the township to the north. Complete sections of the bed were measured at locations 114, 115, 116, 117, 119, 120, 130, 133, 135, 136, 137, and 138, and are shown on Plate IX. Glacial drift overlies the lignite

at location 131, but it seems probable that very little, if any, of the bed has been removed. This bed is everywhere divided into two benches by a shale parting ranging in thickness from 11 inches to 3 feet 4 inches. As mentioned in the description of T. 154 N., R. 100 W., this parting is much thicker to the north. This bed is burned at a few places along its outcrop in the township, but not at so many places as bed C. The only place where it was observed to be burning at the time of examination is near the southeast corner of sec. 4. No mines or strip pits have been opened on this bed in the examined portion of the township.

The section which was measured at location 115 shows a 2-foot bed of lignite near the top. This is the only place in the township at which this bed is exposed. Nowhere else in the area do exposures continue high enough to show whether or not this bed is present. It underlies only a comparatively small portion of the township, as it is above the level of the greater part of the area.

The following logs of drill holes were reported by the United States Reclamation Service:

Logs of United States Reclamation Service drill holes in T. 153 N., R. 100 W.

Drill hole in north part of NW. $\frac{1}{4}$ sec. 4.		Drill hole in east part of NE. $\frac{1}{4}$ sec. 9.	
	Feet.		Ft. in.
Clay.....	50	Wash.....	15
Gravel and sand.....	4	Clay.....	19
Clay and sand.....	6	Lignite.....	3
Gravel.....	5	Clay.....	4
Clay.....	13	Lignite.....	1
Sandstone.....	7	Clay.....	14
Clay.....	5	Lignite.....	1
Sandstone.....	10	Sand and clay.....	12 8
	100	Sand and clay.....	15
Drill hole in west part of SE. $\frac{1}{4}$ sec. 4.		Sandstone and sandy shale.....	5
	Feet.	Clay, sandstone, and iron strips.	20
Gravel, sandy.....	10	Clay and sand.....	5
Sand (trace of lignite).....	16	Clay.....	5
Sand.....	12	Lignite.....	8 4
Sand, clay, and gravel.....	3	Clay with sulphur balls.....	6 8
Clay, sandy.....	7	Clay.....	13
	48	Shale, brown.....	1
		Lignite.....	1
		Clay.....	25
		Lignite.....	2
		Clay.....	8
		Chert and brown shale.....	5 4
		Clay.....	2
		Sandstone, soft.....	20
		Lignite.....	16
		Clay.....	2
		Lignite.....	3
		Clay.....	1
		Lignite.....	8
		Clay.....	17
		Lignite.....	6
		Sandstone, soft.....	35
			17 6

The altitude at the drill hole in the SE. $\frac{1}{4}$ sec. 4 is 1,840 feet, which shows that it is in the river valley. Altitudes are not given in connection with the other drill holes, but it is evident that the one in the NW. $\frac{1}{4}$ sec. 4 is in the valley and the one in sec. 9 is back of the river bluff. Neither of the drill holes in the valley shows any lignite. The greater part of each seems to have been drilled in alluvium. The log of the hole in sec. 9 shows several beds of lignite, but not so much as is exposed in the bluff at location 119, as shown by the preceding section, which was measured at that place. Bed C is recognized in this log 120 feet below the surface, and 34 feet below the surface is a 3-foot bed that bears the same stratigraphic relation to bed C as does bed D, but the section of bed D in the log is different from the sections of bed D shown on Plate IX. There is some possibility that all of the overlying material is glacial drift and that the top of the bed has been removed at this place by glacial action. It seems more probable, however, that the material indicated as "wash" includes all of the glacial covering and that the 19 feet of strata between this and the lignite bed represents shale in place.

The widely distributed sections of bed D shown on Plate IX and treated in the above discussion lead the writer to believe that this log does not represent a true section of the bed. As stated in the preceding discussion, the beds below bed C are irregular along the outcrop. The log probably represents their true character at the drill hole. The log, however, does not show nearly so much lignite as does the average section along the outcrop.

T. 153 N., R. 101 W.

Only that part of T. 153 N., R. 101 W., which lies west of Missouri River, was included in the field examination. As shown on the map, the greater part of the examined portion of the township is covered by alluvium and a portion of sec. 6 is covered by glacial drift. Fort Union rocks exposed in steep bluffs along the railroad in sec. 6 show gray shale and soft yellow sandstone with streaks of carbonaceous shale and a few thin beds of lignite, none more than 14 inches thick. The entire area is underlain by the lignite-bearing Fort Union formation, and it is probable that all of it is underlain at a less depth than 500 feet by lignite beds of considerable thickness, as the corresponding strata contain many beds of lignite where exposed throughout this general region.

The United States Reclamation Service reports the following logs of drill holes which were made in testing for a foundation for a pumping station near the railroad in sec. 6.

Logs of United States Reclamation Service drill holes in sec. 6, T. 153 N., R. 101 W.

Drill hole No. 1.		Drill hole No. 2.	
	Ft. in.		Ft. in.
Surface altitude, 1,875 feet.		Surface altitude, 1,865 feet.	
Loam, sandy.....	2	Clay, sandy.....	7
Gravel and sand.....	17	Sand.....	4
Sand.....	4 5	Gravel.....	12
Lignite.....	2 7	Clay, sand, and gravel.....	8
Clay, white.....	9	Clay, white.....	4
Sulphur ball	1	Sandstone, soft.....	10
	36	Clay.....	7
		Lignite.....	5
		Clay, sandy.....	9
			55

The log of drill hole No. 1 shows a bed of lignite 2 feet 7 inches thick, 23 feet below the surface. This bed has probably been eroded where hole No. 2 was bored, as the material in the log at the corresponding altitude is evidently transported.

T. 153 N., R. 102 W.

As shown on the map, much of the examined portion of T. 153 N., R. 102 W., is covered by alluvium, which is 54 feet thick in the river bluff in the northwest corner of sec. 20. Glacial drift is distributed over the northern part of the township, leaving the Fort Union formation exposed in small areas only. The entire township is underlain by this formation, which generally contains many beds of lignite, and hence it is probable that all of it is underlain at depths less than 500 feet by lignite beds of considerable thickness, as the corresponding strata contain such beds where exposed throughout this general region. This conclusion is drawn with some hesitation, however, because the Fort Union exposures in this township show relatively few beds of lignite as compared with the average character of the formation as exposed elsewhere in the field and in the general region. An exposure near the railroad in sec. 12 is believed to represent an uncommonly barren portion of the Fort Union formation. This section at that place is as follows:

Section exposed just north of railroad near west line of sec. 12, T. 153 N., R. 102 W.

Altitude, 2,012 feet.	
Glacial drift.	Ft. in.
Sandstone, soft, yellow, argillaceous.....	23
Shale, gray.....	2
Lignite.....	7
Sandstone, soft, yellow.....	18
Shale, gray.....	7
Lignite.....	4
Sandstone, soft, yellow.....	33
Lignite.....	3

	Ft.	in.
Shale, gray.....	12	
Lignite.....		2
Shale, gray.....	6	
Shale, yellow.....	5	
Lignite.....		2
Shale, gray.....	24	
Lignite.....		7
Shale, gray.....	6	
	138	1

The above section shows several thin beds of lignite but none of sufficient thickness to be of value. Besides the many thin beds that outcrop in this township two are generally above 25 inches thick. The outcrops of these beds and also some thinner ones that are stratigraphically below them are indicated on the map (Pl. X), and sections of the two thicker beds are shown on Plate IX. Correlation is indicated in some places where there are no exposures for a considerable distance, but the writer feels that sufficient evidence was observed in the field to justify it. The following section shows the stratigraphic relation of the two more important beds and also a lower bed in which the lignite is interstratified with so much shale as to render it valueless.

Section at location 171 in sec. 18, T. 158 N., R. 102 W.

	Ft.	in.
Shale, yellow.....	30	
Shale, brown, carbonaceous.....		6
Lignite.....	2	9
Shale, gray, brown, and yellow.....	60	
Shale, brown, carbonaceous.....		4
Lignite.....	2	2
Shale, gray and yellow.....	35	
Lignite.....		9
Shale, carbonaceous.....		11
Lignite.....		9
Shale, carbonaceous.....		4
Lignite.....		3
Shale, carbonaceous.....		1
Lignite.....		2
Shale, gray.....	6	
	140	

The lowest bed in the above section is exposed also at location 177, where it consists of two benches, 7 inches and $1\frac{1}{2}$ inches thick, that are separated by $1\frac{1}{2}$ inches of shale. At several places in sec. 9 a similar bed is exposed 17 to 20 feet stratigraphically below the bed that was mapped from the one location to the other. At location 154 this lower bed of lignite is 17 feet below the more

important bed and consists of an upper bench 4 inches thick and a lower bench 11 inches thick separated by 13 inches of shale. Near the prospect at location 153 this bed is represented by 9 inches of lignite in one bench. At location 147 a thin bed in about the same stratigraphic position has been opened by a small strip pit and the same bed is exposed a short distance southwest of this pit at location 146.

Section at locations 146 and 147 in sec. 10, T. 153 N., R. 100 W.

Location 146.		Location 147.	
	Ft. in.		Ft. in.
Shale.		Shale.	
Lignite.....	2	Lignite.....	2
Shale.....	10	Shale.....	1 7
Lignite.....	1	Lignite.....	11
Shale.		Shale.	
	2		2 8

The outcrops at location 142, in sec. 11, of two thin beds below the two more important beds in this township are indicated on the map. The following section includes these two beds and also a thinner one between them.

Section in central part of sec. 11, T. 153 N., R. 102 W.

	Ft. in.
Glacial drift.....	7
Sandstone, soft, yellow.....	8
Lignite (location 142).....	8
Sandstone, soft, yellow.....	30
Shale, gray.....	5
Lignite.....	2
Shale, gray.....	16
Lignite.....	1
Shale, gray.....	6
	73 10

The most continuous bed in the township was measured at locations 144, 145, 149, 150, 152, 153, 154, 155, 156, 157, 159, 160, 161, 162, 164, 165, 166, 167, 169, 170, 171, and 177. All these measurements are shown graphically in Plate IX, except 153, 154, and 174. At these locations the beds are 17 inches, 20 inches, and 17 inches, respectively. This bed was mapped in the township to the north, and also for a short distance in the township to the west. East of the mapped outcrop the surface at the altitude at which the bed would normally be exposed is gently rolling and covered by glacial drift. The section measured in sec. 12 and presented on page 51 includes strata at the same altitude, but it shows no lignite bed of corresponding thickness. This bed is either very thin in sec. 12 or else there is an upward fold in

the strata that carried the bed above the surface. More probably, however, the bed is thin and is represented in the section.

A bed 25 to 30 feet higher was measured at locations 143, 144, 145, 148, and 151. An exposure at location 158 probably represents the same bed. The bed at location 158 is separated from that in the strip pit at location 157 by 42 feet of gray shale. Between the bed exposed at location 163 and that exposed at location 162 a bare slope shows 70 feet of gray shale and soft sandstone, so it seems probable that sections 163 and 168 are on the same bed, although the stratigraphic distance between them and the next higher bed is somewhat different at the two locations. Probably the same bed is exposed at locations 171, 172, 173, 174, 175, 176, and 177 B. Graphic sections are shown in Plate IX for all these locations except 175, where the bed is 21 inches thick, and 177 B, where it consists of 17 inches of bone. The bed at location 171 B is 60 feet above 171 A, and 177 B is 50 feet above 177 A, with a continuous exposure of shale between the beds in each case. From these facts it seems probable that the sections measured at locations 143, 144, 145, 148, 151, 158, 163, 171, 172, 173, 174, 175, 176, and 177 B are all on the same bed. The bed is thinnest at location 173 (16 inches), and thickest at location 151 (more than 4 feet 2 inches).

Although the lignite beds are readily accessible to the railroad there has been no extensive mining in the township. This is due mainly to the fact that the lignite beds exposed are not of sufficient thickness to justify mining on a large scale under present conditions. Lignite has been taken from strip pits at several places indicated on the map, and from a small drift mine at location 161. In general the strip pits in this township are small, with one exception not exceeding 100 feet in length along the outcrop. The exception is at location 162, where lignite has been stripped from an area about 300 feet long and 20 to 50 feet wide. At location 161 in sec. 5 is a drift mine owned by Ed. Gorman, who was preparing to make another opening near by at the time of examination. He said that the drift went back 60 feet from the outcrop but that it was so badly caved that it would not be profitable to continue work. Section 161 in Plate IX represents the exposure at the mouth of the drift. Mr. Gorman reports that below the lignite shown in the section 3 inches of shale and then about a foot of impure lignite is found. He says that 5 feet of clean lignite is exposed in the back part of the mine. The lignite has been sold for \$1.75 a ton at the mine.

The United States Reclamation Service reported the following logs of drill holes in this township:

Logs of United States Reclamation Service drill holes in T. 153 N., R. 102 W.

Drill hole near quarter corner between secs. 1 and 2. ¹	Ft. in.	Drill hole near southwest corner of NE. $\frac{1}{4}$ sec. 18.	Ft. in.
Loam and pebbles.....	6	Muck and sand.....	10
Clay and sand.....	13	Sandstone.....	8
Clay, sand and pebbles, and coarse gravel.....	11 7	Lignite.....	5 4
Sand and bowlders.....	5 5	Clay.....	15 4
Clay, brown.....	6 7	Lignite.....	8
Clay, brown, and bowlders.....	7 5	Clay.....	20 8
Sand, gravel, and bowlders.....	7 7	Lignite.....	1 8
Clay, brown.....	1	Clay.....	5 10
Clay, blue.....	7 3	Lignite.....	6
Clay, hard, blue.....	6 2	Clay.....	4 4
Clay, dark brown.....	1	Bowlders.....	2 2
Lignite.....	1	Sandstone.....	2 6
Clay, gray.....	2 6	Clay.....	22 2
Lignite.....	3 6	Lignite.....	8
Clay.....	4	Sandstone.....	3 6
Lignite.....	1 1	Clay.....	5 8
Clay, brown.....	3	Lignite.....	8
Lignite.....	1	Sandstone.....	2 4
Clay.....	3	Bowlders.....	1 2
Lignite.....	1	Sandstone.....	10
Clay with lignite partings.....	11		
Clay, gray.....	19 1	Log of drill hole near west quarter corner of sec. 7.	
Clay, brown.....	1 11	Clay.....	16 3
Clay, dark.....	2 5	Lignite.....	2 10
Lignite.....	1 7	Clay.....	14 6
Clay, dark.....	7	Lignite.....	1 1
Clay.....	42 9	Clay.....	21 4
Lignite.....	5	Bowlders.....	2
Clay.....	2		58
Limestone bowlder.....	1 4		
Clay, gray.....	33 8		
Sandstone, traces of.....	5		
Clay, gray, sandy.....	42		
Clay.....	20		

253

The drill hole near the quarter corner between secs. 1 and 2 extends from the general level of the country to about the level of the river. It shows several thin beds of lignite and one at a depth of 75 feet that is of sufficient thickness to be valuable. This thick bed is probably the same as the higher of the two beds that are exposed along Painted Woods Creek. The lower of the two beds mapped along this creek probably thins out to the east and is either very thin or absent at this drill hole. The drill hole in the western part of sec. 7 shows a bed of lignite 16 feet below the surface and a thin bed below this one. The altitude of the surface at this hole is not given,

¹ Surface altitude, 2,089 feet. Traces of lignite at 110, 123, 132, 162, 166, and 220 feet.

but probably it is considerably higher than the beds exposed at location 171 and the drilling is not deep enough to reach these beds. The drill hole near the southwest corner of the NE. $\frac{1}{4}$ sec. 18 shows a thick bed of lignite 18 feet below the surface and also several thin beds below this one. This thick bed is probably the same as the upper bed mapped in sec. 18, and the lower bed in sec. 18 is probably represented in the log by a thin bed at a depth of 50 feet. These logs are believed to be fairly representative of the character of the strata underlying this township.

T. 153 N., R. 103 W.

The mantle of glacial drift has been eroded from considerable areas in T. 153 N., R. 103 W. Extensive exposures of the Fort Union formation are seen in secs. 26 to 33, inclusive, and typical badlands are present over a large part of the area included in these sections. Fort Union rocks are exposed in the face of a bluff in the northeast part of sec. 24 and the southeast part of sec. 13. Low bluffs along Eightmile Creek in secs. 2, 3, 10, 11, 14, 23, 25, and 26 show exposures of the Fort Union formation. Small areas of Fort Union rocks occur also on a west branch of Eightmile Creek in secs. 15 and 16 and on hillsides in sec. 22. Although the glacial mantle has been mostly removed from these areas, scattered remnants of it yet remain over most of them. As shown on the map, the southeast corner of the township is covered by alluvium.

Thin beds of lignite are distributed throughout the extensive Fort Union exposures in the township, but very few beds are sufficiently thick to be of any value. That part of the Fort Union formation exposed in the township contains far less lignite than the average section in this field or in the general region.

A section of a bare bluff on the east side of Eightmile Creek in the east-central part of sec. 36 shows four thin beds of lignite, only one of which is of sufficient thickness to be of economic value. The section exposed at this place is as follows:

Section at location 184 in sec. 26, T. 153 N., R. 103 W.

	Ft.	in.
Sandstone, soft, yellow.....	20	
Lignite.....		8
Shale, brown.....		6
Lignite.....		4
Shale, gray.....	15	
Lignite.....	1	6
Shale, gray.....	10	
Lignite.....	2	1
Shale, gray.....		7
Lignite.....		10
Shale, sandy, gray, and yellow.....	14	
Lignite.....	1	11
Shale, gray.....		4

The lowest of the beds in the above section is not exposed elsewhere, but the next higher bed is exposed at locations 181 and 182. It is the lower bed in the following section:

Section at location 182 in sec. 26, T. 153 N., R. 103 W.

	Ft. in.
Shale, gray.....	10
Lignite.....	1 7
Shale, gray and brown.....	12
Lignite.....	2 1
Shale, gray.....	9
Lignite, impure.....	11
Shale, gray.....	10
	<hr/>
	37 4

The parting in the lower bed in the above section is persistent in exposures at locations 182, 183, and 184. Lignite has been mined at location 181 from a drift which was caved at the time of examination, but a farmer who lives about a mile south of the mine reports that the drift extends about 100 feet back from the outcrop. From 10 to 15 feet above the bed on which the mine was operated is a bed that is included in the two sections given above and that was measured also at locations 183 and 185. This bed is 1 foot 7 inches thick at location 182, 1 foot 10 inches thick at location 183, and 1 foot at location 185. It is shown in the upper part of the following section:

Section at location 185 in sec. 23, T. 153 N., R. 103 W.

	Ft. in.
Shale, gray.....	10
Shale, carbonaceous.....	4
Lignite.....	1
Shale, carbonaceous.....	4
Lignite, impure.....	3
Shale, gray.....	20
Lignite, impure.....	1
Shale, gray.....	10
	<hr/>
	42 11

The upper bed in the above section is exposed also at location 184 and is shown near the top of the section which was measured at that place.

The following section of an exposure at location 186 shows two thin beds of lignite at approximately the same altitude as the highest of the beds at location 185:

Section at location 186 in south part of sec. 14, T. 153 N., R. 103 W.

	Ft.	in.
Shale, brown and gray.....	25	
Sandstone, soft, white.....	3	
Shale, gray.....	12	
Lignite, impure.....		4
Shale, gray.....	4	
Lignite.....		6
Shale, gray.....	2	
	46	10

The following section represents an exposure slightly higher than that at location 186:

Section at location 188 in eastern part of sec. 15, T. 153 N., R. 103 W.

	Ft.	in.
Scattered glacial drift.....		
Shale, brown and gray.....	15	
Lignite.....		11
Shale, gray.....	18	
Lignite.....		4
Shale, gray.....	5	
Lignite.....		2
Shale, brown and gray.....	20	
	59	5

A lignite bed is exposed at several places in secs. 15 and 16 and was measured at locations 189, 190, 191, 192, 193, and 194. Sections in Plate IX show the thickness of the beds at these exposures, except at locations 191 and 192, where the bed is 1 foot 6 inches thick. Considerable lignite has been taken from this bed at location 189, where there is a strip pit about 250 feet long and 15 to 20 feet wide. Natural exposures afford opportunity for measurement of sections at locations 191 and 192. The bed has been stripped almost continuously along the outcrop from locations 193 to 194. Frank Rogers reports that he operated a mine at this place during the winter of 1907 to secure lignite for neighboring farmers at \$2.75 a ton. He also states that the mine was opened previous to 1903.

Three beds of lignite were mapped along Eightmile Creek in secs. 2, 3, 10, and 11. The lowest of these beds at locations 197 and 198 is shown on Plate IX. The next higher bed, which is about 70 feet stratigraphically above this bed, was measured at natural exposures at locations 195, 196, 199, and 201, and at strip pits at locations 202 and 203. The character of this bed at locations 195, 196, and 202 is shown on Plate IX. At location 199 the bed contains only impure coal and at location 201 this bed is thin and is so broken by partings that it is of no value. It is shown near the bottom of the following section:

Section at location 201 in secs. 2 and 3, T. 153 N., R. 103 W.

	Ft. in.
Scattered glacial drift.	
Shale, gray.....	30
Shale, carbonaceous.....	8
Shale, gray.....	20
Bone.....	1
Shale, gray.....	1
Lignite.....	3
Shale, carbonaceous.....	9
Lignite.....	2 8
Shale, gray.....	13
Lignite.....	9
Shale, gray.....	26
Lignite.....	6
Lignite, impure.....	6½
Shale, carbonaceous.....	3
Lignite.....	3
Shale, brown.....	7
Lignite.....	1½
Shale and sand, gray and yellow.....	17
Lignite.....	7
Shale, brown.....	8
	116 7

The bed containing impure lignite and partings near the bottom of the above section is more promising in small strip pits at locations 202 and 203. At location 203 the same bed has been mined from a strip pit 15 feet wide by 30 feet long. These two pits are slightly less than 300 feet apart and are indicated on the map by one symbol. The bed at location 202 is 2 feet 8 inches thick and at location 203, 20 inches thick, but it is probable that the thinness at this exposure is local. This bed of lignite could be traced only a short distance south of locations 195 and 202 because of the covering of glacial drift. Probably continuous exposures would show that it is the same as the bed mapped in secs. 15 and 16. A bed 40 to 50 feet stratigraphically higher was measured at natural exposures at locations 200 and 201. The exposure at location 200 shows 2 feet 4 inches of lignite overlain by soil and wash from the hillside. Evidently the top of the bed has been eroded. A full section at this place would probably be similar to that at location 201. Within a short distance on either side of these exposures the strata at the altitude of this bed are covered by glacial drift. The exposures along Eightmile Creek in secs. 2, 3, 10, and 11 show other thin beds of lignite. Glacial drift covers the Fort Union rocks along the east side of Eightmile Creek in the north part of this township, so that the outcrop of the lignite beds could not be followed. A small exposure in the east-central part of sec. 14 shows the following section:

Section at location 187 in sec. 14, T. 153 N., R. 103 W.

	Ft. in.
Shale.....	6
Lignite.....	6
Shale.....	2 8
Lignite.....	6
Shale.....	3
Lignite.....	2
Shale.....	5
Lignite.....	8
Shale.....	2
Lignite.....	2
Shale.....	3
Lignite, impure.....	1 .6
Shale, carbonaceous.....	4
Shale, gray.....	1
	<hr/> 14 7

In the high bluffs in the eastern part of secs. 13 and 24 two beds of lignite mapped in the township to the west are exposed. Sections of the lower bed exposed at locations 178 and 179 are shown on Plate IX. Lignite has been taken from this bed at a strip pit about 8 feet wide by 30 feet long near location 178, but the pit was so badly caved at the time of examination that a section could not be measured. The upper bed, which is 50 feet stratigraphically higher, was measured at several places in the township to the east and at location 180 in sec. 24 of this township. The exposure at location 180 shows only 10 inches of weathered lignite, but the other sections indicate that this is not a representative section. The following section at location 178 shows two thin beds of lignite below the lower bed that was mapped:

Section at location 178 in sec. 24, T. 153 N., R. 103 W.

	Ft. in.
Shale, brown.....	10
Shale, carbonaceous.....	9
Shale, gray.....	5
Shale, carbonaceous.....	4
Lignite.....	2 6
Shale, brown.....	9
Lignite.....	8
Shale, brown.....	5
Shale, gray.....	6
Lignite.....	6
Shale, gray.....	7
	<hr/> 42 2

Lignite is exposed near the top of a high ridge in secs. 22, 26, 27, and 33. The two beds that were mapped most extensively in these exposures are at approximately the same altitude as the two beds mapped in the northeast part of sec. 24 and may be the same beds. A lower bed was observed at several places in these exposures, but in

general it is too thin to be mapped. At location 204, where lignite has been taken from a small strip pit, this bed is 2 feet 4 inches thick, but in general it is much thinner. At location 205, about a thousand feet southwest of this small strip pit, it is only 13 inches thick and at location 211 only 6 inches thick. It is exposed at several places between locations 205 and 211, but at all of these exposures it is less than 15 inches thick. It is the lowest lignite bed in each of the following sections:

Sections in secs. 26 and 35, T. 153 N., R. 103 W.

Location 211.		Location 212—Continued.	
	Ft. in.		Ft. in.
Scattered glacial drift.		Shale.....	54
Shale, gray.....	7	Lignite.....	8
Lignite.....	2 4	Shale.....	4
Shale, gray.....	10		67 2
Shale, carbonaceous.....	5		
Shale, brown.....	5		
Sandstone, soft, yellow	15		
Shale, brown.....	12		
Lignite.....	1 6		
Shale, gray.....	20		
Shale, brown.....	15		
Sandstone, soft, yellow	9		
Lignite.....	6		
Shale, gray.....	5		
	102 9		
Location 212.		Location 213.	
Shale.....	7	Scattered glacial drift.	
Lignite.....	1 6	Shale.....	25
		Shale, carbonaceous.....	9
		Lignite.....	2 3
		Shale.....	55
		Lignite.....	1 5
		Shale.....	32
		Lignite.....	1 3
		Shale.....	15
			132 8

The second lignite bed from the bottom in the sections given above is exposed at locations 205, 206, 207, 208, 209, and 210. At location 205 this bed is 20 inches thick and is 45 feet stratigraphically above the bed in the strip pit at location 204. At locations 206, 207, and 208 it is 15 inches, 18 inches, and 20 inches thick, respectively. Its thickness at locations 209 and 210 is shown by the following sections, in which it is the lower bed:

Sections at locations 209 and 210 in sec. 26, T. 153 N., R. 103 W.

Location 209.		Location 210.	
	Ft. in.		Ft. in.
Scattered glacial drift.		Scattered glacial drift.	
Shale, brown and gray.....	20	Shale, brown and gray.....	15
Lignite, impure.....	1 8	Lignite, impure.....	1 10
Shale, gray.....	35	Shale, brown.....	20
Shale, brown.....	10	Shale, gray.....	40
Shale, carbonaceous.....	6	Shale, brown.....	8
Shale, brown.....	14	Sandstone, soft, yellow	15
Shale, gray.....	5 6	Shale, gray.....	9
Lignite.....	1 10	Lignite.....	1 8
Shale, gray.....	7	Shale, brown.....	15
	95 9	Shale, carbonaceous.....	9
		Shale, gray.....	7
			133 3

The lower bed of lignite in the above sections had been opened at a prospect at location 213 previous to the examination. At location 209 there is a small strip pit about 10 feet wide by 20 feet long on this bed. At locations 209, 210, 211, and 213 a higher bed, as shown in the preceding sections, is exposed. It is also shown in the following section, which was measured at a natural exposure near the northwest corner of sec. 27:

Section at location 214 in sec. 27, T. 153 N., R. 103 W.

	Ft. in.
Scattered glacial drift.	
Shale, yellowish gray.....	20
Shale, carbonaceous.....	6
Lignite.....	1
Shale, carbonaceous.....	3
Lignite.....	7
Shale, gray.....	40
	<hr/>
	62 4

The measurements of the distance between the lignite bed in the above section and the next lower one range from 42 to 92 feet, the minimum being at location 211 and the maximum at location 210, less than a quarter of a mile away. This variation is greater than is common in the distance between lignite beds in the Williston field.

The outcrop of a thin bed of lignite on the south branch of Six-mile Creek in secs. 33 and 34 is indicated on the map (Pl. X). This bed at location 216 is 19 inches thick and at location 215 is divided into an upper bench 9 inches thick and a lower bench 6 inches thick, separated by 4 inches of shale. This bed has been stripped from an area of about 400 square feet at location 215, where the covering was in general less than 8 feet thick. Mr. Frank Rogers reported that he worked this pit during the winter of 1910-11.

A bed of lignite outcropping along Fiegley Coulee is 19 inches thick at location 233 in sec. 4, T. 152 N., R. 104 W. A bed 33 inches thick is exposed at location 218 in an old prospect about 75 feet west of a caved drift. Another prospect is located directly across the coulee, but no section could be measured at that place. The bed has been opened at two or three other places in the vicinity of this exposure, but none of the old openings afforded an opportunity for measurement. The drift mine was so badly caved at the time of examination that a section could not be measured, but people living in the vicinity report the lignite bed in this mine to be 4 to 5 feet thick. The following extract¹ probably refers to the pit at the front of this old drift or to one of the near-by strip pits.

Two miles from Buford, in sec. 31, T. 153 N., R. 103 W., a 4-foot bed of good lignite is mined to a limited extent by stripping. About 75 tons were taken out in the winter of 1902.

¹ Third Bienn. Rept. North Dakota Geol. Survey, 1904, p. 19.

Half a mile down the coulee from these workings the bed is of no value. The following section, which includes a thin bed of lignite below the one mapped, shows its character at location 217:

Section at location 217, in sec. 31, T. 155 N., R. 103 W.

	Ft. in.
Scattered glacial drift.	
Shale, brown and gray.....	70
Lignite, impure.....	4
Shale, carbonaceous.....	6
Lignite, impure.....	1 4
Shale, gray.....	15 6
Lignite.....	5
Shale, carbonaceous.....	1
Lignite.....	5
Shale, gray.....	88 7

Extensive exposures in secs. 30 and 31 show the strata above the bed last discussed to be very poor in lignite. The lower part of the exposures is represented by the following section, which was measured upward from this bed where it passes below the level of the coulee east of location 218.

Section in north-central part of sec. 31, T. 153 N., R. 103 W.

	Ft. in.
Scattered glacial drift.	
Sandstone, white.....	2 6
Sandstone, soft, yellow.....	3
Shale, gray.....	16
Lignite, containing silicified wood.....	1 2
Shale, carbonaceous.....	5
Shale, gray.....	10
Lignite.....	6
Sandstone, soft, and shale, yellow and gray.....	80
To stratigraphic position of bed exposed at location 218.	
	113 7

At location 219 there is a bed containing 2 feet of lignite divided in the middle by a parting of 2 inches of shale. A clinker bed capping a small butte at location 220 shows that there was originally a lignite bed at this level, but it has all burned out. The bed of lignite that caused the clinker on the butte probably does not underlie any of the surrounding country. A high, narrow ridge in the south part of secs. 27, 28, and 29 may reach an equal or slightly greater altitude than this bed, but the area of the bed under cover is very small and it is probably not of any value. Between the bed at location 218 and the clinker bed at location 220 there are several thin beds, but the only one that approaches sufficient thickness to be of value is that at location 219. The stratigraphic distance between location 218 and location 220 is about 420 feet. These are the most barren strata known in the Williston lignite field. This absence of lignite seems to be local, and probably extends over only a small area.

The following logs of drill holes were reported by the United States Reclamation Service:

Logs of United States Reclamation Service drill holes in T. 153 N., R. 103 W.

Drill hole No. 1, near center of NW. $\frac{1}{4}$ sec. 31. (Altitude, 2,095 feet.)			Drill hole No. 1, near center of NW. $\frac{1}{4}$ sec. 31—Con.		
	Ft.	in.		Ft.	in.
Sand, clayey.....	12		Clay, hard gray.....	2	
Clay ¹	30	7	Sandstone, soft.....	9	7
Lignite.....	10		Traces of lignite.....	2	
Clay, gray.....	2	7	Clay, brown.....	10	
Lignite, soft.....	2		Sandstone, very soft.....	12	5
Clay, blue.....	10		Lignite.....	11	
Lignite.....	10		Lignite, hard.....	6	
Clay, blue.....	4		Lignite, soft.....	1	
Lignite.....	1	10	Clay, light.....	12	6
Clay, gray.....	1	1	Lignite.....	1	
Lignite.....	4		Clay, gray.....	4	7
Clay, hard, blue.....	12	1	Lignite.....	5	
Lignite.....	1		Clay, brown, lignite partings.....	1	7
Clay, dark gray.....	2		Lignite.....	7	
Clay, tough, dark brown.....	5	5	Clay, gray.....	1	7
Lignite.....	5		Lignite.....	2	
Clay, blue.....	1		Clay, gray.....	1	
Clay, light colored.....	2		Lignite.....	8	
Traces of lignite.....	1		Clay, gray.....	7	4
Clay, light and blue colored.....	4	6	Lignite.....	8	
Lignite.....	3		Clay, brown, lignite partings.....	11	
Clay, blue.....	7		Clay, light gray.....	6	4
Lignite.....	1		Lignite.....	1	
Clay, soft, light.....	2		Clay, brown, and lignite partings.....	4	7
Clay, blue.....	1		Clay, gray, iron pyrites.....	5	5
Lignite.....	6		Clay, light gray.....	6	2
Fire clay.....	1	5	Clay, soft, gray.....	29	10.
Lignite, soft, brown; contains				240	
pyrite.....	3				
Lignite, good.....	1	8			
Clay, greenish.....	1	2	Drill hole No. 2, in NE. $\frac{1}{4}$ sec. 31.		
Lignite, soft, brown.....	1	5		Ft.	in.
Clay, light gray.....	6	8	Loam, sandy.....	1	7
Lignite.....	1		Clay, light.....	1	
Clay, blue.....	1	7	Lignite.....	1	
Lignite.....	5		Clay, blue.....	18	5
Lignite, brown.....	2		Lignite.....	1	
Clay, gray.....	2	3	Sandstone.....	9	7
Clay, blue.....	3		Clay.....	17	5
Lignite.....	2		Clay, blue.....	8	
Clay.....	2		Lignite.....	2	7
Traces of lignite and pyrites.....	2		Clay, blue.....	10	
Sandstone, very soft.....	5	4	Sandstone.....	2	5
Lignite, soft.....	1		Shale.....	2	7
Clay, light.....	6	11	Clay, blue.....	7	5
Traces of lignite.....	1		Sandstone.....	8	
Clay, gray.....	8		Clay, blue.....	10	
				101	

¹ Trace of lignite at 34 feet.

Drill hole No. 3, near NW. corner sec. 31. (Altitude, 2,178 feet.)			Drill hole No. 4, near SE. corner sec. 31—Contd.		
	Ft.	in.		Ft.	in.
Wash.....	5		Rock, very hard.....	2	
Quicksand.....	22		Clay, blue.....	16	11
Clay, sandy.....	48		Lignite.....	2	6
Sandstone.....	3	7	Clay, blue.....	6	6
Lignite.....	3	8			
Clay, blue.....	15	6			
	97	9			
Drill hole No. 4, near SE. corner sec. 31. (Altitude, 2,170 feet.)			Drill hole No. 5, in SW. ¼ sec. 30.		
	Ft.	in.		Ft.	in.
Muck.....	6		Clay.....	17	
Lignite.....		11	Clay and sandstone.....	11	
Sandstone.....	3		Sand, fine.....	6	
Clay, blue.....	7	9	Sand and clay.....	3	
Lignite.....		5	Lignite.....	1	
Clay, blue.....	29	7	Clay, blue.....	33	
Lignite.....		4	Sulphur balls.....		10
Clay, blue.....	4	7	Clay.....	1	2
Rock, very hard.....	1	7	Sandstone, soft.....	18	
Clay, blue.....	1	7	Sulphur balls.....	2	7
Sandstone.....	2	2	Clay, sandy.....	5	5
			Lignite.....	4	
			Clay and sand.....	1	7
				104	7

As shown by these logs, several thin beds of lignite underlie the southwest part of the township but none are of any great thickness. Several beds, however, are above the minimum for land classification—25 inches. Drill hole No. 1 is near the exposure of lignite at location 218 and surely includes that bed, as the surface altitude is considerably higher than the bed and the hole extends nearly to the level of Missouri River. The bed exposed at location 218 is probably the same as the one noted in the log at 47 feet below the surface. This bed can not be correlated with any in the other logs to any degree of certainty as the beds are known to be irregular in thickness and to vary in altitude.

T. 153 N., R. 104 W. (FRACTIONAL).

Nearly the whole surface of fractional T. 153 N., R. 104 W., is covered by a mantle of glacial drift, but Fort Union rocks outcrop at natural exposures in secs. 25, 26, 27, 34, 35, and 36. The exposures at locations 221 and 222 in sec. 3 show slightly more than the lignite bed. Exposures in the south part of the township, and in the townships adjoining on the south and east, indicate that the Fort Union formation carries fewer beds of lignite here than it does in general throughout the Williston field. The map (Pl. X) shows the outcrop of all lignite beds of thickness greater than 18 inches that were found in this township.

The section of a lignite bed which outcrops at locations 221 and 222 in sec. 3 is shown in Plate IX. Water from a spring at location 221 prevented the determination of the thickness of the bed at that place. Except at locations 221 and 222 this bed in secs. 2 and 3 is covered by glacial drift, hence its location was inferred from the topography.

A lignite bed outcropping in the south part of the township is exposed at locations 223, 224, 225, 226, 227, 228, 229, 230, 231, and 232. Sections measured at the various points are shown in Plate IX, except 223 and 224. At location 223 the bed is 10 inches thick; at location 224, 11 inches thick; at location 225, 13 inches thick; and at location 229, 21 inches thick. Throughout these exposures it is only a thin bed, and is thinner at the easternmost exposure than at the westernmost. In the adjoining field to the west a bed with a thick outcrop several miles long was correlated by Beekly¹ with the bed mapped in secs. 2 and 3, and measured at locations 221 and 222.

A bed 30 feet lower stratigraphically than that at location 221 is exposed at several places between that location and Garden Coulee. Its maximum observed thickness is near the line between secs. 34 and 35, where it is 17 inches thick. At other exposures along this branch of Garden Coulee it is 5 to 10 inches thick. This bed was observed also at several places in secs. 26 and 35, and is everywhere less than a foot thick.

The only place at which lignite has been mined in this township is at location 231, where there is a strip pit about 18 feet wide by 50 feet long.

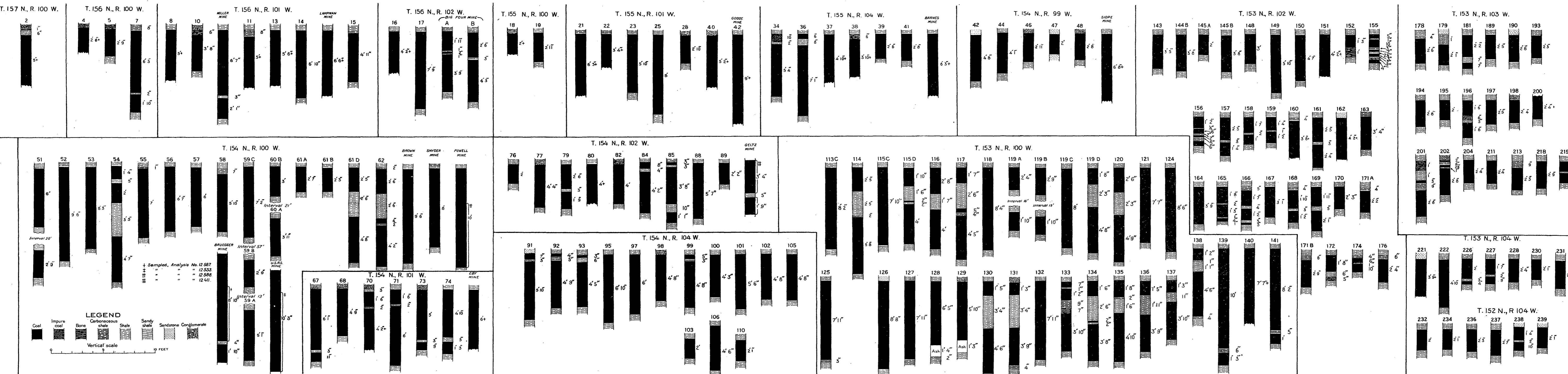
T. 152 N., R. 102 W.

Only that small portion of T. 152 N., R. 102 W., which lies west of Missouri River was included in the examination. This area is in the valley of Missouri River, and is covered by alluvium. Although no lignite beds are exposed in this area it is probable that the whole of it is underlain at a depth less than 500 feet by lignite beds of considerable thickness. That part of the Fort Union formation underlying this area carries a number of beds of lignite throughout its exposures in eastern Montana. Thick beds of lignite which probably underlie this township were mapped in the Culbertson lignite field that joins the Williston field on the west and are discussed in the report on that field noted above.

T. 152 N., R. 103 W.

Only that part of T. 152 N., R. 103 W., which lies north of Missouri River was examined. As shown on the map (Pl. X), alluvium

¹ Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: Bull. U. S. Geol. Survey No. 471, 1912, pp. 319-358.



SECTIONS OF LIGNITE BEDS IN THE WILLISTON LIGNITE FIELD, WILLIAMS COUNTY, NORTH DAKOTA.

THE NORRIS PETERS CO., WASHINGTON, D. C.

covers all the area except a few acres in sec. 6; where Fort Union rocks are exposed, but even there glacial drift is present, and entirely covers a considerable part of the surface. Beneath the covering of alluvium and glacial drift is the Fort Union formation, which generally contains a number of beds of lignite.

T. 152 N., R. 104 W.

Although no beds are exposed in T. 152 N., R. 104 W., it is believed that the township is underlain by lignite beds of commercial value at depths less than 500 feet. The character of that part of the Fort Union exposed in this township is shown by the following sections:

Sections exposed in T. 152 N., R. 104 W.

Location 233 in sec. 4.			Location 235 in sec. 5.		
	Ft.	in.		Ft.	in.
Sandstone, soft, yellow.....	5		Shale, gray.....	24	
Shale, yellow and gray.....	30		Lignite.....	1	11
Lignite.....	10		Shale, yellow and gray.....	55	
Shale, yellow and gray.....	15		Lignite.....	8	
Lignite.....	4		Shale, gray.....	15	
Shale, yellow.....	25		Lignite.....	6	
Shale, gray.....	2		Shale, gray.....	4	
Lignite.....	1	7			
Shale, gray.....	20			101	1
	99	9	Near northeast corner sec. 2.		
Location 237 in sec. 6.				Ft.	in.
	Ft.	in.	Shale, brown.....	8	
Glacial drift.....	7		Sandstone, soft, yellow.....	2	
Shale, gray.....	5		Sandstone, hard, yellow.....	3	
Shale, brown.....	13		Shale, brown.....	13	
Shale, gray.....	11		Shale, carbonaceous.....	3	
Shale, brown.....	6		Shale, gray and brown.....	14	
Lignite.....	2	7	Lignite.....	8	
Shale, gray.....	15		Shale, brown.....	11	
Lignite.....	1		Lignite.....	10	
Shale, gray.....	6		Shale, brown.....	4	
	65	8	Shale, carbonaceous.....	11	
			Shale, gray.....	45	
				102	8

A bed of lignite outcropping along Fiegley Coulee was mapped in sec. 4 of this township and also in sec. 31, T. 153 W., R. 103 W. As shown in the above section it is 1 foot 7 inches thick at location 235 and somewhat thicker to the north, but the only exposure that shows the bed more than 2 feet thick is at location 238, where it is 2 feet 8 inches thick.

A bed of lignite outcrops in secs. 5 and 6, sections of which, measured at locations 234, 235, 236, 237, 238, and 239, are shown on

Plate IX. This bed of lignite was mapped in the township to the north and also in the Culbertson lignite field on the west. It is a good bed for several miles along the outcrop in the Culbertson field, but in the township to the north it thins toward the east and in less than 2 miles east of the State line it is too thin to be of value. The only place at which lignite has been mined in the examined portion of this township is at location 239, where an abandoned drift is reported as extending 300 feet back from the outcrop.

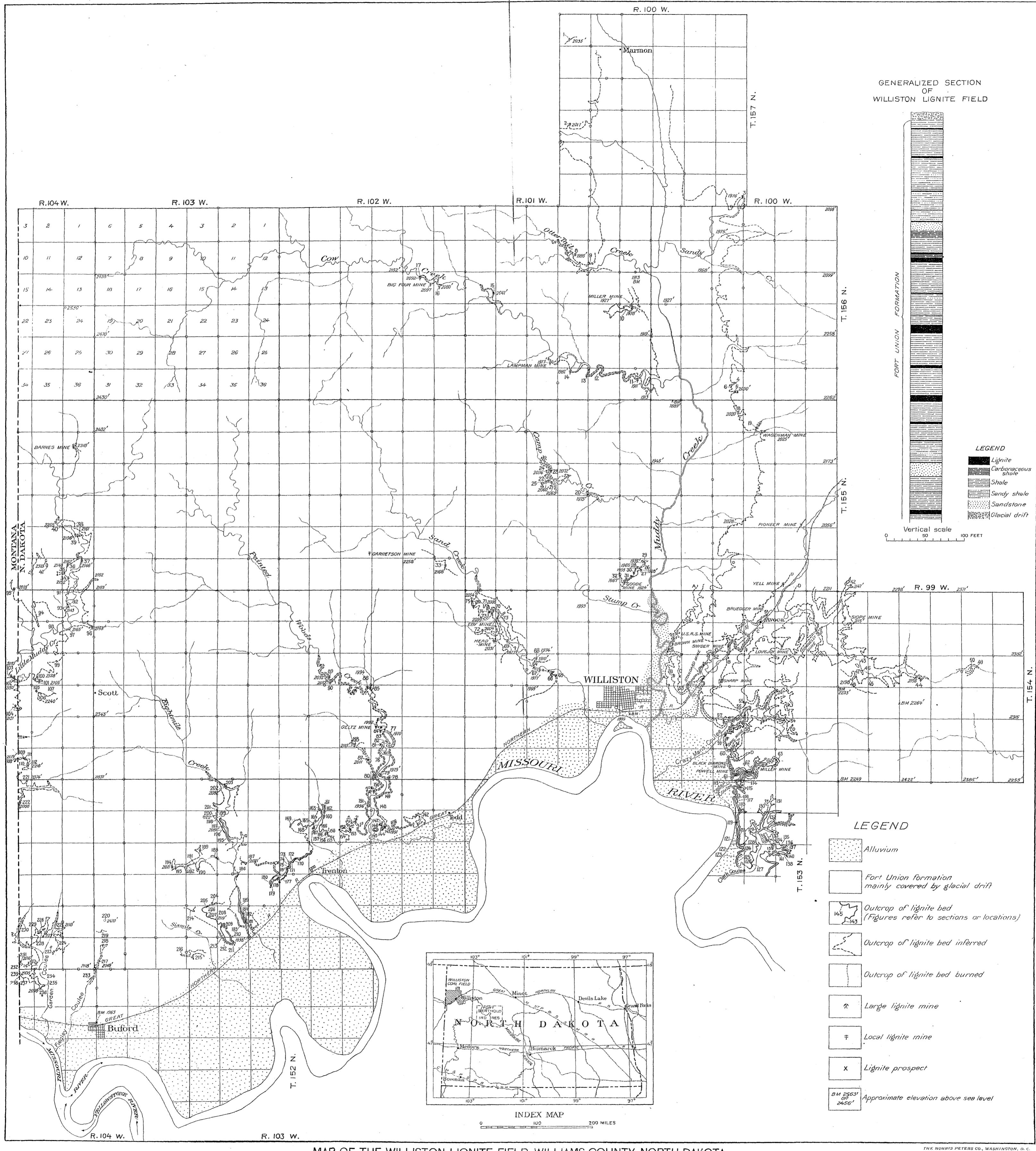
In the Culbertson field, referred to above, two thick beds of lignite were traced by Mr. Beekly for several miles and were thick at all points examined. The upper bed is estimated by him to be about 125 feet below the level of Missouri River at the Montana-North Dakota State line, and the other is about 70 feet lower. As the strata in this township are nearly horizontal, it is probable that both of these beds underlie the township at a depth less than 500 feet. The data collected in the Culbertson field indicate that about 1,000 feet of lignite-bearing Fort Union strata underlie Missouri River and the Montana-North Dakota State line.

That Missouri River has not eroded far below its present channel is indicated by the following drill-hole logs, which were furnished by the United States Reclamation Service. These borings were made in testing for a foundation for a pumping site. The holes are all shallow and show very little lignite, but they are of value in proving that Fort Union strata occur in place at shallow depths under the alluvium-covered valley.

List of United States Reclamation Service test borings for pumping-site foundation in secs. 8, 16, and 17, T. 152 N., R. 104 W.

No. of hole.	Location. ^a	Total depth.	Surface altitude.	
			Feet.	Feet.
1	500 feet north and 300 feet west of A.....	33		1,902
2	450 feet west of A.....	33		1,886
3	About 700 feet south and about 500 feet west of A.....	27		1,873
4	About 900 feet south and about 1,200 feet west of A.....	46		1,875
5	550 feet west of A.....	77		1,908
6	400 feet north and 30 feet west of A.....	76		1,907
7	700 feet west of A.....	51		1,886
8	40 feet west of A.....	53		1,886
9	Center of NW. $\frac{1}{4}$ SE. $\frac{1}{4}$ sec. 16.....	40		.....

^a Location of point A is center of south line of SE. $\frac{1}{4}$ sec. 8.



MAP OF THE WILLISTON LIGNITE FIELD, WILLIAMS COUNTY, NORTH DAKOTA
BY FRANK A. HERALD

THE NORRIS PETERS CO., WASHINGTON, D. C.

Logs of United States Reclamation Service test borings for pumping-site foundation in secs. 8, 16, and 17, T. 152 N., R. 104 W.

Hole No. 1.	Ft. in.	Hole No. 6.	Feet.
Gumbo.....	9	Gumbo.....	19
Sand and pebbles.....	4	Gravel.....	22
Sand.....	5 2	Quicksand.....	16
Sand, fine.....	15 3	Sandstone, soft.....	10
	33 2		
Hole No. 2.	Feet.	Hole No. 7.	Feet. in.
Gumbo.....	9	Sand.....	1 7
Sand.....	23	Gumbo.....	7 5
Sand and pebbles.....	1	Gumbo and sand.....	5
	33	Quicksand.....	16
Hole No. 3.	Feet.	Sand.....	4
Gumbo, sandy.....	1	Clay and sand.....	15
Gumbo.....	7	Lignite.....	11
Sand.....	10	Sand, coarse.....	1 1
Quicksand.....	9		51
	27	Hole No. 8.	Feet. in.
Hole No. 4.	Ft. in.	Gumbo.....	9
Sand.....	5	Sand, fine.....	11
Gumbo.....	14	Quicksand.....	7 7
Sand, fine.....	6	Sand, coarse.....	2 5
Clay.....	1	Lignite.....	1
Sand.....	20 7	Pebbles.....	1
	46 7	Boulder.....	1 7
Hole No. 5.	Feet.	Sand, coarse.....	11
Sand.....	4	Quicksand.....	8 5
Gumbo.....	8		53
Sand.....	3	Hole No. 9.	Feet. in.
Clay.....	5	Sand.....	31
Gravel.....	23	Boulders.....	4 6
Clay.....	23	Lignite.....	1
Sandstone, soft.....	11	Sand.....	3 6
	77		40