LIGNITE IN THE WESTERN PART OF THE FORT BERTHOLD INDIAN RESERVATION SOUTH OF MISSOURI RIVER, NORTH DAKOTA.

By CLYDE MAX. BAUER and FRANK A. HERALD.

INTRODUCTION.

Importance of lignite.—Inasmuch as wood for fuel is practically lacking in the northern Great Plains the lignite of this region is of particular importance in the development of its commerce and industry. The value of lignite in North Dakota is illustrated by its application to the development of agriculture. The early settler and rancher have depended on it either in whole or in part for fuel and power, and the settlement of many districts which are practically destitute of wood has been expedited greatly by its presence. One of these districts which is soon to be opened for settlement is the Fort Berthold Indian Reservation.

Location of field and scope of report.—The Fort Berthold Indian Reservation is in the west-central part of North Dakota, on both sides of Missouri River, about 65 miles northwest of Bismarck, or about halfway between that city and the place where the Missouri enters the State. (See fig. 13.) The reservation lies in the great lignite region of the northern Great Plains and is underlain by many beds of lignite which have been uncovered and measured at a large number of places. The total area of the reservation is about 1,500 square miles, of which approximately 650 square miles in McKenzie, Dunn, and Mercer counties lies south and west of Missouri River and is the subject of this report.

In the following pages the geography and general geology of this part of the reservation are described very briefly, and the lignite beds in detail. The remainder of the reservation has been examined by C. D. Smith,[1] who in 1908 made a reconnaissance of the area adjacent to Missouri River, and by M. A. Pishel,[2] who in 1910 examined that part of the reservation which lies north and east of the river.

Field work and acknowledgments.—The field work on which the present report is based extended over three seasons. In September

[1] Smith, C. D., The Fort Berthold Indian Reservation lignite field, N. Dak.: U. S. Geol. Survey Bull. 381, pp. 30–39, 1908.

[2] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, N. Dak., north of Missouri River: U. S. Geol. Survey Bull. 471, pp. 170–186, 1912.

and October, 1911, a party in charge of F. A. Herald examined the part of the reservation west of Missouri River and north of the south line of T. 149 N. The work was continued during September and October, 1912, by C. M. Bauer, assisted by A. E. Fath and O. H. Pierce. In this year the examination of the part west of Missouri River and north of Little Missouri River was completed. In June and July, 1913, C. M. Bauer, assisted by C. A. Bonine and E. M. Parks, examined that part of the reservation lying south of Little Missouri and Missouri rivers. Acknowledgments are due to M. R. Campbell, for valuable suggestions in preparing the report; to E. G. Woodruff, who had general field supervision in 1911–12;

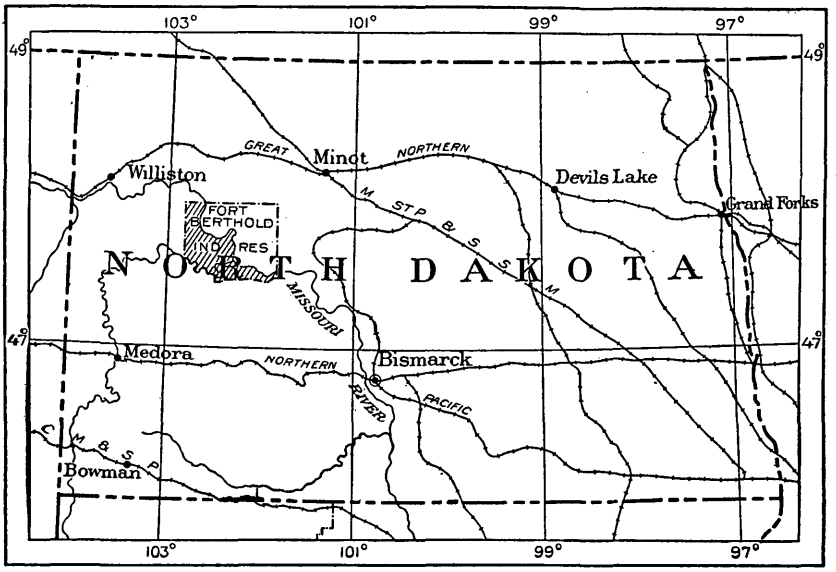


FIGURE 13.—Index map showing location of Fort Berthold Indian Reservation, N. Dak. The area described in this report is indicated by shading.

and to T. W. Stanton and F. H. Knowlton, for the determination of fossil shells and plants collected.

Method of field work.—The examination of the Fort Berthold Reservation was undertaken primarily to obtain data for classifying the land on the basis of its lignite content. All outcrops of lignite beds, especially the places at which measurements of thicknesses were made, were carefully located and mapped on a scale of 2 inches to 1 mile. A telescopic alidade and 15-inch plane table were used, and stadia traverse was employed to make accurate locations. The altitudes of the points located were determined by vertical angles. As the land is classified according to legal subdivisions, all locations were made with respect to land corners. The lignite beds were uncovered in many places by pick and shovel,

and in some places an ordinary wood auger, capable of boring to the depth of 10 feet, was used to prospect for or to determine the thickness of a bed outcropping in a level grass-covered area. Many geologic data were collected incidentally to the examination of lignite beds and are applicable either directly or indirectly to the classification of the land.

Land surveys.—The General Land Office surveys were used as a base upon which to place the economic and geologic data. All the townships west of R. 91 W. were surveyed in 1910, 1911, and 1912. The land corners in these townships are marked by iron pipes with brass tops stamped with the township and section numbers, and in most of the plats the surface features are represented by contour lines with a 50-foot interval. The area from R. 91 W. to the southeast corner of the reservation was surveyed in 1892, and the land corners, being marked by stones, were not readily discovered, although all the corners searched for on the coal outcrops were found.

GEOGRAPHY.

Land forms.—In a broad sense the upland between the streams, as shown in Plate XXII, *B*, is a dissected plain with an average altitude of about 2,100 feet above sea level. On the north and east sides of that part of the Fort Berthold Reservation here described the broad valley of Missouri River, shown in Plate XV, *A*, is eroded to a depth of about 400 feet; on the south the sinuous course of Little Missouri River is intrenched to about the same depth. From the upland the valley of the Little Missouri appears gorgelike, the walls rising precipitously to a height of 300 or 400 feet on either side, but in places they are broken by tributary gullies and valleys, as shown in Plate XIII, *A*. Along the large streams are flood plains ranging in width from a few rods to 1 or 2 miles and commonly separated from the upland by a zone of "breaks," or rough badland country. Surmounting the upland itself are irregular ridges and isolated buttes which rise 300 to 400 feet above the general level.

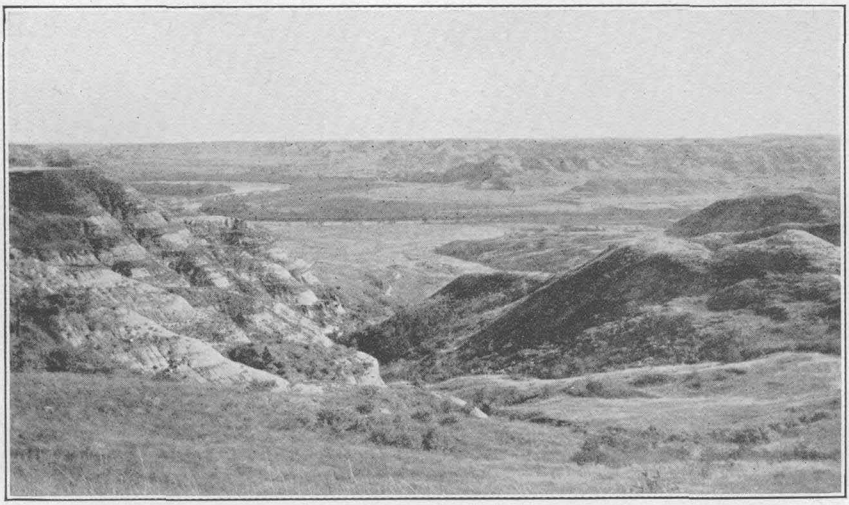
In the northern part of the region (see map, Pl. XXVII, in pocket) the surface is rolling and shows locally the effect of glaciation (see Pl. XIX, *A*). Farther south, on Clark Creek, in T. 151 N., R. 94 W., the rolling plain is broken into badlands, and similar features occur in the valleys of Bear Den and Skunk creeks, which lie still farther to the south, as well as of Moccasin Creek and Little Missouri River (see map). High buttes in T. 151 N., R. 94 W., known as the East Buttes, rise 750 feet above Missouri River. In T. 148 N., Rs. 92 and 93 W., there are other conspicuous ridges and bare buttes, of which Saddle Butte is a striking example. (See Pl. XXVIII.) To the west the plain reaches a greater altitude and the

buttes do not appear to be so high, though their average height above sea level is greater. North of the horse camp, in secs. 9 and 10, T. 148 N., R. 94 W., there is a high grass-covered hill from which a commanding view of most of the western part of the reservation can be obtained, and a little north of this is Eagle's Nest, a comparatively round, bare butte which is a well-known landmark. In the southern part of this township are other prominent buttes which can be seen for many miles. Along Little Missouri River as far east as the mouth of Squaw Creek there are very rough badlands. This badland zone averages about 3 miles in width, but up Moccasin Creek its width is about 6 miles. In the south-central part of T. 147 N., R. 93 W., the maximum relief is more than 600 feet and many of the gullies have nearly vertical sides. (See Pl. XIV, *B*)

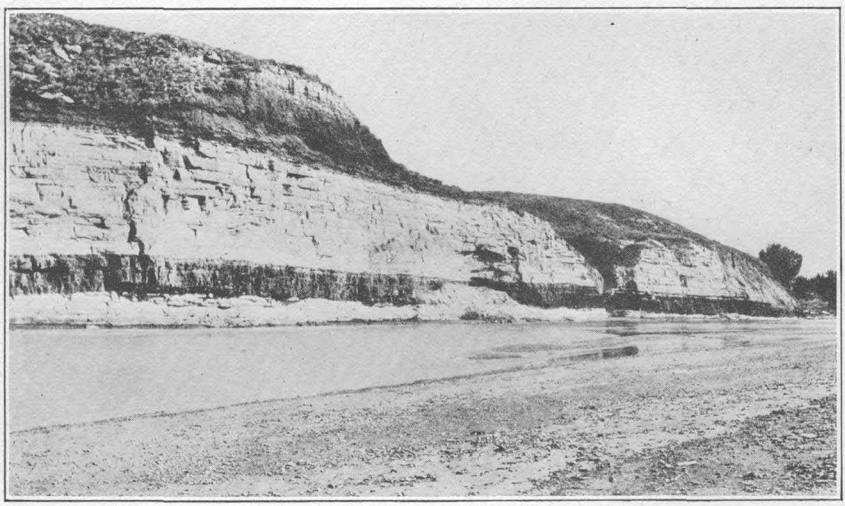
Southeast of Little Missouri River (see map, Pl. XXIX, in pocket) the land rises rather steeply out of badlands to a high rolling plain. This plain contains some excellent grazing and farming land, but in the neighborhood of both Missouri and Little Missouri rivers the land is very much broken by gullies, and badlands are common. Near Crow's Heart Landing, in sec. 1., T. 147 N., R. 91 W., the bluffs are about 400 feet high and break very sharply to the river. In the extreme southeastern part of the reservation the upland is lower, and where the Missouri swings to the north side of its valley the land slopes gently to the river flood plain. A terrace 30 to 40 feet high overlooks the flood plain in the eastern part of T. 147 N., R. 89 W. On Beaver Creek in T. 146 N., R. 88 W., the land is covered with grass and the slopes are gentle.

Drainage.—The southern part of the reservation is drained by Missouri River, in part directly through the main stream and in part through Little Missouri River and numerous smaller tributaries. Missouri River has a sandy channel from a quarter of a mile to a mile in width, the position of which is constantly shifting, giving rise to a wide, barren flat of cross-bedded sand and gravel. The amount of water in the stream is variable, and the channel contains many deeps and shallows which render it dangerous for ferry boats and other craft. The water is always muddy and at times is heavily laden with silt and débris derived largely from the bare, steep slopes of the badlands of the drainage basin. Borings made in the channel of the river 3 miles west of Elbowoods by the Great Northern Railway Co. show the presence of quicksand and river mud to a depth of 60 feet. The alluvium is probably not generally so thick and is commonly spread over a tract roughly coinciding with the river flood plain.

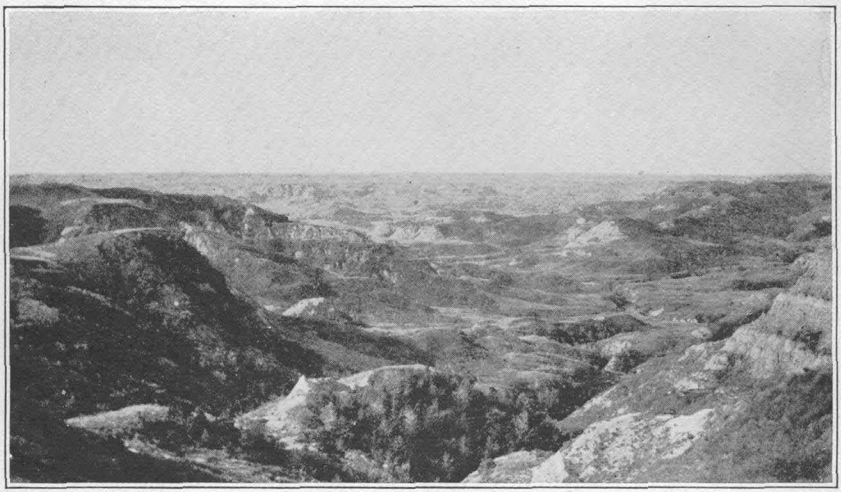
The channel of Little Missouri River is extremely sinuous. The stream meanders in an alluvial flat from half to three-quarters of a mile wide. During most of the year the channel is from 300 to



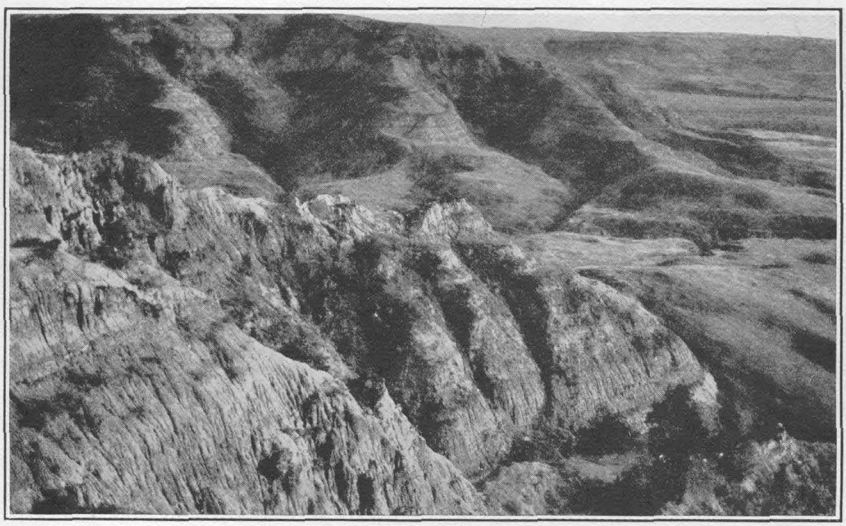
A. "BREAKS" OF THE LITTLE MISSOURI, LOOKING SOUTHEAST TOWARD THE MOUTH OF HANS CREEK, N. DAK.



B. A THICK BED OF LIGNITE IN THE FORT BERTHOLD INDIAN RESERVATION, N. DAK.



A. BADLANDS IN SEC. 26, T. 147 N., R. 93 W., N. DAK.



B. BADLANDS IN SEC. 25, T. 147 N.. R. 93 W., N. DAK.

500 feet wide, but in July and August it carries very little water and can be forded in a few places.

Clark, Bear Den, and Skunk creeks are the chief tributaries of Missouri River in the northern part of the reservation, and Squaw, Moccasin, Sam's, and Hans creeks empty into Little Missouri River in the southern part. Each of these streams has a basin 50 square miles or more in extent and contains flowing water in most of its course throughout the year. Springs and seeps are common on many of the smaller intermittent streams as well as on those just mentioned. Many of the springs issue from the outcrops of lignite beds, because joints in these beds afford free passage for the water that is confined by the relatively impervious adjacent strata. The water is thus conducted down the dip to the outcrop, where it issues in springs.

The spring water in this general region carries a large amount of sodium, calcium, and magnesium sulphate in solution, and around some of the springs there is a deposit of these white alkaline salts. The water in a large number of the springs is discolored by a brownish substance leached from the lignite beds, and the ground in the vicinity of certain springs is covered by thin, scaly layers of this brownish-black material, which is known locally as "black alkali." According to Pishel[3] it is a hydrocarbon leached from the lignite by the action of alkaline water.

Settlement.—Settlement in the southwestern part of the reservation is confined to the valleys of Missouri and Little Missouri rivers. A large part of the reservation south of the river is unfit for cultivation owing to its badland character, and at present most of it is leased to stockmen and devoted to grazing. Farming is limited to vegetable gardening by a few thrifty Indians, who produce enough for their own use. Experiments in raising vegetables in this region have proved that the soil is generally fertile. Although the annual rainfall is only 17 inches, a large portion of it comes during the growing season and makes successful dry farming possible. At present, however, markets are distant and roads are poor, most of them being merely trails, which in many places follow practically the only passable routes through the rough country. The principal trails are shown on the maps (Pls. XXVII–XXIX, in pocket).

GEOLOGY.

STRATIGRAPHY.

The Fort Berthold lignite field contains rocks of three series, namely the Recent (alluvium) and Pleistocene (glacial drift) series

[3] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, N. Dak., north of Missouri River: U. S. Geol. Survey Bull. 471, pp. 177–178, 1912.

of the Quaternary system and the Eocene series (Fort Union formation) of the Tertiary system. Outcrops or exposures of the different formations are more or less widely scattered throughout the field. The glacial drift was not mapped, and the alluvium was mapped only along Missouri and Little Missouri rivers and Hans Creek. The Fort Union formation underlies the entire field and is exposed where the younger formations are absent.

QUATERNARY SYSTEM.

Alluvium.—The alluvium, or recent washed material, is spread out in sheets and ribbon-like deposits on the slopes and along the streams in all parts of the field. It consists of silt, sand, and gravel washed from the older rocks and deposited by the water where the current is checked on account of decreased grade. It ranges in thickness from a few inches to about 60 feet and is thickest in the flood plain of Missouri River. The alluvium is commonly mixed with humus and is sufficiently porous and decomposed to form a basis for good soil. It therefore underlies some of the best agricultural land in the reservation.

Glacial drift.—Both stratified and unstratified drift, probably of Kansan (early Pleistocene) and Wisconsin (late Pleistocene) age, cover large portions of the field and were noted in many localities. In general, however, their thickness is less than 5 feet, and in some places, particularly on the larger streams, they are absent. On Little Missouri River the effects of glaciation can hardly be detected except for the presence, as shown in Plates XIX, *A*, and XXV, *A*, of scattered foreign boulders. In the NW. ¼ sec. 27, T. 148 N., R. 93 W., and the NE. ¼ sec. 23, T. 148 N., R. 92 W., there is some consolidated glacial drift, with a maximum thickness of 15 feet, containing numerous concretions and boulders of shale and sandstone, with a few boulders of granite and limestone. The whole is cemented by gypsum and iron oxide. Along the creek in sec. 7, T. 152 N., R. 93 W., the drift is 37 feet thick but unconsolidated, and at several places in the township to the west it was found to be as thick as 15 feet. This unconsolidated drift is probably younger than Kansan and may belong to the Wisconsin stage of the Pleistocene.

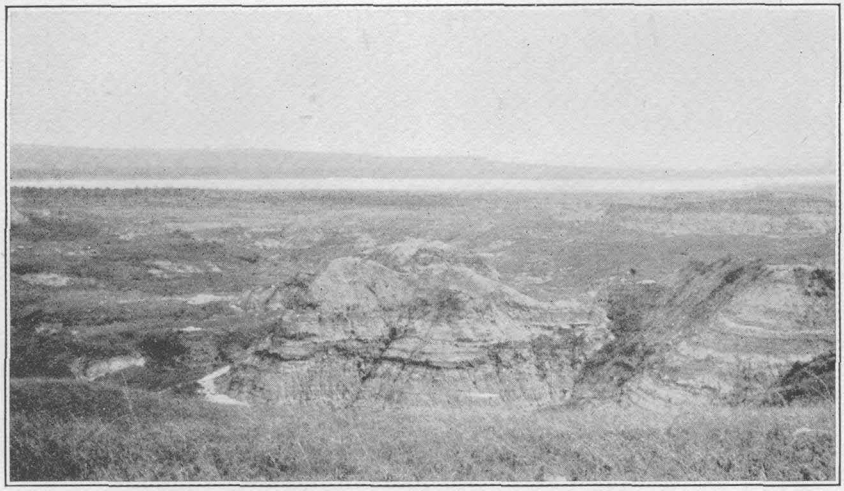
TERTIARY SYSTEM.

FORT UNION FORMATION.

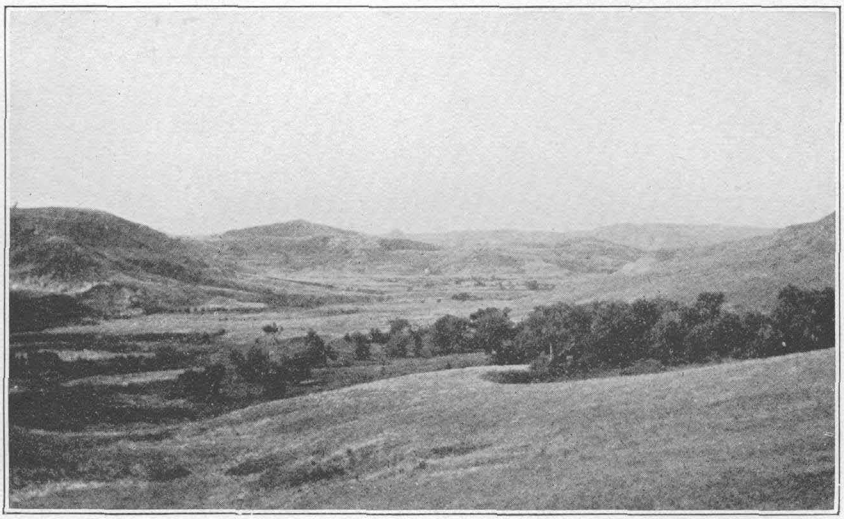
GENERAL CHARACTER.

The lignite-bearing rocks exposed in the Fort Berthold field are a part of the Fort Union formation as described by Meek and Hayden[4]

[4] Meek, F. B., and Hayden, F. V., Acad. Nat. Sci. Philadelphia Proc., vol. 13, p. 433, 1861.



A. MISSOURI RIVER, N. DAK., AS SEEN FROM THE UPPER MARGIN OF THE BADLANDS, LOOKING NORTH.



B. VALLEY OF MOCCASIN CREEK NEAR ITS MOUTH, IN SEC. 6, T. 147 N., R. 92 W., N. DAK.

in their Missouri River section and are assigned to the Eocene or early Tertiary. The Fort Union formation has a wide areal distribution, cropping out in parts of Montana, Wyoming, North Dakota, and South Dakota and also extending northward into Canada. Geographically the Fort Berthold field is in the east-central part of this large region. Between the lowest rocks exposed on Missouri River and the highest capping of the buttes there is a thickness of about 850 feet of strata. The exact stratigraphic position of that part of the Fort Union which is exposed in the Fort Berthold field is not known, but on the assumption that the original thickness is comparable to the known thickness in Billings County, N. Dak.,[5] it seems probable that there is about 200 feet of the formation underlying the lowest exposed stratum in the reservation.

The formation consists of shale, clay, sandstone, and beds of lignite which range in thickness from a few inches to 15 or 20 feet. The strata are dull gray in general appearance, with bands of lighter colors, some of which may be traced for several miles. These bands, however, are not confined to definite strata. A light-colored band may follow one stratum continuously for several miles and then gradually rise or fall in the stratigraphic section. Locally sandy shale grades almost imperceptibly into clayey sandstone within short distances. Certain comparatively thin lenticular layers of limestone are deserving of especial mention. They are bluish gray when fresh but usually weather into light-buff angular fragments. These lenses are generally fossiliferous, containing both leaves and shells.

A siliceous bed, apparently containing no lime, was traced across T. 148 N., Rs. 92 and 93 W. Its average thickness is not more than 18 inches. In fresh exposures it is dark and friable, but where weathered it is white and very resistant, and residual fragments are strewn upon low buttes and scattered widely in front of the outcrop. Many of the weathered boulders show numerous impressions of plant stems and roots. The abundance of plant remains, particularly the casts of stems and roots, in this quartzite suggests that it originated from a soil or muck deposit and that subsequently silica-bearing waters replaced most of the carbon. A microscopic examination shows the rock to be composed almost entirely of minute angular grains of quartz with scattered particles of black material resembling carbon.

Cross-bedding of shale and sandy shale as well as sandstone is very common in the Fort Union formation. This feature is particularly well shown in a lens of reddish-brown sandy shale which crops out in T. 147 N., R. 92 W., and ranges in thickness from about 1 foot to 18 feet within a horizontal distance of less than a mile. In some

[5] Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation: Jour. Geology, vol. 23, pp. 523–547, 1915.

places the material of this bed crumbles in the hand and is very sandy; in other places it contains laminae of soft flaky shale which carries plant remains and carbonaceous material to such an extent that its color is chocolate-brown.

Some of the sandstones of this formation weather into peculiar loglike forms, examples of which are shown in Plate XVIII, *B*. It is supposed that these forms are really concretions, but some geologists have maintained that this particular phase of weathering is due to some irregularity in deposition, possibly in the form of sand bars or sand spits.

FOSSILS.

The early Tertiary or Fort Union age of the coal-bearing formation in the Fort Berthold Indian Reservation is established not only by its continuity with the type Fort Union formation at the mouth of Yellowstone River, but by fossil plants and shells which were collected at several horizons in the formation in this field. A list of these fossils obtained from the southeastern part of the reservation is given below:

Fossil plants.

6683. NE. ¼ sec. 13, T. 147 N., R. 91 W.:
Viburnum nordenskiöldi? Heer.
Populus sp.
6693. NE. ¼ sec. 36, T. 147 N., R. 89 W.:
Sequoia nordenskiöldi Heer.
Celastrus sp.
Celastrus ovatus Ward.
6694. NW. ¼ sec. 35, T. 147 N., R. 89 W.:
Glyptostrobus europaeus Unger.
Dicotyledonous fragments.
6696. SE. ¼ sec. 10, T. 147 N., R. 91 W.:
Platanus nobilis Newberry.
Fragments.

Fossil shells.

8557. SE. ¼ sec. 7, T. 147 N., R. 91 W., in clay above bed FF:
Unio sp.
Viviparus.
8558. SE. ¼ sec. 5, T. 147 N., R. 91 W., 10 feet above bed GG:
Unio sp.
Goniobasis nebrascensis Meek and Hayden.

Owing to the ease with which the fossil-bearing rocks crumble it is difficult to preserve the specimens collected, and many of the fossils obtained are broken to fragments in transit before they can be examined and identified. For that reason the number of determinable species obtained from this field is small. Those listed above are referred by Messrs. Knowlton and Stanton to the Fort Union.

CLINKER.

Red baked rock, known locally as "scoria" or clinker, is common at certain horizons in the Fort Union formation. In several localities, particularly in secs. 21 and 28, T. 148 N., R. 93 W., and secs. 16, 17, 20, and 21, T. 147 N., R. 93 W., it covers areas a square mile or more in extent. The clinker is formed by the burning of beds of lignite on their outcrop. The ignition of the lignite may have been due to prairie fire, lightning, the agency of man, spontaneous combustion caused by rapid oxidation on weathering, or other causes.

The burning becomes slower as it progresses back from the outcrop under thickening cover, owing to a decrease in the supply of air. The lignite in the vicinity of the fire may be heated to the kindling temperature, but owing to lack of air it smolders until slumping takes place, admitting air or directly exposing fresh surfaces of heated lignite, which then begin to burn. Sometimes crevices afford natural chimneys, and in these openings the heat becomes intense. In such places the overlying clay and shale have been fused by the heat and the product is vesicular and shows flow structure. Many beautiful colors are developed, differing according to the composition of the rocks and the temperature to which they have been subjected.

If a bed of lignite is under thick cover when it is burning, the thickness of the clinker produced at or near the outcrop generally varies directly as the thickness of the lignite, though thick beds of lignite may burn slowly without fusing the adjacent strata. On the other hand, if the cover is thin it may be affected throughout, even by the burning of thin beds, and combustion may continue under large areas. As the quantity of ash which remains is smaller than the quantity of lignite burned the total thickness of the strata is materially diminished in areas of considerable burning, and the overlying beds settle. This causes local discordance in the dip of the beds above and below zones of burning.

In mapping the outcrops of lignite beds in this field the burned areas were located, and their extent is shown on the maps (Pls. XXVII–XXIX, in pocket). In most localities the extent of the burning could be mapped with a fair degree of certainty; but in a few places where the cover is thin the effect of the fire is uncertain, hence the approximate edge of the lignite bed in these places is represented by a broken line.

STRUCTURE.

Except for slight undulations, which in some places show noticeable dips for short distances, the beds of the Fort Union formation lie nearly flat. These local variations in direction and degree of dip

are numerous, but as the dips are commonly less than 2° they are not easily detected. By comparing the carefully determined altitudes of many points on the outcrops of the lignite beds it was found that the strata in the western part of the area dip in general in a northeasterly direction at an average rate of less than 8 feet to the mile. The lowest point structurally in the area is in the southeastern part of T. 149 N., R. 91 W., and east of this point the strata rises toward the east at the rate of a few feet to the mile. Observations on the minor undulations are given in the township descriptions (pp. 129–172).

ORIGIN OF THE COAL-BEARING FORMATION.

A full discussion of the problem of the origin of the Fort Union formation will not be presented here, but only a preliminary statement of the meaning of some of the prominent features as suggested in the cursory study of this field.

It is probable that the generally tilted attitude of the strata in this part of North Dakota is due partly to deformation and partly to the original slope of deposition. To what degree deformation has affected the strata since they were laid down is difficult to determine, but it seems certain that many of the minor undulations noted in the outcropping portion of the formation are due largely to the varying thickness of the strata themselves as well as of the underlying beds. Not only do its fossil remains of plants and animals indicate that the Fort Union formation was made up largely of sediments deposited in fresh water, but the character and constitution of the beds themselves furnish additional evidence of their continental origin. Some of the beds show ripple marks, shrinkage cracks, and silicified tree stumps (Pl. XXI, *B*) in place, indicating that they originated in very shallow water and that possibly part of their material is wind blown. Other beds indicate deeper and more quiet water, but the tree trunks, limbs, and knots (Pl. XXI, *A*) which are so well preserved in the lignite beds show clearly that forests must have existed in the area where a considerable part of the lignite was deposited. As a result of the deposition of the sediments in lakes and swamps and on flood plains, many of the beds, both of sandstone and shale, are lenticular and cross-bedded, like shale that originates in extensive deltas. At times during the deposition of the strata large areas of the sediments were covered by shallow, stagnant water in which vegetation grew and carbonaceous material accumulated. Owing to occasional changes in climate, or to further submergence of the sediments, these swamps were at times replaced by deeper water. The stronger currents consequent on these changes brought about conditions favorable to the deposition of sand and mud, which when indurated formed sandstone and

shale. The weight of these later sediments helped to compress the carbonaceous material into lignite.

Since their deposition the strata have been elevated and subjected to long periods of erosion. Streams have removed hundreds of feet of material and are still furrowing the strata and carrying the débris seaward. Glaciers have also covered the region and in places have reduced the relief by rounding off the hills and partly filling the valleys.

LIGNITE.

PHYSICAL PROPERTIES.

The most pronounced physical property of lignite is its tendency to slack on exposure to the air. This tendency is due to the fact that it contains a large percentage of water, which evaporates on exposure, causing shrinkage and the development of an irregular network of cracks and an eventual breaking up into small irregular fragments. Fresh lignite is dark brown and has a dull to waxy luster. In the bed the principal structure is usually parallel to the bedding, in places laminated, and generally shows a cubic jointing. The texture is dense in some places and woody in others. The wood is in many places so well preserved that it still retains its elasticity and may be bent in the hands to a considerable angle and will spring back to its original position. Pieces of wood and stems are generally flattened, such harder parts as knots being best preserved. The lignite contains other minerals in small quantities; the commonest are gypsum and iron pyrites. Some layers contain a large percentage of mineral charcoal, which may indicate extensive fires or temporary desiccation of the swamps[6] during the accumulation of the vegetable matter.

CHEMICAL CHARACTER.

In the examination of the western part of the Fort Berthold Reservation it was not possible without a great amount of labor to obtain samples of lignite sufficiently fresh to give valuable results on chemical analysis. The chemical composition of North Dakota lignite, however, is well known from the results of numerous analyses of samples collected in many parts of the State, either from working mines or from freshly opened prospects. Six representative analyses of lignite from neighboring fields have been selected and may be accepted as showing fairly accurately the composition of the lignite in this reservation. Five analyses of bituminous coal are also given in the accompanying table for comparison of values.

[6] Savage, T. E., On the conditions under which the vegetable matter of the Illinois coal beds accumulated: Jour. Geology, vol. 22, pp. 754–765, 1914. White, David, and Thiessen, R., The origin of coal: Bur. Mines Bull. 38, 1913.

In the table the analyses are given in four forms, marked A, B, C, D. Form A is the analysis of the lignite exactly as it comes from the mine. Owing to the fact, however, that the original moisture content of a sample is largely a matter of accident and depends in part on the amount of water in the mine from which it came, it is best for comparative purposes to use form B, which is the analysis of the sample air-dried under uniform conditions. Form C is the theoretical analysis of the sample after all moisture has been eliminated. Form D is also computed and is the analysis of the sample after all moisture and ash have been theoretically removed. Neither of the two conditions last mentioned exists in nature, but form C is used by mechanical engineers and form D is valuable for comparing the quality of the pure coal substance and the effect on its heating value of the impurities present. The analyses given show a moisture content in the samples as received ranging from 34.8 to 44.1 per cent and in the air-dried samples from 8.6 to 12.6 per cent. The heat value of the air-dried samples ranges from 8,600 to 9,860 British thermal units.

Analyses of coal and lignite samples from North Dakota fields and from fields sending coal into the Fort Berthold district.

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

	Location.				Designation on fig. 14.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.			Ultimate.						Heating value.	
	Quarter.	Sec.	T.	R.					Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
Washburne Lignite Coal Co., Wilton, N. Dak.	.....	1	142 N.	80 W..	D.....	1935	32.3	A	40.5	27.1	27.4	5.0	.76	.....	.....	.....	.....	3,690	6,640
								B	12.1	39.9	40.4	7.5	1.12	.....	.....	.....	.....	5,450	9,810
								C	.....	45.5	46.0	8.5	1.28	.....	.....	.....	.....	6,205	11,170
								D	.....	49.7	50.3	.....	1.40	.....	.....	.....	.....	6,785	11,210
Consolidated Coal Co., Lehigh, N. Dak.	.....	8	139 N.	95 W..	C.....	1971	35.6	A	42.1	24.5	25.7	7.7	1.13	.....	.....	.....	.....	3,420	6,160
								B	10.0	38.1	40.0	11.9	1.75	.....	.....	.....	.....	5,310	9,560
								C	.....	42.4	44.4	13.2	1.95	.....	.....	.....	.....	5,905	10,630
								D	.....	48.8	51.2	.....	2.25	.....	.....	.....	.....	6,805	12,250
Dakota Products Mine Co., New Salem, N. Dak.	.....	15	139 N.	85 W..	E.....	20033	32.7	A	38.5	27.6	26.6	7.28	1.31	7.03	39.22	.60	44.56	3,725	6,700
								B	8.6	41.1	39.5	10.83	1.95	5.04	58.31	.89	22.98	5,535	9,970
								C	.....	44.9	43.3	11.84	2.13	4.47	63.79	.98	16.79	6,055	10,900
								D	.....	50.9	49.1	.....	2.42	5.07	72.36	1.11	19.04	6,870	12,360
U. S. Reclamation Service, Williston, N. Dak.	.....	7	154 N.	100 W.	B.....	19367	32.8	A	44.1	23.8	26.3	5.76	.56	7.28	36.11	.63	49.66	3,355	6,040
								B	16.9	35.4	39.1	8.58	.84	5.40	53.74	.94	30.50	4,990	8,980
								C	.....	42.6	47.1	10.32	1.00	4.25	64.68	1.13	18.62	6,005	10,810
								D	.....	47.5	52.5	.....	1.12	4.74	72.11	1.26	20.77	6,655	12,060
Beulah mine, Beulah, N. Dak.	.....	25	144 N.	88 W..	F.....	33069	26.9	A	34.8	28.2	30.8	6.20	.70	6.73	42.41	.69	43.27	4,005	7,210
								B	10.9	38.5	42.1	8.48	.96	5.12	58.00	.94	26.50	5,480	9,860
								C	.....	43.2	47.3	9.51	1.07	4.39	65.07	1.06	18.90	6,145	11,060
								D	.....	47.8	52.2	.....	1.18	4.85	71.91	1.17	20.89	6,790	12,230
Canon mine of J. F. Casteel, Burlington, N. Dak.	.....	....	150 N.	84 W..	A.....	31705	30.1	A	37.0	24.9	27.7	10.43	.22	6.39	37.36	.61	44.99	3,340	6,010
								B	9.8	35.6	39.7	14.92	.32	4.38	53.44	.87	26.07	4,775	8,600
								C	.....	39.5	44.0	16.54	.35	3.63	59.23	.97	19.28	5,295	9,530
								D	.....	47.3	52.7	.....	.42	4.35	70.97	1.16	23.10	6,345	11,420
Monarch mine, Sheridan, Wyo	SE..	24	57 N.	85 W..	G.....	12005	11.1	A	22.3	35.0	39.0	3.73	.37	6.27	55.28	1.07	33.28	5,345	9,620
								B	12.5	39.4	43.9	4.20	.42	5.67	62.18	1.20	26.33	6,010	10,820
								C	.....	45.0	50.2	4.80	.48	4.89	71.10	1.38	17.35	6,870	12,370
								D	.....	47.3	52.7	.....	.50	5.14	74.68	1.45	18.23	7,220	12,990
Cottonwood Coal Co., Sand Coulee, Mont.	NW	36	19 N..	4 E....	H.....	4115	2.4	A	6.0	28.5	51.4	14.14	2.38	4.46	63.61	.91	14.50	6,195	11,150
								B	3.7	29.1	52.7	14.49	2.44	4.28	65.18	.93	12.68	6,350	11,430
								C	.....	30.3	54.7	15.04	2.53	4.03	67.67	.97	9.76	6,590	11,870
								D	.....	35.6	64.4	.....	2.98	4.75	79.66	1.14	11.47	7,760	13,970

Analyses of coal and lignite samples from North Dakota fields and from fields sending coal into the Fort Berthold district—Continued.

	Location.				Designation on fig. 14.	Laboratory No.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.						Heating value.	
	Quarter.	Sec.	T.	R.					Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		Calories.	British thermal units.
Galt mine, Canadian Pacific Ry., Lethbridge, Canada.	.....	....	9 N...	22 E ..	I.....	14882	2.0	A	9.8	40.1	43.3	6.77	.71	5.60	64.99	1.73	20.20		6,340	11,410
								B	7.9	41.0	44.2	6.91	.72	5.49	66.32	1.77	18.79		6,470	11,640
								C	.....	44.5	48.0	7.50	.79	5.00	72.04	1.92	12.75		7,030	12,650
								D	.....	48.1	51.9	.....	.85	5.41	77.88	2.08	13.78		7,600	13,680
Coal No. 6, Hocking Valley, Ohio.	.....	....	.....	.....	J.....	7712	5.5	A	9.8	32.4	53.4	4.43	.54	5.70	69.50	1.25	18.58		6,805	12,250
								B	4.5	34.3	56.5	4.69	.57	5.38	73.55	1.32	14.49		7,200	12,960
								C	.....	35.9	59.2	4.91	.60	5.12	76.99	1.38	11.00		7,535	13,570
								D	.....	37.8	62.2	.....	63	5.38	80.96	1.45	11.58		7,925	14,270
Pittsburgh coal, Fayette County, Pa.	.....	....	.....	.....	K.....	23097	1.2	A	2.5	35.7	53.6	8.17	1.76	5.19	76.15	1.49	7.24		7,585	13,650
								B	1.3	36.1	54.3	8.27	1.78	5.12	77.08	1.51	6.24		7,675	13,820
								C	.....	36.6	55.0	8.38	1.81	5.04	78.13	1.53	5.11		7,780	14,000
								D	.....	40.0	60.0	.....	1.98	5.50	85.28	1.67	5.57		8,490	15,290

Most users of lignite are little concerned about the percentage of sulphur it contains or even the relative amounts of volatile matter and fixed carbon, but they are vitally interested in the heat-producing quality of the lignite, for this determines its value for ordinary purposes, such as heating buildings, raising steam, and manufacturing uses generally.

Many persons think it best to foster home industries, even though it involves some sacrifice on their part, but to most persons the deciding question regarding a fuel as well as any other commodity is that of economy, and economy in the purchase of fuel means generally the getting of fuel with the greatest heating power for the least money. Lignite is so different from bituminous coal that most persons are unable to make a direct comparison, but such a comparison

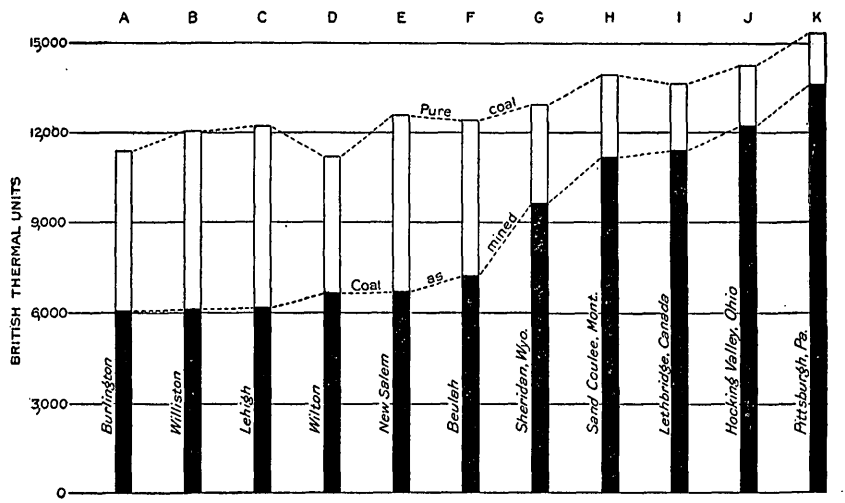


FIGURE 14.—Diagram showing heating value of North Dakota lignite compared with that of certain subbituminous and bituminous coals. See text for explanation.

is essential in order to determine which kind of fuel is the most economical to use. The ordinary analysis of a coal will not furnish the data directly for the comparison, but the calorific determinations given in the table on pages 121–122 will enable anyone to make a direct comparison of the coals and lignites there listed, and in fact their comparative values may be expressed in dollars and cents.

Figure 14 shows graphically the heating value of certain of the coals and lignites whose analyses are given on pages 121–122. These analyses have been selected because they were made from samples collected in working mines and so had suffered no deterioration from exposure to the weather. For convenience in reference these analyses will be designated A, B, C, etc., as shown in the diagram. A to F represent samples from neighboring fields of North

Dakota, in which the lignite is essentially of the same heating value as that of the Fort Berthold Reservation. G is one of the standard subbituminous coals of Wyoming, and I a similar though better coal from Lethbridge, Canada. H is a bituminous coal from Sand Coulee, near Great Falls, Mont., and J and K are two well-known eastern bituminous coals—the Hocking Valley coal of Ohio and the Pittsburgh coal of Pennsylvania. If mines are developed in the Fort Berthold Reservation the output will be likely to come into active competition with one or more of the coals represented in figure 14, and for that reason their relative values should be known alike to the producer and to the consumer.

The line marked "pure coal" shows the comparative heating value of the coals in nearly the pure form—that is, after the moisture and ash, the ordinary impurities, have been eliminated. This line, so far as it concerns the lignite, is nearly horizontal, showing that, in their pure form, the lignites differ but little in their heating value. According to this line the lignites here considered rank as follows: E, F, C, B, A, D. In other words, the New Salem lignite is intrinsically a little better than any other lignite here considered. The line marked "pure coal" ascends rapidly to the right, reaching its highest point at K. This shows that the best coal represented in the table is the Pittsburgh coal, and that both this and the Hocking Valley coal are superior in heating value to the coals of Wyoming and Montana here considered.

The comparison just made is interesting, but it has no practical value because it refers to pure coal and not to coal in the bin. The line marked "coal as mined" shows the comparative heating values of the coals as they are taken from the mine, which is in approximately the same condition as when they are consumed. This line shows much greater variations than the line marked "pure coal," because it involves not only inherent differences in the coal substance but also differences due to the presence of ash and moisture, both of which are very detrimental to a fuel. The lignites stand in the following order: F, E, D, C, B, A. The Beulah lignite is a little the best, New Salem a close second, and Wilton third. Here again the subbituminous and bituminous coals stand higher than the lignites. The difference between them is more marked than it is in the other line, mainly because the high-rank coals contain little moisture, whereas lignite is heavily charged with it.

The relative values to the consumer are proportional to the British thermal units in the coal "as received." For example, the values of Burlington lignite and Pittsburgh coal are as 6,010 is to 13,650; or, expressed in another way, if Burlington lignite sells for $5 a ton the consumer could afford to pay $11.36 for Pittsburgh coal. If he could buy Pittsburgh coal for less than that amount it would be

cheaper than the lignite, but if it cost more than that the lignite would be the cheaper of the two.

The comparative values of the lignites and coals shown in the diagram, on the assumption that Burlington lignite costs $5 a ton, are as follows:

Burlington lignite	$5.00
Williston lignite	5.02
Lehigh lignite	5.12
Wilton lignite	5.52
New Salem lignite	5.57
Beulah lignite	6.00
Sheridan subbituminous coal	8.00
Sand Coulee bituminous coal	9.28
Lethbridge subbituminous coal	9.49
Hocking Valley bituminous coal	10.19
Pittsburgh bituminous coal	11.36

QUANTITY.

An estimate of the quantity of lignite within a given field presents many difficulties, even if data on the outcrops of the beds are abundant. Lignite beds are not only lenticular in cross section, but their areal distribution is extremely irregular. In the following estimate only beds 2 feet or more in thickness are considered. For a bed that is more than 2 feet thick in one locality and less in another, the extent of the thick portion was carefully estimated and the thin portion was ignored. Another factor to be taken into account in estimating the tonnage for this field is the amount of each bed which has been carried away by the erosive action of streams. It is calculated from topographic data that 30 to 40 per cent of the exposed portion of the lignite-bearing formation has been removed in this way. In estimating the amount of lignite in the several beds it was necessary to assume that each bed maintained under cover characteristics similar to those which were discovered on the outcrop. For beds high in the section a large amount of data per unit of area could be obtained, because of the excellent exposures along their sinuous outcrops, but for low beds the data are more meager. Bed A, which is the lowest one outcropping in the field, has on its outcrop an average thickness of 8 feet and is assumed to maintain that average in the area north of the twelfth standard parallel. South of that parallel there are no outcrops of bed A, but it is assumed to underlie the southern part of the field, with an average thickness of 6 feet. The area of this bed used in the computation therefore nearly coincides with the area of the field. In obtaining the quantity of lignite in beds higher than bed A, the area in acres and the average thickness in feet of each bed was obtained. The product of these multiplied by 1,800, which is the

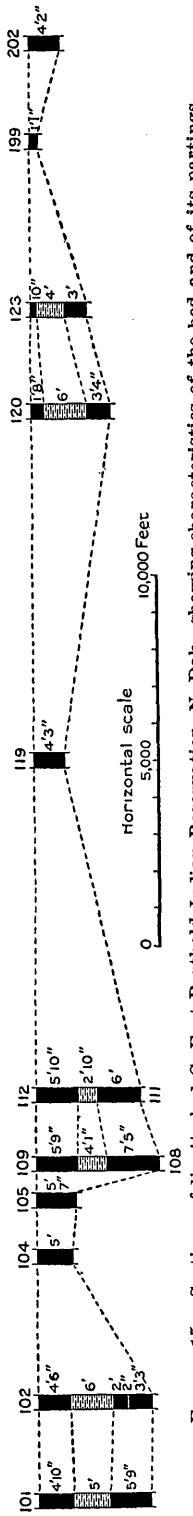


FIGURE 15.—Sections of lignite bed C, Fort Berthold Indian Reservation, N. Dak., showing characteristics of the bed and of its partings.

approximate weight in short tons of a bed of lignite 1 acre in extent and 1 foot thick, gave the tonnage for each bed. The total quantity of lignite estimated in this way is 8,655,000,000 short tons.

If this amount were distributed equally throughout the field and concentrated into one stratum, it would form one bed 11½ feet thick. As a matter of fact, however, the lignite is localized, as noted in the township descriptions, both by its lenticular habit and by erosion, so that large areas contain much less than 11½ feet of lignite in beds 2 feet or more in thickness, whereas other areas may contain as much as 25 feet or more. In addition to the estimated quantity, there is a large tonnage in beds less than 2 feet thick, which is not of value at present and is very difficult to estimate.

DISTRIBUTION.

Beds of lignite are well exposed in the bluffs of Missouri and Little Missouri rivers (see Pls. XIII, *B* and XIX, *B*) and on most of the tributary creeks as far as the badlands extend. Outcrops of some of these beds are continuous for distances ranging from 5 to 30 miles or even more. Other beds are lenticular and within short distances range from a few inches to several feet in thickness. A conspicuous example of this extensive variation in thickness is furnished by bed C in T. 151 N., R. 94 W., as shown in figure 15. The several stratigraphic sections from different parts of the field, given on Plate XVI, also show the variation of the beds from place to place.

It follows from the preceding statements that the total amount of lignite in any stratigraphic section varies within wide limits, but nowhere in this field is there exposed as much as 500 feet of the Fort Union formation which does not contain one or more beds of lignite 2 feet or more in thickness. It is therefore probable that the entire area is underlain by lignite beds, some of which do not crop out in the field but are nevertheless near enough to the surface to be of value.

At least 14 beds of lignite in this field have been considered valuable enough to map—that is, they contain 2 feet or more of lignite somewhere along their outcrops. The correlation of the outcrops is in many places difficult, owing to the variation in the thickness of the lignite beds as well as in the thickness and composition of the strata between them. Some beds, however, that show exceptional thickness or uncommon partings or other striking characteristics can be used as keys for correlation, providing the distance between the outcrops is not too great. Correlation between some beds of lignite that crop out on opposite sides of Missouri River is therefore possible and can be made with considerable certainty. A bed of lignite called bed C in this report is correlated with bed 1 described by Pishel,[7] and likewise bed CC of this report is probably the same as bed 1–A north of the river. Further correlations of beds on opposite sides of Missouri River will not be attempted owing to the great variations in the stratigraphic sections within short distances and the difficulty of drawing exact conclusions without first-hand knowledge of the stratigraphy on both sides of the river.

DEVELOPMENT.

At present the lignite in the western part of the Fort Berthold Indian Reservation is used very little. The region is almost unsettled, and only a few log houses, occupied by Indians, are built in the valleys of Missouri and Little Missouri rivers. The upland is inhabited by a few transient stockmen, who lease the land for grazing. Wood can be obtained along the principal streams, and lignite is used in conjunction with wood only during the winter. Hence the lignite has not been mined to any extent, and that which is used is obtained directly from outcrops. As lignite is plentiful in the surrounding country, no attempt has been made to market the fuel in settlements bordering the reservation.

Roads are poor and in many places are mere trails; therefore hauling for long distances is expensive, and railroads have not entered the reservation west of Missouri River. The nearest railway station is Sanish, on the left bank of the Missouri near the north line of the reservation. The most accessible railway from the southern part of the region is a branch of the Northern Pacific that ends at Killdeer, about 16 miles south of the southwest corner of the reservation, and extends eastward nearly parallel with its south boundary. The lack of transportation facilities, together with the poor shipping qualities of the lignite, preclude extensive exploitation of it in this field for many years. As general commercial de-

[7] Pishel, M. A., Lignite in the Fort Berthold Indian Reservation, N. Dak., north of Missouri River: U. S. Geol. Survey Bull. 471, pp. 170–186, 1912.

velopment in this region proceeds, however, the lignite will probably be used in near-by power plants or made into briquets for shipping, as lignite briquets have proved a very satisfactory and good stocking fuel.[8] But when the location of the field and the added cost of briquetting are considered, it seems improbable that the lignite of the Fort Berthold field will be able to compete in outside markets until the supply of high-grade coal is sufficiently diminished to render lignite briquets economical for general industrial use.

LIGNITE BEDS.

The positions in the stratigraphic section occupied by the lignite beds are shown in Plate XVI. The lowest bed of lignite exposed crops out along the foot of the river bluff in T. 151 N., R. 94 W., and as far south as sec. 18, T. 150 N., R. 93 W. It also crops out in many cut banks in the bottom of the valley of Bear Den Creek. As it is the lowest bed of lignite exposed in this field it is called bed A for convenience. From numerous measurements on bed A it was found to average nearly 8 feet in thickness. Owing to a local easterly dip of about 75 feet to the mile in the eastern part of T. 151 N., R. 94 W., and also in T. 151 N., R. 93 W., this bed does not crop out in the reservation east of Missouri River, but it probably underlies large areas on both sides of the river.

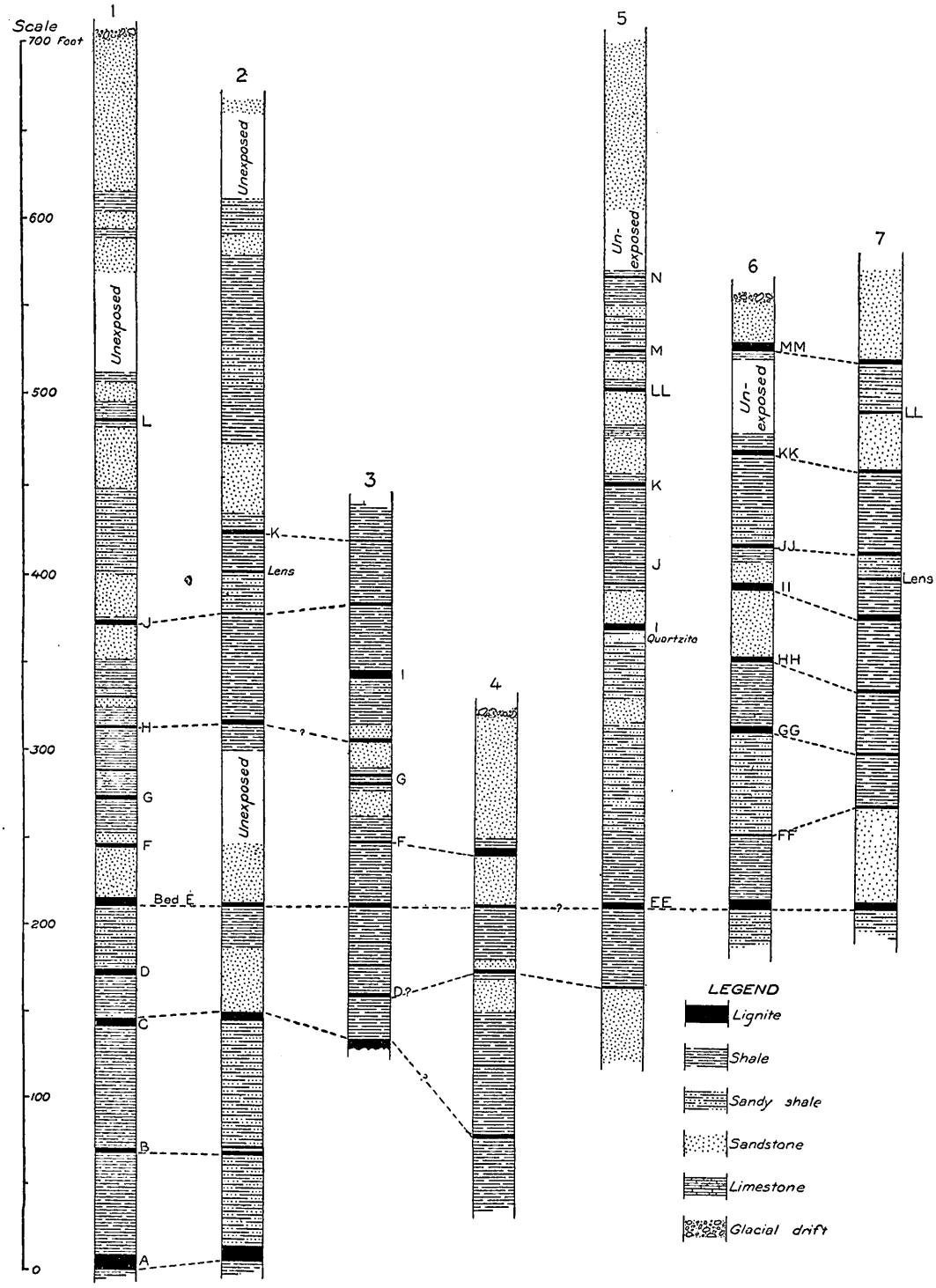
Bed B, the next higher bed of lignite of any value, is lenticular, and its valuable portion lies largely in Tps. 150 and 151 N., R. 94 W. Its outcrop along Clark and Bear Den creeks shows it to be variable in thickness and quality, carrying in many places much impure lignite and carbonaceous shale.

Beds C and CC, which may be the same, are remarkably widespread, cropping out in a large number of places from the northernmost township to the extreme southeasternmost part of the field. Their average thickness is nearly 4 feet, but in many places they are much thicker.

Beds D and DD are similar in character. They occur at about the same stratigraphic position and are variable in quality and thickness. Bed D is valuable in Tps. 150 and 151 N., R. 94 W., and bed DD, which occupies only a small area, reaches its maximum thickness of $5\frac{1}{2}$ feet at location 851, in T. 146 N., R. 88 W.

Another valuable bed of lignite of wide extent in this field is bed E, which is probably the same as bed EE. This bed has been mapped almost continuously from sec. 36, T. 152 N., R. 95 W., to the southeastern extremity of the reservation in T. 146 N., R. 88 W. It averages about 4 feet in thickness, but near the western boundary of

[8] Babcock, E. J., Investigation of lignite coal relative to the production of gas and briquets: North Dakota Univ. Rept. School of Mines and Exper. Sta., 1911.



STRATIGRAPHIC SECTIONS IN FORT BERTHOLD INDIAN RESERVATION, N. DAK., SHOWING CORRELATION OF COAL BEDS.

Numbers explained in text.

the reservation it reaches a thickness of 14 feet 9 inches, and near Crow's Heart Landing it thins to less than 2 feet. In general, however, it is of such quality and thickness as to make it one of the most valuable beds in the field. In places this bed contains a small parting of shale and silicified wood, which aids in its recognition.

Beds of lignite higher in the section do not underlie as large areas as the lower beds, owing to the fact that large portions of them have been removed by the erosive action of the rivers and their numerous tributaries. Because of this erosion many of the higher beds appear to have only a local distribution, whereas originally they may have been coextensive with those beneath. Each of these beds will be described in connection with the township in which it crops out.

TOWNSHIP DESCRIPTIONS.

A description of each township in the region examined, setting forth the main surface features, with a detailed statement of its lignite resources, is given below. The descriptions are presented in geographic order, beginning at the north line of the field (see Pl. XXVII) and proceeding from east to west along each tier of townships until the area shown in Plate XXVIII is reached. The townships of the southern part of the field (represented in Pl. XXIX) are described from north to south along each succeeding range beginning with the northwest corner.

The numbering of the lignite sections is consecutive from north to south on Plate XXVII, from east to west on Plate XXVIII, and from west to east on Plate XXIX. Many of the measurements of lignite beds 2 feet or more in thickness are shown graphically on Plates XVII, XX, XXIII, and XXVI, with numbers corresponding to those used on the maps.

T. 152 N., R. 93 W.

Only that part of T. 152 N., R. 93 W., that lies within the reservation and west of Missouri River was examined by the Geological Survey party. (See Pl. XXVII, in pocket.) The surface is a rolling upland on the west, bordered on the east by a rather abrupt but low bluff, below and east of which lies the flat flood plain of Missouri River. The upland is grass grown; the flood plain is covered with trees and brush. The lignite-bearing strata are largely concealed beneath glacial drift and alluvium, so that exposures of them are almost lacking in that part of the township which lies west of the river. On a creek in the SW. ¼ sec. 7 the drift reaches a thickness of 37 feet. The measurements of lignite beds at locations 1, 2, and 3, in sec. 15, and 7, in sec. 20, are shown diagrammatically in the accompanying plate of lignite sections (Pl. XVII), but owing to insufficient

exposures the beds measured at these places could not be correlated either with one another or with beds in adjoining townships. At location 4 the following section is exposed:

Section of lignite bed at location 4, sec. 16, T. 152 N., R. 93 W.

	Ft.	in.
Shale.		
Lignite		6
Shale	21	
Sandstone	4	
Lignite		11
Shale.		
	26	5

At location 5, in sec. 16, two thin beds of lignite, the upper of which is 9 inches thick and the lower 6 inches, are separated by 3 feet of shale. At location 6, on the same bed as location 7, in sec. 20 (Pl. XVII), 1 foot 8 inches of lignite is exposed, which, however, is not the full thickness of the bed, as the upper portion has been eroded and the remainder is now covered by glacial drift. No attempt was made to correlate these beds of lignite, as the exposures are far apart and of small extent.

A bed of lignite (called bed C in this report), which is over 5 feet thick at locations 8 and 9 (see Pl. XVII), in sec. 36 of the township immediately to the west, probably underlies the southwestern portion of this township also. The approximate outcrop of this bed in secs. 30 and 31 is shown on Plate XXVII (in pocket).

T. 152 N., R. 94 W.

Only that part of T. 152 N., R. 94 W., which lies within the reservation was examined by the Geological Survey party. The surface is rolling and grass covered. The greatest difference in elevation between any two points in the township is about 300 feet. In general the surface material is glacial drift, and outcrops of stratified rocks are few and of small extent; the principal exposures occur in secs. 11, 12, 20, 31, 32, and 36. No lignite beds of commercial importance crop out in secs. 11 and 12. At location 10, sec. 20, however, 10 inches of lignite is exposed, and at location 11 the following section was measured:

Section of lignite bed at location 11, sec. 20, T. 152 N., R. 94 W.

	Ft.	in.
Shale.		
Lignite		5
Shale		2
Lignite (bottom of bed not exposed)	1	10+
	2	5+

The beds of lignite represented by these sections are high in the stratigraphic section of this field and are not correlated with any other beds. At location 11 a local dip of 7° NE. was noted, but it is probable that this dip does not persist for more than a few hundred feet. Representative sections of beds of lignite are very difficult to obtain, owing to the covering of glacial drift and the disturbed condition of the strata, caused by the movement of the ice sheet. It is probable, however, that bed C, measured at locations 8 and 9, in sec. 36, underlies the greater part of this township at a depth of less than 300 feet. The bed averages 5½ feet in thickness where it is exposed in this township (see sections 8 and 9, Pl. XVII) and is thicker farther south. About 25 feet above bed C there is a bed containing about 3½ feet of lignite (bed D), exposed at location 12, in sec. 32. The section measured at this place is shown in Plate XVII. About 4 feet of lignite at location 13, sec. 31, is in a bed probably bed E) about 60 feet higher than bed C and is also shown in Plate XVII.

T. 152 N., R. 95 W.

Only a part of secs. 12, 13, 24, 25, and 36, T. 152 N., R. 95 W., was examined. This area is a narrow strip less than a mile wide and about 4½ miles long which lies within the reservation. The southern part is traversed by a tributary of Clark Creek, which has cut a deep trough into the lignite-bearing strata, exposing them in bluffs on either side. In the remainder of this belt the land is rolling and grass covered.

Bed C, which crops out extensively in the township immediately to the southeast, is not exposed in this township but probably underlies the greater part of it within 300 feet of the surface.

Three beds of lignite were mapped and measured in secs. 25 and 36. These beds occupy positions above bed C and correspond to beds D, E, and F, which were mapped also in the townships immediately to the south and southeast. Their general relations are shown in section 1, Plate XVI.

Lignite sections 22 and 23, Plate XVII, representing bed D, show that it contains about 3 feet of lignite. A satisfactory measurement of bed E could not be obtained in this township, owing to the fact that springs issue from the bed wherever it is exposed. At location 21, however, 2 feet of lignite was found above the surface of the water in a spring.

Bed F ranges in thickness from about 3 to 6 feet, as shown by sections 14 to 19, inclusive, on Plate XVII. At location 20 bed F contains 1 foot 8 inches of lignite, but owing to a slump at this place the measurement is not reliable.

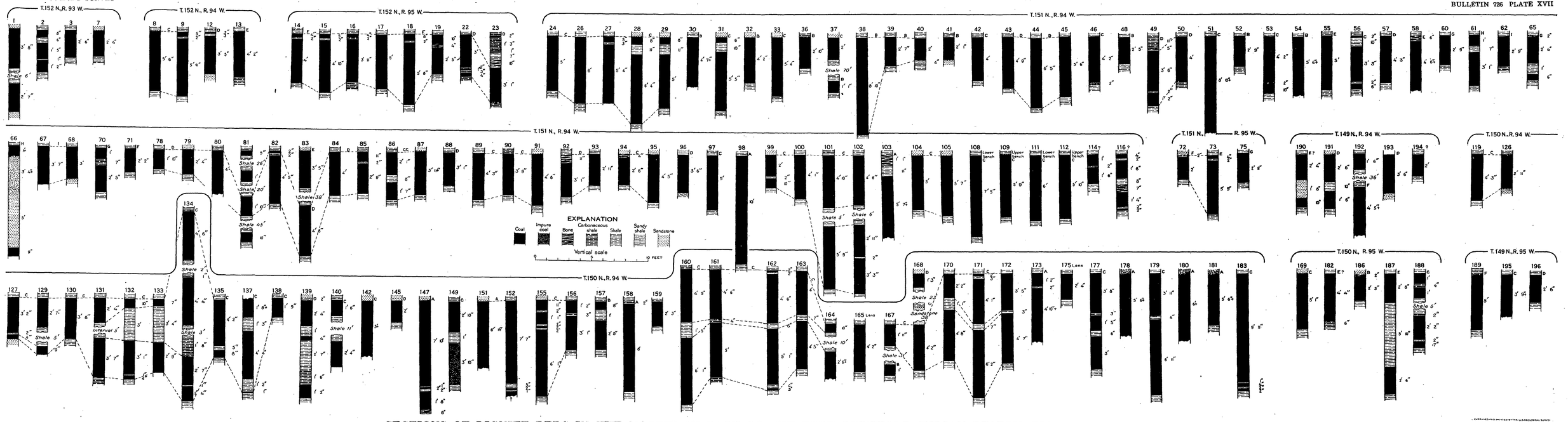
T. 151 N., R. 93 W.

Only a small part of T. 151 N., R. 93 W., is included in the territory here described. This part lies in the flood plain of Missouri River and contains no exposures of lignite. It is probable, however, that the land is underlain by beds of lignite lower in the formation than those exposed along the river bluffs in this vicinity—such, for example, as bed A, mapped along the river in Tps. 150 and 151 N., R. 94 W.

T. 151 N., R. 94 W.

Practically all of T. 151 N., R. 94 W., lies west of Missouri River and is included in the area described in this report. The eastern tier of sections, except sec. 1, is crossed by the river. The northern part of the township is deeply incised by Clark Creek and its tributary gullies, which have produced extensive badlands. The upland is very irregular in outline, and level portions of it are of small extent and confined largely to the southern and western parts of the township. Surmounting the upland in secs. 28, 29, 32, and 33 are high buttes, reaching altitudes of over 2,600 feet above sea level, or 870 feet above Missouri River. These buttes, known locally as the East Buttes, are part of a group of hills called the Blue Buttes, which lie largely west of the reservation. The upland in this township is thinly covered by glacial drift. Along the streams where erosion has been most rapid the lignite-bearing strata are well exposed. Altitudes on the lignite beds indicate a general eastward dip of about 8 feet to the mile. In secs. 1 and 12 this increases to about 75 feet to the mile in a northeasterly direction, and in secs. 25 and 26 a dip to the southeast of about the same magnitude was determined. As the relief is about 800 feet in this township, opportunity is offered for measuring long stratigraphic sections. One of these (section 1, Pl. XVI) shows the approximate position and relation of the lignite beds. There are fourteen of these beds exposed in the valley of Clark Creek and its tributaries, but only nine were considered of sufficient thickness to warrant mapping. The lowest bed that is exposed in the Fort Berthold field (bed A) crops out on the bluff facing Missouri River at location 98, in sec. 24, where it has a thickness of 10 feet (Pl. XVII). A measurement of an incomplete section of the same bed was made at location 103, in sec. 25, where it is more than 5 feet 7 inches thick. Elsewhere in the township the outcrop of this bed is covered with alluvium.

The next higher bed of lignite (bed B) is separated from bed A by 25 to 60 feet of sandy shale. Bed B is variable in thickness, and the lignite varies from place to place in quality. The bed crops out along Clark Creek and Missouri River and was measured at locations 30, 32, 36, 38, 39, 40, 41, 48, 52, 54, and 110. At location 110, in sec. 36, the following section was measured:



SECTIONS OF LIGNITE BEDS IN THE NORTHERN PART OF THE FORT BERTHOLD INDIAN RESERVATION, NORTH DAKOTA

Section of lignite bed at location 110, sec. 36, T. 151 N., R. 94 W.

	Ft.	in.
Shale, carbonaceous.		
Lignite, high in ash	1	10
Shale		5
Lignite	1	6
Shale.		
	3	9

The bed ranges in thickness from 2 feet at location 40, sec. 4, to 8 feet 10 inches at location 38, sec. 3; but its average thickness in this township is about 3 feet 8 inches. Plate XVII contains graphic sections of these beds, except that at location 110.

The next higher bed of lignite (bed C) is separated from bed B by about 70 feet of shale. It is represented on Plate XVII by sections 24, 26, 27, 28, 29, 31, 33, 37, 42, 46, 51, 53, 56, 86, 87, 89, 90, 91, 94, 95, 97, 99, 100, 101, 102, 104, 105, 108, 109, 111, and 112. The bed ranges in thickness from 2 feet at location 37, sec. 3, to almost 9 feet at location 51, sec. 6, but averages somewhat less than 5 feet. It is persistent and crops out for many miles along Missouri River, Clark Creek, and Bear Den Creek. It is separated into two benches in sec. 35, as shown by sections 101, 102, 108, 109, 111, and 112. The measurements on the bed in this locality are shown graphically in figure 15 (p. 126). Section 104 represents the entire bed, sections 108 and 111 the lower bench, and sections 109 and 112 the upper bench. In sec. 12 of the township immediately to the south, this bed was measured at location 119, where it consists of a single bench. The separation of lignite beds into two benches by partings of variable thickness is common to many of the beds of this region, and the sections shown in figure 15 are illustrative of this feature.

Bed D is about 25 feet above bed C in this township and is represented by sections 34, 35, 43, 44, 45, 47, 49, 50, 57, 78, 79, 80, 81, 82, 83, 84, 85, 88, 92, 93, and 96. All these sections except those given in the following table are shown on Plate XVII. Lignite sections 25 and 106 probably also represent this bed. Its average thickness is 3 feet.

Sections of lignite bed D in T. 151 N., R. 94 W.

[In addition to those shown on Pl. XVII.]

No. on map (Pl. XXVII).	Location.	Section.	*Ft.*	*in.*
25	NE. ¼ sec. 1	Shale.		
		Lignite	1	3
		Shale.		
34	NW. ¼ sec. 2	Lignite	1	2
35	NE. ¼ sec. 3	Lignite		8
47	NE. ¼ sec. 5	Lignite, crushed	1±	
97	NW. ¼ sec. 24	Lignite (bed D is 30 feet above bed C at this place)	3	3
106	NW. ¼ sec. 35	Lignite	1	3

Bed E, about 38 feet above bed D, was measured at locations 55, 58, and 83 and averages about 4½ feet in thickness in this township. All these sections are shown on Plate XVII.

A higher bed of lignite (bed F) averaging only 1½ feet was measured at locations 59, 71, and 107. Section 71 is given on Plate XVII.

Sections of lignite bed F in T. 151 N., R. 94 W.

[In addition to that shown on Pl. XVII.]

No. on map (Pl. XXVII).	Location.	Section.	
			Ft. in.
59	SE. ¼ sec. 7	Lignite	1 6
107	NE. ¼ sec. 35	Lignite	1 2

Beds G, H, and I crop out in secs. 18 and 19 of this township. Measurements taken at locations 60, 65, and 70, shown on Plate XVII, averaging 2 feet 9 inches, are on bed G; those at locations 61, 66 (Pl. XVII), and 69, bed H. The section at location 69 shows several thin beds of lignite, as follows:

Section of lignite bed H at location 69, sec. 19, T. 151 N., R. 94 W.

	Ft.	in.
Shale.		
Lignite		6
Shale, carbonaceous	10	
Lignite		6
Shale, carbonaceous		8
Shale	4	
Sandstone	1	
Lignite		6
Sandstone	3	
Sandstone, carbonaceous	2	
Shale	14	
Lignite (bed H)	1	8
Shale.		
	37	10

Bed I was measured at locations 62, 67, and 68. These sections, averaging about 3 feet, are given on Plate XVII. A number of thin, unimportant beds of lignite which were measured at locations 114, 116, 117, and 118, in secs. 33 and 34, are shown graphically in section 1, Plate XVI, with their approximate correlation. Sections 114 and 116 are also shown on Plate XVII.

T. 151 N., R. 95 W.

The eastern part of T. 151 N., R. 95 W., which lies within the reservation, comprises a strip less than 1 mile wide and about 6 miles long. This strip of land is crossed by Clark Creek, whose steep valley walls expose the strata of the lignite-bearing Fort Union forma-

tion. Many of the lignite beds mapped in the township immediately to the east along Clark Creek were also mapped in this township. Beds A, B, C, and D lie too deep to be prospected except with a drill, hence their thickness is not known. The lowest lignite bed that crops out in this part of the township is bed E, which at location 73 is about 6 feet thick. (See Pl. XVII.) Bed F is 1 foot 3 inches thick at location 64, 2 feet at location 72,[9] and 1 foot 11 inches at location 74. A measurement obtained at location 75 shows 2 feet 9 inches of lignite in bed G. Bed H is partly burned at location 76, the only exposure of it in this vicinity, where the following section was measured:

Section of lignite bed at location 76, sec. 24, T. 151 N., R. 95 W.

	Ft.	in.
Shale.		
Lignite		10
Ash		10
Shale.		
	1	8

Bed J was measured at location 77, in sec. 24, where it contains 1 foot 10 inches of lignite.

T. 150 N., R. 91 W.

Only a small part of T. 150 N., R. 91 W., is south of Missouri River, and this part lies almost entirely on the flood plain of the river. South of the flood plain is a low grass-covered bluff that rises about 65 feet to the rolling upland, which stretches southward. Glacial drift forms the surface in many places, but its maximum thickness is apparently only a few feet. Only one bed of lignite (bed E) crops out in the township. Measurements on this bed were obtained at locations 356, sec. 31, and 357, sec. 32, as given on Plate XX, and show that the thickness of the bed ranges in a distance of half a mile from 5 feet 1 inch to 3 feet 3 inches. It is believed that bed A, which in T. 151 N., R. 94 W., and adjoining townships has an average thickness of nearly 8 feet, lies beneath this part of T. 150 N., R. 91 W., at a depth of less than 300 feet. It is also probable that either one or all of beds B, C, and D, which lie too deep to be prospected without the aid of a drill, are thick enough to be of commercial value.

T. 150 N., R. 92 W.

Only a small part of T. 150 N., R. 92 W., lies south of Missouri River, and most of this part is in the flood plain of the river. Two beds of lignite crop out in the bluff in sec. 31. The lower of these, bed E, was measured at location 249, where it is 1 foot 4 inches thick. A section of the upper bed was not obtained in this town-

[9] On Plate XVII sections 72 and 73 are erroneously connected by correlation lines.

ship, but it was measured in the township immediately to the south, where it has an average thickness of about 3 feet.

T. 150 N., R. 93 W.

T. 150 N., R. 93 W., is crossed by Missouri River from west to east, and only the part south of the river is here described. A prominent bluff rises abruptly from the river in the western part of the township and from the flood plain in the eastern part to a height of about 150 feet. This bluff has been dissected by the run-off of rains into a fringe of gullies, breaks, ridges, and points. The rough topography here affords an excellent opportunity for measuring and tracing the outcrops of lignite beds. The strata have a slight eastward dip of about 18 feet to the mile, as determined by a comparison of altitudes on the lignite beds. Four beds of lignite (beds A, C, E, and F) were mapped here, of which bed C is the most valuable. A partial section of bed A was obtained at an exposure at location 124, in sec. 18, near the water's edge of Missouri River. The entire thickness could not be measured, as part of the bed was beneath the water and only 1 foot 8 inches above. This bed, however, crops out extensively along Bear Den Creek in the township immediately to the west and has been found to have an average thickness of nearly 8 feet. Bed A, east of location 124, is lower than the surface of Missouri River.

Bed B contains at location 122 only 8 inches of lignite, between beds of carbonaceous shale.

Bed C is about 55 feet above bed B in this township and crops out almost continuously along the river bluff across the township. Beginning in the northwestern part of the township the sections of this bed are as follows: Nos. 120, 121, 123, 199, 200, 201, 202, 203, 208, 209, 210, 211, 212, 213, 214, 215, 226, 230, 232, 233, 234, and 235. The average thickness of bed C, as shown by these sections, is about 3 feet. Its maximum thickness, at location 202, in the SW. ¼ sec. 20, is 4 feet 2 inches. The more important sections listed above are shown on Plate XX, and the remainder are given in the following table:

Sections of lignite bed C in T. 150 N., R. 93 W.

[In addition to those shown on Pl. XX.]

No. on map (Pl. XXVII).	Location.	Section.	Ft.	in.
199	NW. ¼ sec. 20	Lignite	1	1
200	NW. ¼ sec. 20	Lignite		8
213	SW. ¼ sec. 27	Shale.		
		Bone	1	2
		Shale	1	6
		Lignite	1	
		Shale.		

Sections of lignite bed C in T. 150 N., R. 93 W.—Continued.

No. on map (Pl. XXVII).	Location.	Section.	Ft.	in.
215	NW. ¼ sec. 34	Shale.		
		Shale, carbonaceous	1	
		Lignite		4
		Shale, carbonaceous	1	8
		Bone		10
		Shale, carbonaceous		2
		Shale	25	
		Lignite (bed C)	1	6
		Shale	18	
		Lignite		6
		Shale.		
232	NE. ¼ sec. 35	Shale.		
		Shale, carbonaceous		4
		Bone	1	8
		Lignite	1	6
		Shale.		
233	NW. ¼ sec. 36	Lignite, weathered	1	2

Sections 204, 205, 206, 207, 228, 229, and 231 represent a bed of lignite higher than bed C, probably bed D. The lignite is of poor quality and contains many partings of shale and bone, as shown in the sections which are given on Plate XX.

A bed of lignite averaging 2 feet 2 inches in thickness and lying approximately 145 feet higher than bed C was measured at locations 216, 218, 223, 225, and 227 and is probably bed E, though the correlation can not be made with certainty. These sections are given on Plate XX, with the exception of Nos. 223 and 225.

Sections of lignite bed E in T. 150 N., R. 93 W.

[In addition to those shown on Pl. XX.]

No. on map (Pl. XXVII).	Location.	Section.	Ft.	in.
223	SW. ¼ sec. 35	Lignite	1	9
225	SW. ¼ sec. 35	Lignite	1	1

Bed F is separated from bed E by 25 to 35 feet of yellow sandstone, which is fairly regular in thickness and color and which was used as a marker in locating beds E and F in this township and townships farther east. Bed F was measured at locations 217, 219, 220, 222, and 224 (see Pl. XX) and averages about 2½ feet in thickness.

A bed of lignite higher in the section in this township, which is believed to be bed G, was measured at location 221, in sec. 35, where it contains 3 feet 6 inches of good lignite. (See Pl. XX.)

T. 150 N., R. 94 W.

All of T. 150 N., R. 94 W., is included in the area described in this report, except a small tract in the eastern part of sec. 1 and the NE. ¼ sec. 12, which lies in the flood plain of Missouri River. West of the flood plain the bluffs rise over 125 feet to a rolling upland which

gradually increases in altitude away from the river. Farther west the upland is broken across the central part of the township by the deep valley of Bear Den Creek. Along this valley and also that of Missouri River badlands are developed in which the lignite-bearing strata are well exposed, and the beds of lignite are easily measured at many places. Only four beds, A, B, C, and D, were mapped continuously in this township.

Bed A has an average thickness of nearly 8 feet, as shown in sections 147, 151, 152, 158, 173, 178, 180, and 181 on Plate XVII. This thick bed of lignite is low in the strata exposed and probably underlies most of the township, as well as a considerable portion of the adjoining townships.

Bed B is separated from bed A by 40 feet of argillaceous sandstone. It contains very poor lignite and in many places has been found to be merely a bed of carbonaceous shale. Sections 157 and 159 of this bed are shown on Plate XVII. Its best development is at location 157, where the lower bench and the only one to be considered is 2 feet 8 inches thick; other measurements of it are given in the following table:

Sections of lignite bed B in T. 150 N., R. 94 W.

[In addition to section 157, Pl. XVII.]

No. on map (Pl. XXVII).	Location.	Section.	Ft.	in.
148	SW. ¼ sec. 15	Lignite, impure	5	6
153	NW. ¼ sec. 16	Shale.		
		Lignite	1	2±
		Shale, carbonaceous	3	8
		Shale.		
174	NW. ¼ sec. 17	Lignite	1	3
184	NE. ¼ sec. 30	Lignite	1	8

Bed C, which averages over 5 feet in thickness, is about 70 feet above bed B in this township and was measured at locations 119, 126 to 135, 137, 138, 140, 142, 149, 150, 154 to 156, 160 to 164, 167, 168, 170 to 172, 177, 179, and 183. These sections, except Nos. 128, 150, and 154, are shown graphically on Pl. XVII.

Sections of lignite bed C in T. 150 N., R. 94 W.

[In addition to those shown on Pl. XVII.]

No. on map (Pl. XXVII).	Location.	Section.	Ft.	in.
128	NW. ¼ sec. 24	Lignite	1	6
150	SW. ¼ sec. 16	Lignite (base not exposed)	2	6+
154	NE. ¼ sec. 16	Shale.		
		Lignite		8
		Bone	3	11
		Shale.		

The outcrop of bed D, which in this township is about 90 feet higher than bed C, was mapped for a short distance, and measurements were obtained at locations 125, 136, 139, 141, 143, 145, 146, and 185. As shown by the sections, this is an unpromising bed, containing on an average less than 2 feet of lignite. Sections 139 and 145 are shown on Plate XVII, and other measurements are given in the following table:

Sections of lignite bed D in T. 150 N., R. 94 W.

[In addition to those shown on Pl. XVII.]

No. on map (Pl. XXVII).	Location.	Section.	Ft.	in.
125	NW. ¼ sec. 24	Lignite	1	2
136	NW. ¼ sec. 23	Shale.		
		Lignite	1	2
		Shale, carbonaceous		1
		Lignite		4
		Shale	2	6
		Lignite		1
		Shale		5
		Lignite		7
		Shale.		
141	SE. ¼ sec. 10	Lignite	1	3
143	SE. ¼ sec. 10	Lignite	1	4
146	NW. ¼ sec. 15	Lignite	1	6
185	SW. ¼ sec. 29	Lignite	1	2

Isolated outcrops of higher beds of lignite were measured at locations 165, 175, and 176. Sections 165 and 175 are shown on Plate XVII. The bed measured at location 176 carries 1 foot 11 inches of lignite and is probably the same bed as that at location 175. The relation of this bed to other beds is shown in stratigraphic section 2, Plate XVI. Other measurements of lignite beds were made at locations 114 and 166. The beds at both locations are impure; they contain 2 feet of lignite at location 144 and 2 feet 10 inches of lignite at location 166.

T. 150 N., R. 95 W.

That part of T. 150 N., R. 95 W., included in the Fort Berthold Reservation is a strip less than a mile wide along the eastern edge of the township. Along the steep bluffs of Bear Den Creek, which crosses this strip, four beds of lignite (A, B, C, and E) were mapped. No measurements were made on bed A in this township, but its average thickness in the township to the east is nearly 8 feet, and it probably underlies this township also. A measurement of bed B was obtained at location 186, sec. 25, where it contains 2 feet 3 inches of lignite, as shown on Plate XVII. Section 169, showing 5 feet 1

inch of bed C, is given on Plate XVII. Another bed of lignite about 125 feet higher in the section, which may be bed E, is represented by sections 182, 187, and 188, Plate XVII. At location 182 this bed contains 4 feet 4 inches of lignite, and at locations 187 and 188 [10] it is separated by a thick shale parting into two benches, each of which is over 2½ feet thick.

T. 149 N., R. 91 W.

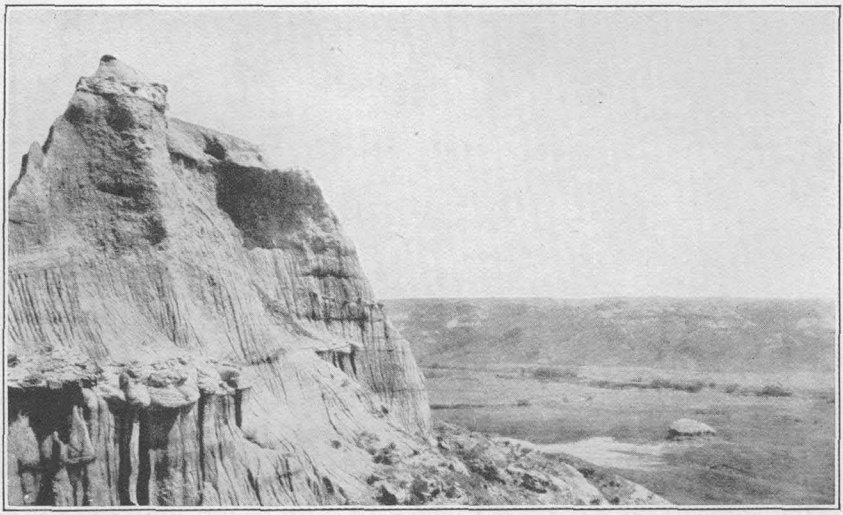
The greater part of T. 149 N., R. 91 W., is a rolling upland covered thinly with glacial drift. The eastern part, however, includes a portion of the wide flood plain of Missouri River. The maximum relief within the boundaries of the township is about 450 feet. Throughout most of the township the strata have a slight dip to the northeast, but in secs. 35 and 36 there is an eastward dip of about 100 feet to the mile.

Six beds of lignite were mapped at several places in this township. Bed E is probably the most valuable, although bed CC, which is about 110 feet below bed E and at about the same position in the section as bed C, was mapped for a considerable distance in the eastern part of the township. Beds A and B lie too deep to crop out in this township, hence no data regarding them were obtained. Measurements of bed CC were obtained at locations 362, 367, 368, and 369. (See Pl. XX.) Sections 376 and 377 probably also represent the same bed. It is of fair quality and averages 3 feet in thickness. At location 377, in sec. 36, the bed carries at least 1 foot 8 inches of lignite, but the base could not be reached on account of the water from a spring at the outcrop.

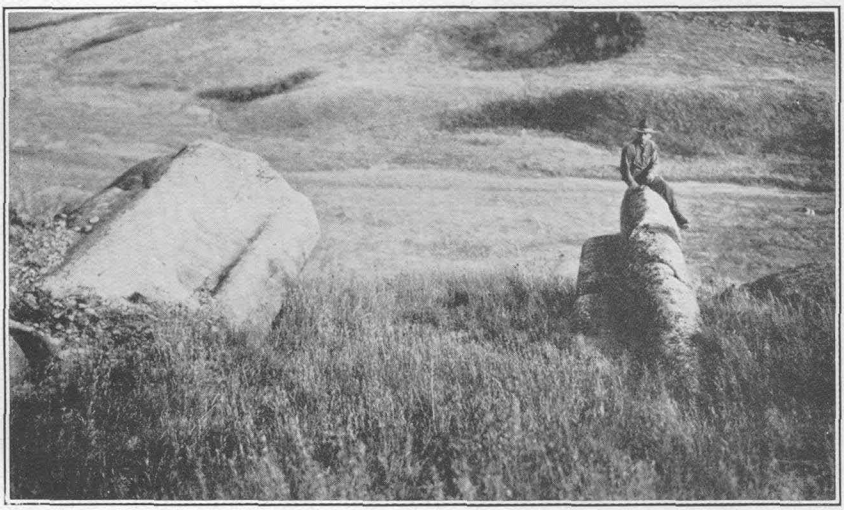
Bed E was mapped continuously along the bluffs in a northwest-southeast direction across the central part of the township. The sections of this bed are Nos. 353, 354, 355, 358, 359, 360, 361, 363, 365, 370, 372, 373, and probably also 378. At location 354 it contains 1 foot 11 inches of lignite. Southeast of this place it is generally thicker, but at location 370 it carries only about 8 inches of lignite. It is quite probable that the measurement at location 370 is not complete, as the lignite was much weathered and the shale above may not have been in place. At location 365 bed E carries 4 feet 2 inches of good lignite. Other sections of this bed are shown on Plate XX.

Measurements on a thin bed of lignite about 30 feet below bed E and near the horizon of bed D were obtained at a number of places, and its thickness is shown by sections 364, 374, and 375. Section 364 shows 1 foot 4 inches of lignite, and section 375 shows 1 foot 2 inches. Section 374 is shown on Plate XX.

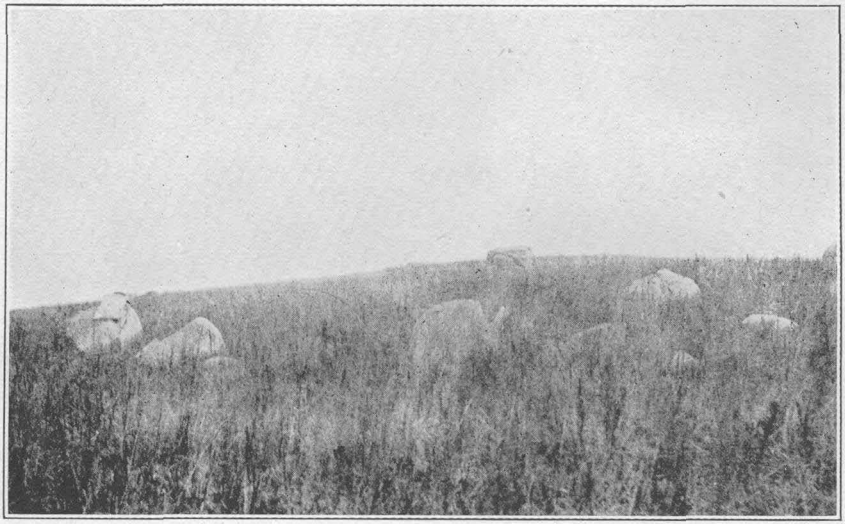
[10] Section 188 is erroneously labeled bed C on Plate XVII.



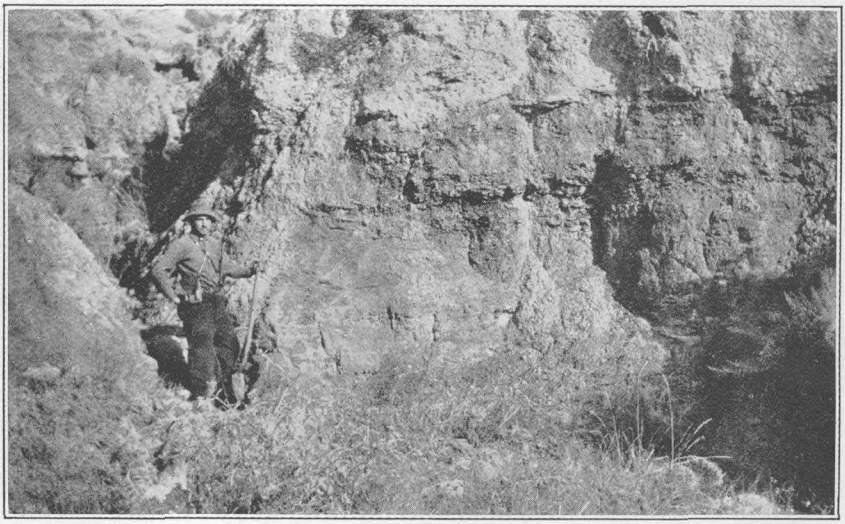
A. BARE BUTTES OF THE FORT UNION FORMATION ON THE SOUTH SIDE OF HANS CREEK, N. DAK.



B. LOG CONCRETIONS IN FORT UNION FORMATION.



A. GLACIAL BOULDERS ON THE UPLAND IN T. 147 N., R. 93 W., N. DAK.



B. BED OF LIGNITE 8 FEET THICK IN NATURAL EXPOSURE IN SEC. 14, T. 147 N., R. 93 W., N. DAK.

Bed F, which is about 40 feet above bed E, was measured at location 363 (see Pl. XX) and also at location 366, where it contains 1 foot 9 inches of lignite. A section obtained at location 371, containing 1 foot 9 inches of lignite, may also represent bed F.

Three beds of lignite from 100 to 180 feet higher in the formation than bed E were mapped in secs. 27, 28, 31, 32, and 33. These beds probably correspond to beds I, K, and M in the township to the south. In T. 149 N., R. 91 W. they are thin and variable in quality, but in the township to the south they have been traced continuously for long distances. Beds I and K were measured at location 382, where they are 2 feet 5+ inches and 2 feet 8 inches thick, respectively. Bed K carries 2 feet 4 inches of lignite at location 380. Bed M was measured at locations 379, 381, and 383, and the sections are given below:

Sections of lignite bed M in T. 149 N., R. 91 W.

No. on map (Pl. XXVII).	Location.	Section.		
			Ft.	*in*
379	NW. ¼ sec. 27	Lignite	1	9
381	SW. ¼ sec. 33	Lignite	1	3
383	SE. ¼ sec. 32	Lignite	2	

T. 149 N., R. 92 W.

All of T. 149 N., R. 92 W., except the northern parts of secs. 1, 2, and 3 is here described. The maximum relief in the township is about 525 feet. Excellent exposures of the stratified rocks occur in the bluffs and gullies along Missouri River and on both sides of the valley of Skunk Creek, which flows through the central part of the township. The course of the lower part of Skunk Creek apparently follows a shallow syncline.

Outcrops of lignite beds E and F were mapped almost continuously throughout this township. The beds are not constant in thickness, however, and both of them are thinner in the eastern part of the township than they are in the western part. Beds D and G were also measured in this township and mapped for short distances. The stratigraphic relations of these beds are shown in Plate XVI, section 4.

Several sections of lignite beds lower in the formation than bed E were obtained, but correlation of these beds is uncertain. Their thicknesses are given in the following table:

Sections of lignite beds below bed E in T. 149 N., R. 92 W.

No. on map (Pl. XXVII).	Location.	Section.	Ft.	in.
281	SE. ¼ sec. 9	Lignite	1	9
297	SE. ¼ sec. 19	Lignite	1	3
302	NE. ¼ sec. 20	Shale.		
		Lignite	1	
		Shale, carbonaceous		8
		Lignite		5
		Bone		4
		Shale.		
310	SW. ¼ sec. 15	Lignite	1	11
314	SE. ¼ sec. 15	Shale.		
		Lignite	1	6
		Bone	1	
		Lignite		6
		Shale, carbonaceous	1	7
		Shale.		
345	NW. ¼ sec. 12	Lignite (bed D?)		9
347	SE. ¼ sec. 2	Lignite	1	9
348	SW. ¼ sec. 1	Lignite	1	2
352	NE. ¼ sec. 1	Lignite	1	8

Sections 312, 313, and 346, averaging about 3 feet, probably represent bed D and are shown in Plate XX. All the preceding measurements were obtained on lenticular beds of lignite that occur at about the same horizon as bed D, but they can not be exactly correlated.

Bed E, the lower one of the beds mapped, has an average thickness of about 3 feet in this township. It was measured at locations 250, 253, 261, 276, 279, 280, 284, 285, 287, 290, 293, 294, 306, 309, 311, 315 to 317, 320, 322, 323, 325, 326, 330, 331, 333, 334, 338, 339, 341 to 344, 348, 350, and 351. Most of the sections of this bed are shown in Plate XX. Measurements of bed E not shown graphically are as follows:

Sections of lignite bed E in T. 149 N., R. 92 W.

[In addition to those shown on Pl. XX.]

No. on map (Pl. XVII).	Location.	Section.	Ft.	in.
250	NW. ¼ sec. 6	Bone	3	4
253	NW. ¼ sec. 6	Lignite	1	6
261	NW. ¼ sec. 5	Lignite	1	5
279	SW. ¼ sec. 10	Lignite	1	10
348	SW. ¼ sec. 1	Lignite	1	0
350	SE. ¼ sec. 1	Lignite	1	5
351	SE. ¼ sec. 1	Lignite	1	4

Bed E is commonly separated from Bed F by 40 to 50 feet of yellow friable sandstone, which is easily distinguished from other beds of the formation in this locality.

Bed F, which is about 55 feet above bed E, is exposed at a great many places in this township with an average thickness of about 3 feet 2 inches. Its sections are Nos. 251, 254, 255, 258 to 260, 262 to 265, 269, 271 to 275, 277, 278, 282, 283, 285, 288, 291, 295, 296, 298, 307, 308, 318, 319, 321, 324, 327, 328, 329, 332, 335 to 337, 340, and 349. All these sections, except those measured where the bed was only partly exposed or was too thin to be workable, are shown on Plate XX. The other measurements are tabulated below:

Sections of lignite bed F in T. 149 N., R. 92 W.

[In addition to those shown on Pl. XX.]

No. on map (Pl. XXVII).	Location.	Section.	Ft.	in.
251	NW. ¼ sec. 6	Lignite	3	4
262	NE. ¼ sec. 5	Lignite	1	10
264	NE. ¼ sec. 5	Lignite	1	7
272	SE. ¼ sec. 4	Lignite (top of bed eroded)	1	2+
273	SW. ¼ sec. 3	Bone	1	5
274	NW. ¼ sec. 10	Lignite	1	6
277	SW. ¼ sec. 10	Lignite	1	8
282	SE. ¼ sec. 9	Lignite	1	3
337	SE. ¼ sec. 14	Lignite	1	8

Bed G, with an average thickness of 2 feet 8 inches, crops out in some of the higher parts of this township. It was measured at locations 252, 256, 257, 266, 267, 268, 286, 289, and 292. All these sections are shown graphically on Plate XX, except No. 268, which is given below.

Section of lignite bed at location 268, sec. 8, T. 149 N., R. 92 W.

	Ft.	in.
Shale.		
Lignite		4
Shale	1	7
Lignite		6
Shale.		

At location 270 a bed of lignite, whose position is not known, has a thickness of 1 foot 5 inches.

T. 149 N., R. 93 W.

T. 149 N., R. 93 W., is a rolling upland, broken on the north by the badlands along Missouri River and on the south by Squaw Creek and its tributaries. The central part of this township contains very poor rock exposures, and no outcrops of lignite beds were found except in secs. 1, 2, 3, 4, 35, and 36, where beds D, E, and F were measured. The relations of these beds are shown in the stratigraphic sections on Plate XVI.

Bed D, the lowest one, is broken by shale partings as shown by the following section, and the lignite is poor:

Section of lignite bed D at location 243, sec. 1, T. 149 N., R. 93 W.

	Ft.	in.
Shale.		
Bone		2
Lignite	1	9
Shale, carbonaceous	1	4
Bone		4
Shale	1	
Shale, carbonaceous		6
Lignite		3
Shale.		

Bed E is exposed in the bluffs at many places, and sections were measured at locations 237, 238, 239, 240, 244, 247, and 248. All these sections except Nos. 244 and 248, given below, are shown in Plate XX. The average thickness of bed E obtained from these measurements is 2 feet 6 inches.

Sections of lignite bed E in T. 149 N., R. 93 W.

[In addition to those shown on Pl. XX.]

No. on map (Pl. XXVII).	Location.	Section.		
244	NE. ¼ sec. 1	Shale.	*Ft.*	*in.*
		Bone	1	8
		Lignite	1	8
		Shale.		
248	NE. ¼ sec. 1	Lignite	1	11

Bed F, which averages in this township a little over 2½ feet in thickness, is 52 feet higher than bed E at location 245 and 25 feet higher at location 239. Measured sections of this bed at locations 236, 239, 241, 242, and 245 are shown on Plate XX.

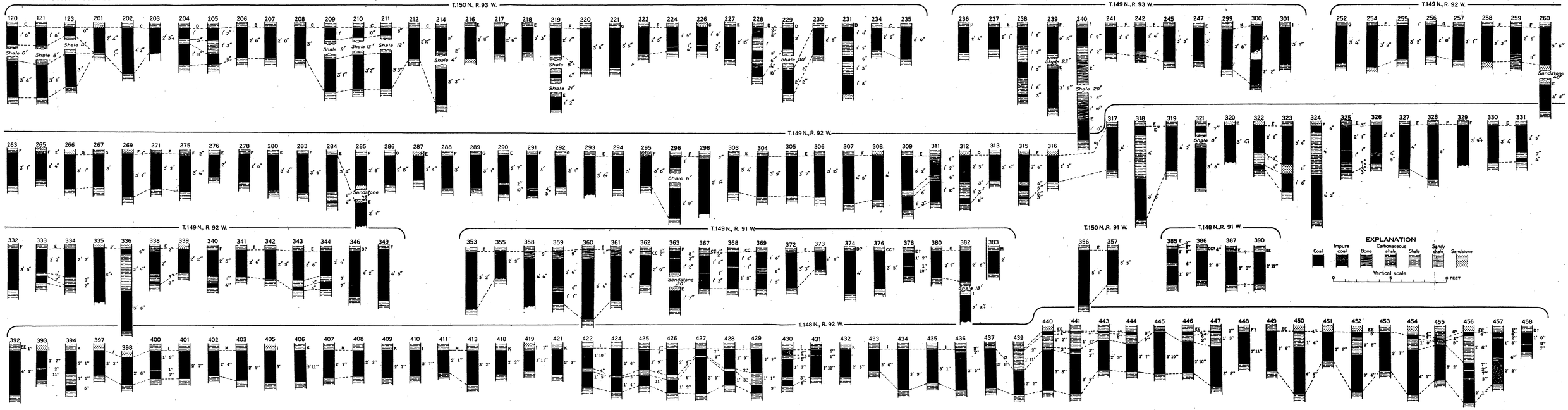
At location 246, in sec. 1, bed G is 1 foot 10 inches thick. In secs. 32, 35, and 36 there is a bed of lignite at about the same position as bed I. However, no measurement, except at location 301 (see Pl. XX), was obtained on this bed, but in the township to the south, where it was mapped extensively, it was measured in many places and averages over 3 feet in thickness.

Another bed corresponding to bed K in the township immediately to the south was measured at locations 299 and 300, in sec. 36, and averages 4½ feet in thickness, though its upper portion is bony at location 300. (See Pl. XX.)

Bed M was measured in a number of places in the township to the south and was mapped for a short distance in this township, although no section of it was obtained here.

T. 149 N., R. 94 W.

T. 149 N., R. 94 W., is largely a grass-covered upland. Several streams head in the township, among them Squaw and Bear Den



SECTIONS OF LIGNITE BEDS IN THE NORTHERN PART OF THE FORT BERTHOLD INDIAN RESERVATION, NORTH DAKOTA

creeks. The valleys, as shown in Plate XXV, *A*, are broad, with gentle slopes, and do not seem to have been affected by the advance of the ice sheet, although here and there erratic boulders are found. Most of the township is lacking in rock exposures, and outcrops of lignite beds were found only in a few localities in secs. 6 and 7. Section 194 represents a lenticular bed of lignite that lies between beds C and D and is 2 feet thick. Sections 191 and 193 represent bed D, which averages about 3½ feet in thickness in this township. (See Pl. XVII.) Section 190 probably shows bed E, and sec. 192, bed F.

T. 149 N., R. 95 W.

The eastern part of T. 149 N., R. 95 W., comprising a strip of land less than 1 mile wide and about 6 miles long, is included in the Fort Berthold Reservation. The southern part of this strip is a high, rolling upland. The northern part lies in the valley of Bear Den Creek, which furnishes several good exposures of the lignite-bearing formation. Four beds of lignite (beds C, D, E, and F) that are exposed in the township immediately to the north crop out in this township also and were measured in the NE. ¼ sec. 12. Their thickness and general relations are given in stratigraphic section 3, Plate XVI, the upper 180 feet of which was measured on a butte just outside of the reservation. Location 195 is on bed C, 196 on bed D, 197 on bed E, and 198 on bed F. (See Pl. XVII.) At location 197 bed E contains 2 feet 1 inch of lignite separated into two equal benches by 3 feet of shale. The section at location 189, in the NE. ¼ sec. 1, represents bed F and is given on Plate XVII. At location 198 bed F contains 1 foot 2 inches of lignite.

T. 148 N., R. 91 W., NORTH OF LITTLE MISSOURI RIVER.

The part of T. 148 N., R. 91 W., lying north of Little Missouri River and west of Missouri River is here described. The part lying south of Little Missouri River is described on page 162. The eastern half of the area here described consists of the flood plain of Missouri and Little Missouri rivers. The western part of the township is a rolling upland about 150 feet above the river. Outcrops of stratified rocks are few and limited to small areas. Two beds of lignite crop out in secs. 4, 5, 8, and 9, and one bed in secs. 19 and 30. The lower bed mapped in this township (called bed CC?) is probably the same as the lowest bed mapped in the township to the north. It was measured only at location 386, in sec. 5, where it carries 2 feet 8 inches of lignite.

The next higher bed is correlated with bed E of the township to the north and was measured at locations 285 and 287. The bed

mapped in secs. 19 and 30 is probably bed E, as it has about the same position. However, owing to the uncertainty of the correlation, it is called bed EE. It was measured at locations 388, 389, and 390. Section 390 is shown on Plate XX; the other two are given below.

Sections of lignite bed EE in T. 148 N., R. 91 W.

[In addition to that shown on Pl. XX.]

No. on map (Pl. XXVIII).	Location.	Section.	
			Ft. in.
388	NE. ¼ sec. 30	Lignite	2 2
389	NW. ¼ sec. 30	Lignite	2 11

This bed becomes thicker toward the west and was mapped continuously in that direction for more than 25 miles.

T. 148 N., R. 92 W.

T. 148 N., R. 92 W., is drained by Squaw Creek and other small streams that flow into Little Missouri River. The valley of Squaw Creek is nearly as wide as the valley of the Little Missouri, though the creek is about one-tenth the size of the river. The central part of the township is a rolling upland dissected by the sharp, steep-sided valleys of southward-flowing intermittent streams. Near the north boundary of the township is a group of high buttes headed on the east by Saddle Butte. A spur of bare buttes extends southward from this group in the west-central part of the township. The relief is about 700 feet.

The general character and relation of the rocks in this township are shown in stratigraphic section 5, Plate XVI. The beds have a general eastward dip of about 12 feet to the mile. Minor structural features, such as a shallow syncline in sec. 16, a low dome in secs. 4 and 9 pitching rather steeply to the east in sec. 15, and a synclinal basin with its center in sec. 11, were determined by careful plane-table traverse on lignite bed I. However, the greatest observed dip in this township is less than 2°. A thin mantle of glacial drift covers the gentle slopes of Squaw Creek valley (Pl. XXV, *A*), and in the NE. ¼ sec. 33 glacial till was noted with a maximum thickness of 6 feet.

Four valuable beds of lignite are exposed in this township. Bed EE crops out along Little Missouri River and Squaw Creek, with an average thickness of 3 feet. Sections measured at locations 391, 392, 437, 439 to 447, and 449 to 457 show the character of this bed. These sections are shown graphically in Plate XX, except those at locations 391 and 442, at both of which bed EE carries 1 foot 10 inches of lignite.

A thin bed of lignite about 30 feet below bed EE was measured at locations 451[11] and 458. Its correlation with bed D is uncertain. The measurements are tabulated below.

Sections of lignite lens in T. 148 N., R. 92 W.

[Not included in Pl. XX.]

No. on map (Pl. XXVIII).	Location.	Section.	Ft.	in.
451	SW. ¼ sec. 27	Lignite	2	6
458	SE. ¼ sec. 32	Lignite	1	7

A bed of lignite higher than bed EE and probably corresponding to bed F was measured at location 448, in sec. 26, where it contains 3 feet of lignite. This bed is about 40 feet above bed EE and carries lignite of poor quality.

A second bed of importance in the township is bed I, which is about 175 feet above bed EE. This bed is somewhat variable in thickness, but as shown by the measurements on Plate XX, it averages over 2 feet 6 inches of good lignite. It is represented by sections 393, 395, 397, 398, 400, 401, 405, 410, 416, 419, 420, 422 to 431, and 433 to 436, all of which except those tabulated below are given on Plate XX.

Sections of lignite bed I in T. 148 N., R. 92 W.

[In addition to those shown on Pl. XX.]

No. on map (Pl. XXVIII).	Location.	Section.	Ft.	in.
395	NE. ¼ sec. 13	Lignite	1	11
416	NE. ¼ sec. 11	Lignite	1	9
420	NE. ¼ sec. 14	Lignite	1	9
423	NE. ¼ sec. 15	Shale, carbonaceous.		
		Lignite	1	4
		Shale		9
		Lignite		4
		Shale.		

Bed K, which lies about 80 feet above bed I, was mapped in the northeastern part of this township and also in sec. 18. It has an average thickness of about 2 feet and is represented by sections 394, 396, 399, 404, 406, 409, 417, 418, 421, and 432. These sections are shown graphically on Plate XX, with the exception of those given in the following table:

[11] On Plate XX section 451 is erroneously credited to bed EE, whereas it represents a bed 30 feet below bed EE.

Sections of lignite bed K in T. 148 N., R. 92 W.

[In addition to those shown on Pl. XX.]

No. on map (Pl. XXVIII).	Location.	Section.	
			Ft. in.
396	SE. ¼ sec. 12	Lignite	1 9
399	SW. ¼ sec. 12	Lignite	1 8
404	SW. ¼ sec. 1	Lignite	1 6
417	SW. ¼ sec. 12	Lignite	1 5

Bed M is about 25 feet above bed K and is thick enough to warrant mapping (2 feet or more) only in secs. 1, 2, 3, 11, and 12. Measurements of this bed were obtained at locations 402, 403, 407, 408, 411, 412, 413, 414, and 415, and are shown graphically on Plate XX, with the exception of those which are tabulated below.

Sections of lignite bed M in T. 148 N., R. 92 W.

[In addition to those shown on Pl. XX.]

No. on map (Pl. XXVIII).	Location.	Section.	
			Ft. in.
412	NW. ¼ sec. 2	Lignite	1 4
414	NW. ¼ sec. 11	Lignite	1 5
415	NE. ¼ sec. 11	Lignite	1 8

A stratigraphic section including about 300 feet of strata was measured in a butte at location 438. Two beds of lignite, corresponding to beds I and K of the townships farther north, were found. Both were less than 2 feet thick at this place.

T. 148 N., R. 93 W.

T. 148 N., R. 93 W., is traversed diagonally from northwest to southeast by the broad valley of Squaw Creek, which at its upper ends opens out into the broad flat of the upland, as shown in Plate XXV, *A*, but which lower down in this township is bordered by badlands that give it a much more rugged appearance. A group of these buttes in sec. 9 is shown in Plate XXIV, *A*, and another group exhibiting typical topography of the western part of the reservation is shown in Plate XXIV, *B*.

The lignite-bearing rocks are very well exposed along Moccasin Creek and in the high buttes on the north side of Squaw Creek. The southern exposures, as shown in Plate XXV, *B*, are much better than those on the hillsides facing the north. This seems to be due partly to the lodging of glacial drift and partly to the greater abundance of vegetation on the northern slopes. The general dip of the strata in this township is about 12 feet to the mile N. 70° E., but there are

many minor undulations in the beds which cause local dips in various directions. A low anticline with its axis approximately in secs. 8 and 9 and a shallow syncline with its axis in sec. 14 were determined by comparing altitudes on the lignite beds. None of the observed dips exceed 2°. A thin mantle of glacial drift forms the surface over most of the highland and in a few of the larger valleys. In the NW. ¼ sec. 27 a section of glacial drift 12 feet thick was measured. The drift contains at this place principally limonite concretions, boulders of sandstone and shale, and pebbles of limestone, granite, and quartzite. The whole is loosely cemented with gypsum and limonite.

Five beds of lignite were mapped in this township, but none of them is thick enough to justify mapping all along its outcrop. Bed EE, the lowest bed exposed, was measured only at locations 524 and 525, in sec. 36. At location 524 this bed contains less than 12 inches of lignite, and at location 525 it carries 3 feet 3 inches of lignite. In the township immediately to the south, where this bed is much thicker, its outcrop has been mapped for long distances.

Bed FF is poorly exposed, and where it crops out it is too thin to be of value.

Bed I in this township is about 150 feet higher than bed EE, and its average thickness is about 3 feet. Sections 459, 463, 464, 465, 469, 474, 475, 479, 486, 487, 492, 493, 494, 497, 499, 500, 502, 506, 507, 509, 516, 519, 520, and 521 (Pl. XXIII) represent this bed. At location 465, in sec. 13, this bed contains 2 feet 3 inches of impure lignite; at location 494, in sec. 4, 1 foot 10 inches of lignite. Section 522, showing nearly 4 feet of lignite, is probably on the same bed but could not be identified with certainty. A lenticular bed of lignite about 25 feet above bed I was measured at location 473, where it is 2 feet thick. Both east and west of this place this bed is thinner. Section 481 represents a worthless bed somewhat higher than bed I, which may correspond to bed J.

Bed K, which has an average thickness of about 3 feet, is represented by sections 468, 471, 476, 480, 485, 489, 491, 495, 498, 501, 503, 505, 508, 512, 515, 517, 518, and probably also 523. These are shown graphically on Plate XXIII. At location 523 a bed of lignite is 1 foot 2 inches thick.

Sections 460, 461, 466, 470, 472, 477, 482, 484, 488, 490, 496, 504, 510, 511, 513, and 514 represent bed M. (See Pl. XXIII.) This bed contains 1 foot 11 inches of lignite at location 496, but its average thickness is 3 feet 6 inches. Bed N, the highest bed of lignite stratigraphically that is mapped in this township, is represented by sections 467, 478, and 483. It is lenticular, but in its lower part the lignite is of very good quality and averages 2 feet 10 inches in thickness.

Good exposures of the rocks occur in secs. 34 and 35, but they are noticeably lacking in beds of lignite. The strata here are composed mainly of yellow sandstone and gray clayey sandstone.

T. 148 N., R. 94 W.

T. 148 N., R. 94 W., lies largely on the upland, which is surmounted here and there by buttes 200 to 300 feet high. Exposures of the lignite-bearing formation are confined almost entirely to the few isolated hills and the badlands in sec. 31. The strata apparently lie nearly flat. Only one lignite section was obtained in the township, at location 636, in sec. 27, where a bed of lignite 2 feet 10 inches thick crops out in a tributary of Moccasin Creek. It is probable that the bed which was mapped in sec. 31 underlies most of this township and may be the same as the bed mapped in secs. 1 and 12. The strata exposed in the high hills in this township seem to be barren of lignite.

T. 148 N., R. 95 W.

That part of T. 148 N., R. 95 W., that lies within the Fort Berthold Reservation is described here. The lignite-bearing rocks are very well exposed in this township, especially in the almost vertical cliffs in the badlands along Sams Creek. Two valuable beds of lignite and numerous thin beds crop out here. The lowest one is probably bed EE, whose average thickness is about 12 feet. It is represented by sections 627, 628, and 631, Plate XXIII. Owing to the burning of the outcrop it is generally concealed by clinker. A lenticular bed about 2 feet 10 inches thick and 20 feet higher (bed FF ?) was measured at location 632. Another thin bed (bed HH) was measured at location 633, where it contains 2 feet 4 inches of impure lignite. Bed I–J, with an average thickness of 3 feet 10 inches, crops out for some distance in this township and is represented by sections 626, 629, 630, 634, and 635, Plate XXIII. At location 635 the bed is composed principally of shale, as shown below.

Section of lignite bed I–J at location 635, sec. 27, T. 148 N., R. 95 W.

	Ft.	in.
Shale.		
Bone	2	1
Shale		8
Lignite		5
Shale		3
Lignite	1	3
Shale.		
	4	8

Several beds of lignite were noted in the northern part of the township, but as they are less than 2 feet thick they were not mapped.

T. 147 N., RS. 92 AND 93 W., WEST OF LITTLE MISSOURI RIVER.

The parts of T. 147 N., Rs. 92 and 93 W., that are here described lie north and west of Little Missouri River. (See Pl. XXVIII.) These contiguous townships are described together because of the similarity of their surfaces and the continuity of outcrops of lignite beds from one to the other. That part of the townships adjacent to the Little Missouri contains some of the roughest badlands in North Dakota. Views of these badlands in secs. 25 and 26 are shown in Plate XIV. They are generally without vegetation and thus afford excellent exposures of the lignite-bearing formation. The southern slopes are almost free of vegetation, but the northern slopes are commonly covered with grass, and some of the coulees contain a dense growth of scrub pines. In sec. 6, T. 147 N., R. 92 W., the badlands are not so prominent as farther south, and the valley of Moccasin Creek, as shown in Plate XV, *B*, is broad and has comparatively gentle slopes.

In sec. 19, T. 147 N., R. 93 W., there is a flat tract on which the glacial boulders shown in Plate XIX, *A*, are scattered in great numbers. At several places blocks of granite a yard or two in length lie upon the surface.

The dip of the beds is about 8 feet to the mile in a southeasterly direction, as determined by stadia traverse on the lignite beds. Eight beds of lignite of sufficient thickness to justify mapping crop out in these two townships, and owing to the excellent exposures in the badlands most of the lignite beds can readily be studied in detail. The stratigraphic position of lignite beds in these townships is shown in section 7, Plate XVI.

The lowest bed stratigraphically is at about the same horizon as bed DD and crops out in several localities, but is not thick enough to justify mapping except at location 594, in sec. 20, T. 147 N., R. 93 W., where it contains 3 feet 2 inches of good lignite. West of this place the bed is burned on the outcrop for a short distance, and beyond the burned area it is covered by alluvium of the river flood plain. At location 579 the following section of this bed was measured:

Section of lignite bed at location 579, sec. 28, T. 147 N., R. 93 W.

	Ft.	in.
Shale.		
Lignite	1	
Shale	9	
Lignite	1	3
Shale.		
	11	3

Bed EE, which is perhaps the most persistent and valuable bed in these townships, is about 30 feet above bed DD. In the NW. ¼ sec. 1, T. 147 N., R. 93 W., it is less than 30 inches thick, but east and

south of this place it generally measures 3 feet or more. It is represented on Plate XXIII by sections 526 to 531, 542, 549, 569, 573, 578, 591, and 595.

The greater part of the outcrop of bed EE is covered by clinker, and as it crops out near the bases of talus slopes it is also covered in many places by débris from the weathering of younger strata.

A thin bed of lignite about 20 feet above bed EE was measured at locations 550, 583, and 598, in T. 147 N., R. 93 W. At location 550 it carries 10 inches of lignite; at location 583, 2 feet; and at location 598, 1 foot 9 inches.

The beds of lignite higher in the formation can not be certainly correlated with those in the northern part of the Fort Berthold field; therefore double letters are used to designate the beds. Bed GG, which is at about the horizon of bed G, has a more sinuous outcrop than any other lignite bed in these townships and is also the best exposed, as it crops out at an altitude where rapid erosion is in progress. It is fairly constant in thickness, averaging about 5 feet, but contains a high percentage of ash. It is present at locations 535, 541, 551, 557, 559, 560, 563, 576, 577, 580, 584, 585, 590, 596, 597, and 599, in T. 147 N., R. 93 W.; and locations 564 and 572, in T. 147 N., R. 92 W. The sections at these locations are shown graphically on Plate XXIII, with the exception of section 535, which includes only 10 inches of lignite.

Bed HH is generally separated from bed GG by 20 to 35 feet of yellow sandstone. It occurs at locations 540, 543, 546, 565, and 571, in T. 147 N., T. 92 W.; and locations 534, 537, 552, 558, 561, 577, 586, 588, and 589, in T. 147 N., R. 93 W. (See Pl. XXIII.) Its average thickness is nearly 4 feet.

Bed II is represented in T. 147 N., R. 92 W., by sections 545 and 568, and in T. 147 N., R. 93 W., by sections 539, 548, 553, 577, and 592 (Pl. XXIII); it averages about 3 feet in thickness.

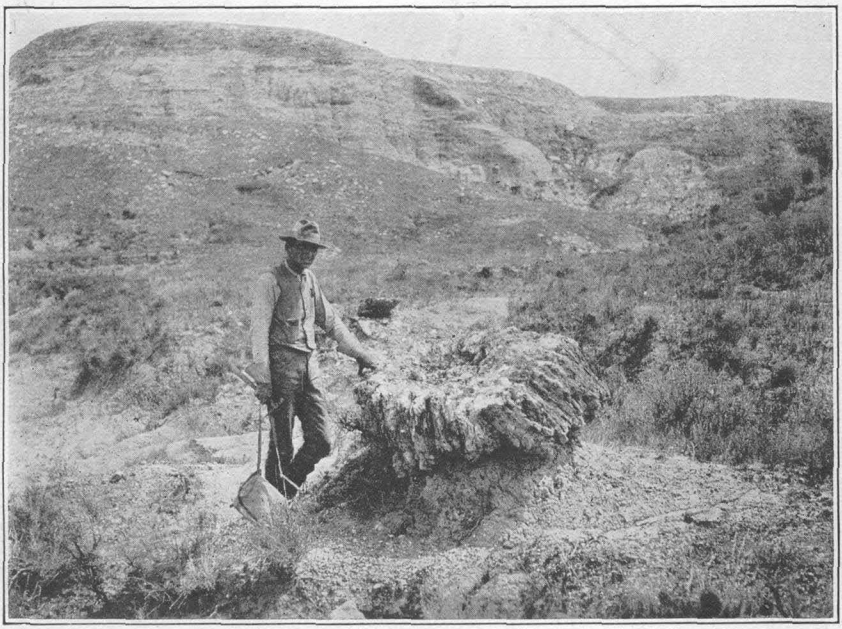
Bed JJ is mapped for a considerable distance in these townships. It lies in a zone of shale and in some places contains a small amount of gypsum. This bed occurs at locations 544, 566, and 570, in T. 147 N., R. 92 W., and locations 532, 533, 536, 538, 547, 554, 562, 581, 582, and 587, in T. 147 N., R. 93 W. The sections at these locations, with the exception of those tabulated below, are shown graphically on Plate XXIII.

Sections of lignite bed JJ in T. 147 N., Rs. 92 and 93 W.

[In addition to those shown on Pl. XXIII.]

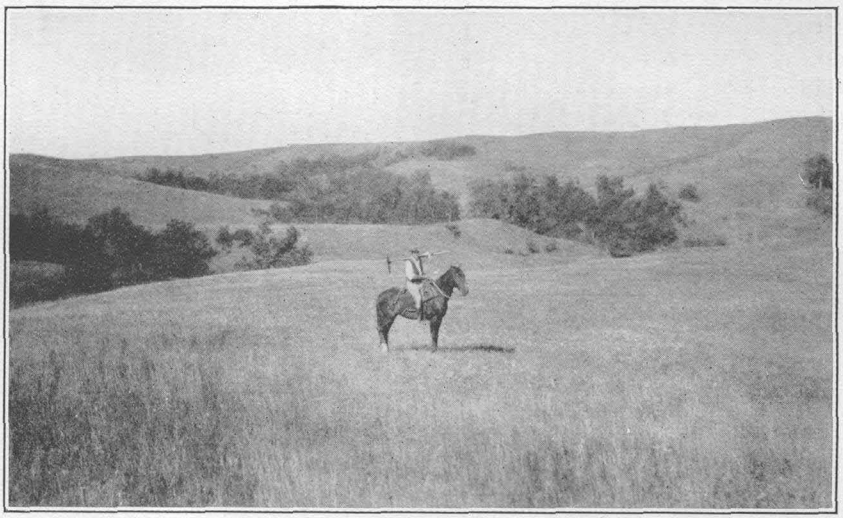
No. on map (Pl. XXVIII).	Location.	Section.		
			Ft.	*in.*
566	SE. ¼ sec. 19.	Lignite	3	2
554	NE. ¼ sec. 14.	Bone	2	8

A. FOSSIL LOG STANDING NEARLY UPRIGHT IN CLAY SHALE OF THE FORT UNION FORMATION.



B. FOSSIL STUMP IN FORT UNION FORMATION.

A. SAGE-BRUSH FLAT OF HANS CREEK, N. DAK., AND BLUFFS OF THE FORT UNION FORMATION.



B. ROLLING UPLAND IN THE FORT BERTHOLD INDIAN RESERVATION, N. DAK.

Sections 555 and 574, representing bed KK, were measured in T. 147 N., R. 93 W. (See Pl. XXIII.) A section of this bed in T. 147 N., R. 92 W., is given below.

Section of lignite bed KK at location 567, in sec. 19, T. 147 N., R. 92 W.

	Ft.	in.
Sandstone.		
Lignite		8
Shale, carbonaceous	3	
Lignite	1	6
Shale.		
	5	2

Sections 556, 575, and 593 represent lignite bed MM in T. 147 N., R. 93 W. The bed averages over 5 feet in thickness and is the highest bed of lignite that is exposed in this township. In many places its outcrop is obscured by clinker. In secs. 11, 14, 15, 16, 17, and 20, T. 147 N., R. 93 W., there are several large areas in which this bed has been burned.

In secs. 2, 5, and 34, T. 147 N., R. 93 W., excellent exposures of the rocks, chiefly above the horizon of bed MM, reveal only thin beds of lignite or none at all.

T. 147 N., R. 94 W.

The part of T. 147 N., R. 94 W., here described lies north of Little Missouri River. The lignite-bearing rocks are well exposed along that stream and its tributary gullies. The ground in the northern part of the township is level and covered by a thin mantle of glacial débris. A few foreign boulders derived from glacial drift are also found in the stream valleys, mingled with the alluvium of the river flood plain. A northwestward dip of 15 feet to the mile was noted in sec. 15, but elsewhere the beds have a general southeastward dip. Several high buttes occur in sec. 2.

Five beds of lignite crop out in this township. Bed EE, the lowest one, is represented by sections 604, 609, 613, and 614 (Pl. XXIII) and ranges in thickness from 7 feet 11 inches at location 604 to 10 feet 3 inches at location 614.

A lenticular bed near the horizon of bed FF and about 25 feet higher than bed EE has the following section at location 603:

Section of lignite bed at location 603, sec. 13, T. 147 N., R. 94 W.

	Ft.	in.
Shale, sandy.		
Lignite		8
Shale, carbonaceous	1	
Lignite		10
Shale, carbonaceous.		
	2	6

Sections 602, 605, 610, 617, and 618, Plate XXIII, represent bed GG, which ranges in thickness from 1 foot 2 inches at location

622 to 4 feet 2 inches at location 618. At location 617 the bed carries 2 feet 7 inches of lignite, containing a large amount of gypsum. At location 622 bed GG contains 1 foot 2 inches of lignite.

Bed HH was mapped in the western part of the township and is represented by sections 619, 620, and 622, Plate XXIII. Beds GG and HH are separated by about 20 feet of yellow sandstone, and it is notable that where one is thin the other is thick. Both beds are lenticular, and the lignite is variable in quality.

In the western part of this township beds II and JJ are mapped as one because they are generally separated by not more than 5 feet of strata, but in the eastern part (sec. 13, locations 600 and 601) these beds are separated by about 40 feet of shale and are mapped separately. This divergence of strata is not an uncommon feature in this field among thin beds of shale and sandstone as well as beds of lignite. (See fig. 15, p. 126.) Sections 601, 606, and 611 represent bed II; sections 600, 607, and 612 bed JJ; and sections 615, 616, 621, 623, and 624 the combined beds I–J.

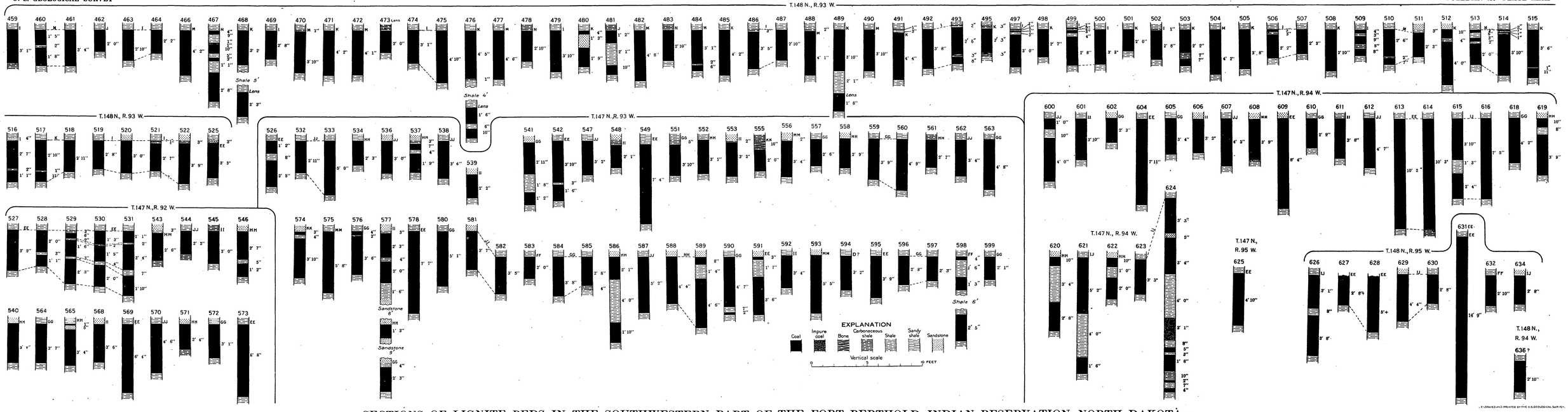
Bed KK is less than 2 feet thick in this township and was not mapped. The highest bed mapped is bed MM, which, as measured at location 608, is 3 feet 9 inches thick. (See Pl. XXIII.)

T. 147 N., R. 95 W.

The part of T. 147 N., R. 95 W., here described lies north of Little Missouri River. Rocks are exposed in the SE. ¼ NE. ¼ sec. 1, but elsewhere the surface material is the alluvium of the river flood plain. One bed of lignite was found and as measured at location 625 (see Pl. XXIII) has a thickness of 4 feet 10 inches. This bed is believed to be bed EE, mapped in T. 147 N., R. 93 W. The strata have a slight eastward dip.

T. 147 N., R. 92 W., EAST OF LITTLE MISSOURI RIVER.

The part of T. 147 N., R. 92 W., which lies west of Little Missouri River is described on pages 151–153, in connection with T. 147 N., R. 93 W.; the part here described lies east of Little Missouri River. This stream has a deep troughlike valley, on either side of which, in a belt 3 or 4 miles wide, are the extensive badlands shown in Plate XIV. These consist of small gorges or steep-sided gulches cut into the uplands so as to form an intricate network of drainage and make the tract practically impassable. In many places these gullies are only a few feet in width, but their depth may be so great as to make it impossible to cross them. The upland is rolling and well covered with grass. The rocks exposed in the township consist principally of sandy shale and sandstone, with numerous beds of lignite. Some of the strata are cross-bedded and exhibit other features indicative of



SECTIONS OF LIGNITE BEDS IN THE SOUTHWESTERN PART OF THE FORT BERTHOLD INDIAN RESERVATION, NORTH DAKOTA

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deposition by rapidly moving currents of water; some suggest eolian deposition; others suggest deposition in swirls or eddies of streams; still others appear to have been formed in deltas; and undoubtedly some of the beds of carbonaceous shale and lignite were formed in marshes. The strata lie nearly flat, as is proved by the fact that altitudes on the same bed of lignite 5 or 6 miles apart are, as a rule, nearly the same. However, local dips in various directions were noted. The maximum relief in this township is about 600 feet.

Nine beds of lignite 2 feet or more in thickness have been traced and mapped in this township, some for only short distances and others across the entire township. The approximate stratigraphic positions of these beds are shown in section 7, Plate XVI. At many of the locations two or more lignite beds are exposed, and in the following descriptions the numbers are repeated for each bed. The lowest bed exposed is bed DD, which was mapped for a short distance in secs. 1 and 12 and measured at locations 749 and 750. At location 749 it contains 2 feet 4 inches of lignite, and at location 750 it contains 1 foot 7 inches.

Bed EE is about 30 feet higher than bed DD and is probably the most valuable bed in this township and the one immediately to the west, as it averages over 4 feet in thickness and underlies practically all of the area except the flood plain of Little Missouri River. It was measured at locations 641, 715, 726, 729, 730, 732, 733, 739, 740, 745, 746, 748, 749, and 751. Sections at all these locations are shown on Plate XXVI, except Nos. 748 and 749, which are given below.

Sections of lignite bed EE in T. 147 N., R. 92 W.

[In addition to those shown on Plate XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
748	NE. ¼ sec. 13	Shale.		
		Shale, carbonaceous		3
		Lignite	1	
		Shale, carbonaceous	1	
		Lignite, dirty		8
749	NE. ¼ sec. 12	Shale.		
		Shale, carbonaceous	1	2
		Lignite	1	8
		Shale.		

Bed FF is about 20 feet above bed EE and is very lenticular. It was mapped only in the northern part of this township and was measured at locations 730, 732, 733, and 739 (Pl. XXVI). The bed contains 1 foot 9 inches of lignite at location 730 and 1 foot 8 inches at location 739.

Bed GG is about 30 feet above bed FF and averages more than 3 feet in thickness in the eastern part of the township, but in the western part it is very thin or absent. Sections 729, 730, 739, 742,

746, and 747 were measured on bed GG; section 746 is shown on Plate XXVI, and the other measurements are given in the following table:

Sections of lignite bed GG in T. 147 N., R. 92 W.

[In addition to that shown on Plate XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
729	SW. ¼ sec. 4	Sandstone.		
		Lignite		10
		Shale		8
		Lignite, poor	1	2
		Shale.		
730	NW. ¼ sec. 3	Shale.		
		Lignite		6
		Shale		5
		Lignite, dirty	1	2
		Shale.		
739	NW. ¼ sec. 13	Shale.		
		Lignite		5
		Shale		2
		Lignite	1	3
		Shale.		
742	SW. ¼ sec. 13	Lignite		8
		Shale, carbonaceous		4
		Lignite,	1	8
747	NE. ¼ sec. 13	Shale.		
		Lignite	1	7
		Shale, sandy.		

A lenticular bed at about the horizon of bed GG was measured at location 718, where it contains but 1 foot 2 inches of lignite. Bed HH is separated from bed GG by about 25 feet of drab shale, and it has an average thickness of 2 feet 8 inches. In this township the bed was measured at locations 637, 638, 642, 714, 716, 719, 726, 727, 729, and 745.[12] These sections are shown on Plate XXVI, with the exception of those given below.

Sections of lignite bed HH in T. 147 N., R. 92 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
716	SE. ¼ sec. 29	Lignite		2
719	SW. ¼ sec. 20	Shale.		
		Bone		4
		Shale		5
		Lignite	1	4
		Shale.		
727	SE. ¼ sec. 16	Sandstone.		
		Lignite		8
		Shale		3
		Lignite	1	9
		Shale.		
729	SW. ¼ sec. 4	Lignite		8
745	NW. ¼ sec. 24	Lignite	2	

[12] Section 745 is labeled bed GG on Plate XXVI; it should be labeled bed HH.

The next important bed of lignite higher in the section is bed II, which averages 3 feet in thickness and was measured at locations 639, 642, 700, 710, 712, 714, 716, 720, 726, 727, 728, 729, 731, 735, 736, 737, 738, 741, 742, 743, and 746. These sections are given graphically on Plate XXVI with the exception of those tabulated below.

Sections of lignite bed II in T. 147 N., R. 92 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
712	NE. ¼ sec. 34	Sandstone.		
		Lignite	3	4
		Shale.		
716	SE. ¼ sec. 29	Lignite	3	
729	SW. ¼ sec. 4	Lignite	1	8
737	SE. ¼ sec. 16	Lignite	2	
742	SE. ¼ sec. 13	Lignite	2	
746	SE. ¼ sec. 13	Shale.		
		Lignite	1	
		Shale, carbonaceous		11
		Shale.		

Bed JJ, whose average thickness is 1 foot 8 inches, was measured at locations 716, 721, 726 to 729, 731, 735 to 738, 741 to 743, and 745. These measurements are shown graphically on Plate XXVI, with the exception of those tabulated below.

Sections of lignite bed JJ in T. 147 N., R. 92 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	In.
716	SE. ¼ sec. 29	Lignite	2	
721	SE. ¼ sec. 20	Lignite	2	2
727	SE. ¼ sec. 16	Lignite	1	10
728	NE ¼ sec. 16	Lignite	1	5
729	SW ¼ sec. 4	Lignite	1	7
731	SE. ¼ sec. 3	Lignite	1	2
735	SE. ¼ sec. 11	Lignite	1	
736	SE. ¼ sec. 11	Lignite	1	5
737	SE. ¼ sec. 15	Lignite	1	1
738	SW. ¼ sec. 14	Lignite	1	3
741	NE. ¼ sec. 14	Lignite	1	6
742	SE. ¼ sec. 14	Lignite	1	2
743	SE. ¼ sec. 14	Lignite	1	2

Bed KK, which averages 2½ feet in thickness in this township, was measured at locations 640, 701, 704, 706, 708, 709, 713, 716, 717, 722, 726 to 728, 731, 734 to 738, and 741 to 743. The measurements of this bed are shown graphically on Plate XXVI, with the exception of those tabulated on page 158.

Sections of lignite bed KK in T. 147 N., R. 92 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
701	SW. ¼ sec. 35	Lignite	1	2
704	NW. ¼ sec. 35	Lignite	1	8
706	SW. ¼ sec. 26	Lignite	1	10
708	SW. ¼ sec. 26	Lignite	1	10
709	SE. ¼ sec. 27	Lignite	2	
716	SE. ¼ sec. 29	Lignite	2	4
736	SE. ¼ sec. 11	Lignite	2	2
738	SW. ¼ sec. 14	Lignite	1	5
741	NW. ¼ sec. 14	Lignite	1	10
742	SE. ¼ sec. 14	Lignite	1	5
743	SE. ¼ sec. 14	Lignite (bottom of bed unexposed)	1	6+

Bed LL is generally less than 2 feet thick in this township and contains lignite of poor quality. It is represented by sections 702, 708, 713, 716, 723, 728, 737, and 745. Sections 713 and 745 are shown graphically on Plate XXVI; the remainder are tabulated below.

Sections of lignite bed LL in T. 147 N., R. 92 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
702	SW. ¼ sec. 35	Lignite	1	10
708	SW. ¼ sec. 26	Lignite		8
716	SE. ¼ sec. 29	Lignite	3	
723	SE. ¼ sec. 20	Lignite	1	11
728	NE. ¼ sec. 16	Lignite, very impure	2	
737	SE. ¼ sec. 15	Lignite, impure	2	11

Bed MM is the highest bed of lignite mapped in the township, and it averages 3 feet in thickness, as shown by sections 689, 705, 708, 711, 713, 716, 724, and 725. All these sections are given on Plate XXVI except section 716, which shows 1 foot of lignite.

Several thin lenses of lignite from 10 to 15 feet above bed MM were measured at locations 688, 707, 713, and 728. These measurements are tabulated below.

Sections of lignite lenses above bed MM in T. 147 N., R. 92 W.

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
688	SW. ¼ sec. 36	Lignite, dirty	1	4
707	SW. ¼ sec. 26	Lignite		9
713	NW. ¼ sec. 34	Lignite	1	2
728	NE. ¼ sec. 16	Lignite	1	10

T. 146 N., R. 92 W.

The part of T. 146 N., R. 92 W., here described lies within the Fort Berthold Reservation. Hans Creek flows northwestward through the township, entering at sec. 12 and leaving at sec. 4. Its valley, as shown in Plate XXII, *A*, is fairly wide for the size of the stream and is bordered on either side by badlands, particularly in the northwestern part of the township. Many of the tributary streams are cut into the soft Fort Union strata, so that gorges and canyons are common. Fantastic peaks of Fort Union strata, such as the one shown in Plate XVIII, *A*, overlook the valley from the south, and the wash of the rain has carved them into fantastic shapes and seamed them with countless channels of the most delicate tracery. These precipitous peaks, together with the steep-sided canyons, make the country exceedingly difficult to cross. The relief amounts to about 400 feet in the maximum but is considerably less in the eastern part of the township than in the western part.

The lignite-bearing rocks are exposed in the bluffs on either side of Hans Creek and along its tributaries. Along the stream itself alluvium covers the stratified formation to a considerable depth. On the uplands a thin mantle of glacial drift is found in several localities, but usually the drift amounts to only a scattering of pebbles and boulders. It is doubtful if at any place in this township the drift is more than 15 feet thick. Consolidated glacial drift 12 feet thick was found in sec. 6 on a high ridge within half a mile of Little Missouri River. The drift does not, however, generally obscure the outcrops of lignite beds in this township.

The approximate vertical position of the lignite beds in this township is shown in stratigraphic section 7, Plate XVI. At several of the locations indicated by numbers on this section two or more beds of lignite occur. The lowest bed of lignite exposed in this township was measured at location 647, in sec. 5. This bed, as indicated by measurements in the surrounding townships, has an average thickness of over 5 feet and has been called for convenience bed EE and correlated with bed EE north of Little Missouri River. At location 647 the entire thickness could not be measured owing to the fact that the base of the bed was covered by a large slump. However, it carries over 6 feet of lignite at this place. (See Pl. XXVI.) The next higher important bed of lignite in this township is separated from bed EE by about 100 feet of sandy shale and sandstone containing two thin beds of lignite. These thin beds (FF and GG) were not mapped, as each contains less than 2 feet of good lignite. Bed HH, which has an average thickness of about 4 feet 6 inches in this township, was measured at locations 645, 646, 648, 649, 651, 654, 657, 658,

659, 666, 668, 670, 695, 697, and 699. All the sections are shown on Plate XXVI.

Bed II, which has an average thickness of about 2 feet 6 inches, was measured at locations 645, 646, 651, 652, 653, 656, 658, 660, 664, 665, 667, 671, 672, 685, 694, 696, and 699, as shown in Plate XXVI. Sections of bed II not shown on this plate are given in the following table:

Sections of lignite bed II in T. 146 N., R. 92 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
658	NE. ¼ sec. 9	Lignite	2	2
660	SE. ¼ sec. 9	Lignite	2	2
667	NE. ¼ sec. 10	Lignite	3	

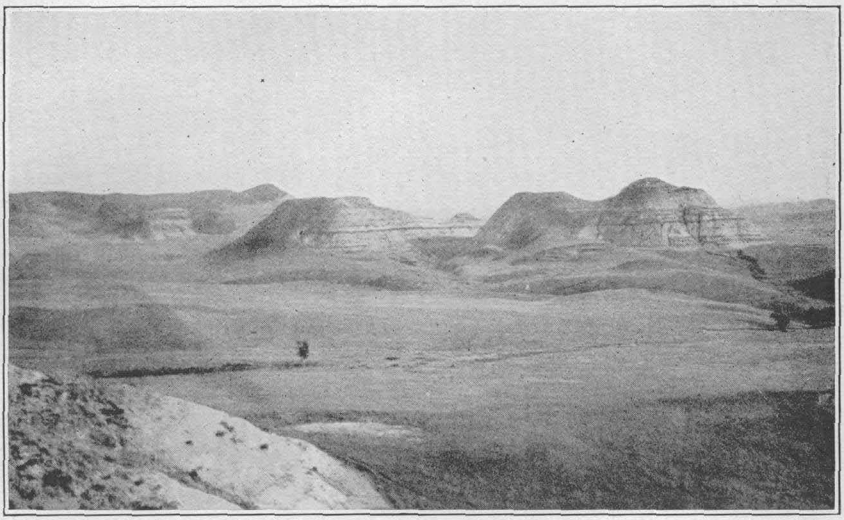
Bed JJ was measured at locations 645, 651, 655, 658, 661, 662, 669, 673, and 698. This bed averages less than 2 feet in thickness and is of poor quality. Section 661 is shown on Plate XXVI, and others are given in the following table:

Sections of lignite bed JJ in T. 146 N., R. 92 W.

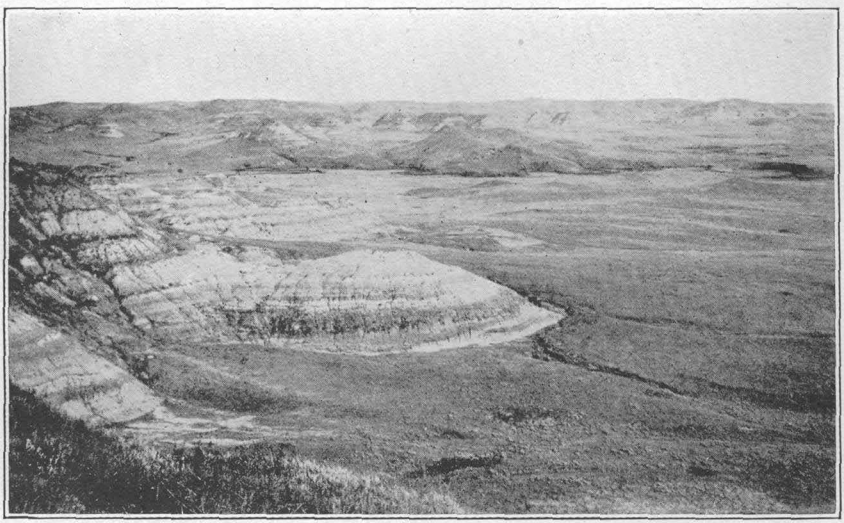
[In addition to that shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
645	NW. ¼ sec. 5	Lignite	2	1
651	SW. ¼ sec. 8	Shale, carbonaceous		8
		Lignite	1	10
		Shale, carbonaceous		8
655	SE. ¼ sec. 8	Lignite	1	5
658	NE. ¼ sec. 9	Lignite	1	3
662	SW. ¼ sec. 9	Lignite	1	7
669	NE. ¼ sec. 11	Lignite	1	10
673	NE. ¼ sec. 13	Lignite	1	8
698	NE. ¼ sec. 3	Lignite	1	6

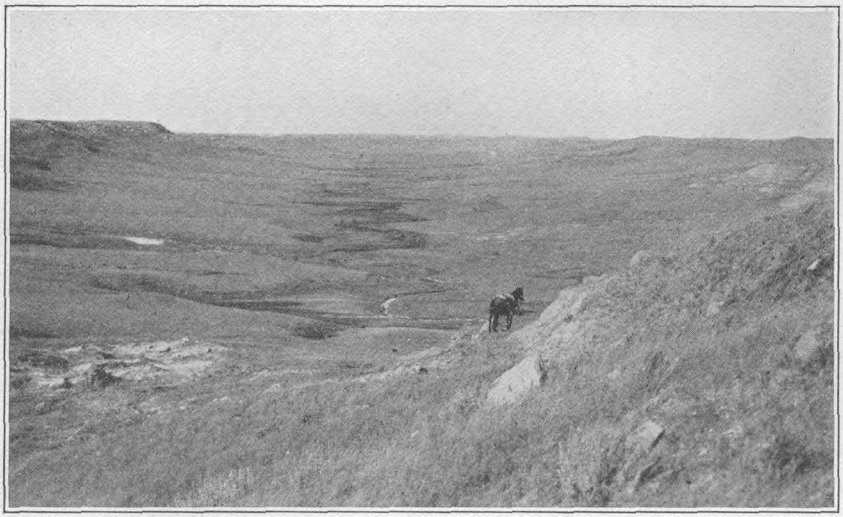
Bed KK is of value in the township to the north but is thin or absent throughout most of this township. It was measured, however, at locations 651, 655, 658, 661, 662, 682, 683, 686, 687, 690, and 692. All these sections are tabulated below, with the exception of sections 683 and 686, which are shown graphically on Plate XXVI.



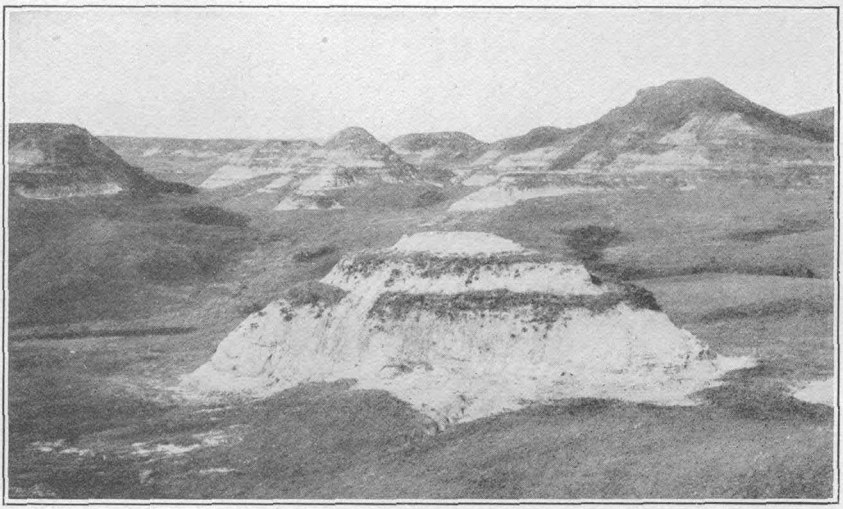
A. BUTTES IN SEC. 9, T. 148 N., R. 93 W., N. DAK.



B. BUTTES IN T. 148 N., R. 93 W., N. DAK.



A. VIEW UP SQUAW CREEK, N. DAK.



B. BARE BUTTES IN SQUAW CREEK VALLEY IN SEC. 10, T. 148 N., R. 93 W., N. DAK.

Sections of lignite bed KK in T. 146 N., R. 92 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	
			Ft. in.
651	SW. ¼ sec. 8	Lignite	1 8
655	SE. ¼ sec. 8	Lignite	1 5
658	NE. ¼ sec. 9	Lignite	1 10
661	SW. ¼ sec. 9	Lignite	1 6
662	SW. ¼ sec. 9	Lignite	1 7
682	NE. ¼ sec. 12	Lignite	2 3
687	NW. ¼ sec. 1	Lignite	2 2
690	NE. ¼ sec. 2	Lignite	2 2
692	NE. ¼ sec. 2	Lignite	1 1

A carbonaceous shale bed about 20 feet thick and about 15 feet above bed KK was noted at location 691, where it pinches out southward, being replaced by a bed of buff sandstone 20 feet thick. Half a mile to the north this carbonaceous bed suddenly becomes thin, and at location 693 it is replaced by a coarse buff sandstone, which is cross-bedded.

Bed LL lies in a zone of carbonaceous shale and is generally thin and shaly. Measurements of it were obtained at locations 643, 651, 658, 661, 663, and 681. These measurements are tabulated below or shown graphically on Plate XXVI.

Sections of lignite bed LL in T. 146 N., R. 92 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	
			Ft. in.
643	NW. ¼ sec. 6	Lignite	1 8
651	SW. ¼ sec. 8	Lignite	1 8
663	NW. ¼ sec. 16	Lignite	1 11
681	NE. ¼ sec. 12	Lignite	11

The highest bed of lignite in this township is bed MM. It is about 300 feet above bed EE and ranges in thickness from about 1 foot 1 inch at location 650 to 6 feet 4 inches at location 661, having an average thickness of about 3 feet of good lignite. Sections were measured at locations 644, 650, 651, 658, 661, 680, and 684 and are shown on Plate XXVI or tabulated below.

Sections of lignite bed MM in T. 146 N., R. 92 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	
			Ft. in.
650	NW. ¼ sec. 17	Lignite	1 1
651	SW. ¼ sec. 8	Shale, carbonaceous	5
		Lignite	2 4
		Shale.	
680	NE. ¼ sec. 12	Lignite	1 6

So far as known there are in this immediate locality no beds of lignite of any importance higher than bed MM, nor any lower than bed EE. The nearest location on a bed greater than 3 feet in thickness and stratigraphically below bed EE is in sec. 9, T. 147 N., R. 90 E., where bed CC has a reported thickness of 6 feet. As bed CC dips beneath the surface of Missouri River at this place it is probable that the bed underlies all of this township, with an average thickness of more than 3 feet.

T. 148 N., R. 91 W., SOUTH OF LITTLE MISSOURI RIVER.

The part of T. 148 N., R. 91 W., that is described here lies south of Little Missouri River and west of Missouri River. The surface of this part of the township is made up of the flood plains of the main rivers and a strip of badlands along the south. The maximum relief is about 200 feet.

The rocks consist mainly of sandy shale and sandstone interbedded with carbonaceous shale and thin beds of lignite. The surface material is largely alluvium. In places a few boulders of crystalline rock weighing several tons each were noted, which indicate that this area has been subjected to glaciation.

Altitudes of certain beds of lignite at different places indicate that the dip of the strata is very slight or practically horizontal. Two beds of lignite are mapped in this township. Bed EE is the lower one, and was measured at locations 758, 759, 760, and 761. At location 758 it contains 2 feet 2 inches of lignite; at location 761, 11 inches of lignite overlain by 8 inches of bone; and at location 759, 2 feet 7 inches of lignite. Sections 759 and 760 appear on Plate XXVI. Bed GG was mapped in sec. 34 of this township. Sections on this bed were obtained in sec. 3 of the township immediately to the south. As both of these beds of lignite average less than 2 feet in thickness they are not considered valuable. However, it is believed that the township is underlain by thicker beds of lignite at a depth of less than 300 feet.

T. 147 N., R. 91 W.

All of T. 147 N., R. 91 W., is described here except part of sec. 1, which lies northeast of Missouri River.

In the northern part of this township steep-sided gullies and ravines cut into the upland to a depth of about 300 feet. The maximum relief in the township, however, amounts to about 500 feet. South of the central part is a high rolling upland surmounted in places by grass-covered mounds 50 or 60 feet higher than the main level. Along Missouri River in secs. 1 and 12 are steep bluffs caused by the undercutting of the stream. Many landslides occur on these bluffs; the largest seen, in sec. 1, is about half a mile in length and

800 to 1,000 feet in width. The vertical displacement due to the slide is about 300 feet. Part of the material has slid into Missouri River and is gradually being carried away by the stream. Another slide, which is probably older than the one just mentioned, extends for about half a mile along the river bluff in the NE. ¼ sec. 12 and into sec. 1 of this township and sec. 7 of the township to the east. The strata in every slide in this locality dip from 1° or 2° to 40° toward the bluff from which the material is derived.

The rocks in this township are composed of sandy shale and sandstone interbedded with thin layers of carbonaceous shale and lignite. The strata lie nearly flat; a northwestward dip of perhaps as much as 8 feet to the mile has been noted in secs. 3 and 10. A few glacial boulders are scattered on the upland, but in the rough country near Missouri River and in the northern part of this township practically all the drift has been removed by stream erosion.

The lignite beds in the township are much thinner than those of adjoining townships. The number of mappable beds is four, whereas in the township immediately to the west there are nine. The lowest bed of lignite mapped in this township is bed DD. Only one measurement of this bed was obtained—at location 780, in sec. 12, where it contains 1 foot 1 inch of lignite.

The next higher bed is EE, on which measurements were made at locations 764, 769, and 777.

Sections of lignite bed EE in T. 147 N., R. 91 W.

[In addition to that shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.		
			Ft.	*in.*
764	NW. ¼ sec. 4	Shale.		
		Lignite		6
		Shale		8
		Shale, carbonaceous		2
		Lignite		10
		Shale, carbonaceous		10
		Lignite		4
		Shale, carbonaceous		8
777	NW. ¼ sec. 12	Lignite	1	7

At location 769 only 3 feet of lignite is exposed, the lower part of the bed being concealed by water. The section is shown on Plate XXVI. Bed EE becomes thinner to the north and is less than 2 feet in thickness near the township line. South and west of this township this bed is much thicker; in the township immediately to the west it has an average thickness of over 4 feet; and in T. 147 N., R. 94 W., it has a maximum observed thickness of 14 feet. It is probable that bed CC lies at a depth of less than 500 feet beneath this township and carries more than 2 feet of lignite. A bed about

20 feet above bed EE and 3 feet thick was measured at locations 755, 778, 779, and 780. Section 755 is shown on Plate XXVI. Other sections of bed FF are tabulated below:

Sections of lignite bed FF in T. 147 N., R. 91 W.

[In addition to that shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
778	SW. ¼ sec. 1	Shale, carbonaceous		10
		Lignite		11
		Shale		5
		Lignite	1	
		Shale.		
779	NE. ¼ sec. 12	Shale.		
		Lignite	1	7
		Shale, carbonaceous		8
		Lignite		6
		Shale		3
		Lignite, dirty		6
		Shale.		
780	SE. ¼ sec. 12	Shale.		
		Shale, carbonaceous		10
		Lignite	1	4
		Shale, carbonaceous	1	
		Shale.		

Bed GG, which has an average thickness in this township of 2 feet 6 inches, is separated from bed FF by abount 30 feet of sandy shale and crops out in secs. 3, 4, 5, 9, and 10. Measurements of this bed were obtained at locations 762, 763, 765 to 768, 770, 772, 773, and 775. (See Pl. XXVI.)

Sections of lignite bed GG in T. 147 N., R. 91 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
762	NE. ¼ sec. 5	Lignite	1	10
767	SW. ¼ sec. 3	Shale, sandy.		
		Shale, carbonaceous		6
		Lignite	1	8
		Shale, carbonaceous		7
		Lignite		5
		Shale.		
768	NE. ¼ sec. 3	Shale.		
		Shale, carbonaceous		5
		Lignite	1	
		Shale, carbonaceous		2
		Lignite		7
770	NE. ¼ sec. 10	Lignite	2	6
772	NE. ¼ sec. 10	Shale.		
		Lignite	1	5
		Shale, carbonaceous	1	1
		Lignite		3
		Shale.		

West of location 762 bed GG is less than 2 feet thick and was not mapped for several miles.

Bed HH is of mappable thickness in sec. 17. It is 2 feet 5 inches thick at location 754 (Pl. XXVI) and 1 foot 3 inches at location 771. Thin beds of lignite higher in the section were measured in secs. 7, 18, and 19. Bed II was measured at location 757, in the SW. ¼ sec. 7, where it carries 1 foot 10 inches of lignite.

The thickness of bed JJ was obtained at locations 752, 753, and 774.

Sections of lignite bed JJ in T. 147 N., R. 91 W.

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
752	SW. ¼ sec. 18	Lignite	2	1
753	NW. ¼ sec. 19	Lignite	1	7
774	SE. ¼ sec. 10	Shale.		
		Shale, carbonaceous.		6
		Lignite	1	3
		Shale.		

Other sections of thin beds which may be the same as higher beds already described were obtained at locations 678 and 776. At location 678 a bed carrying 1 foot 11 inches of lignite was measured, and at location 776 a section 1 foot 3 inches thick was obtained.

T. 146 N., R. 91 W.

That part of T. 146 N., R. 91 W., which lies within the Fort Berthold Reservation has a fairly regular surface, though in the western part the relief amounts to several hundred feet. In the central and eastern parts the surface is rolling and generally grass covered. Although the ground is commonly covered with glacial drift it does not affect the surface features noticeably. The rocks are composed of light-yellow sandstone and gray shale interbedded with lignite. The lignite is thin and usually of poor quality. The township is probably underlain by a bed of lignite which crops out on Hans Creek in T. 146 N., R. 92 W., and was measured at locations 668 and 695. This bed (HH) averages over 4 feet in thickness on Hans Creek. Another still lower bed that may underlie this township is bed EE, which averages about 5 feet in thickness on Hans Creek and Little Missouri River in Tps. 146 and 147 N., R. 92 W. Beds II, KK, and MM are mapped for short distances in secs. 6, 7, and 18 of this township. All these beds, however, are less than 2 feet 6 inches thick. Measurements of them are given in the following table:

Sections of lignite beds II and KK in T. 146 N., R. 91 W.

No. on map (Pl. XXIX).	Location.	Bed.	Section.	Ft.	in.
674	NW. ¼ sec. 18	II	Lignite (thickness reported)	3±	
675	NW. ¼ sec. 7	II	Lignite	1	10
676	NE. ¼ sec. 7	II	Lignite	1	8
677	SW. ¼ sec. 6	KK	Lignite	1	10
679	NE. ¼ sec. 6	KK	Lignite	1	9

Bed MM was not measured in this township but was mapped a short distance on the strength of a measurement made at location 680, in the township immediately to the west, where it is only 1 foot 6 inches thick.

T. 147 N., R. 90 W.

That part of T. 147 N., R. 90 W., here described lies south of Missouri River. The principal surface features are Missouri River and its bluffs. The river flows through secs. 7, 8, 9, 10, and 11 and for the greater part of the way is undercutting the bluffs on its south bank, which in many places are 250 to 300 feet high, forming sheer walls of sedimentary rocks. In other places landslides have caused thousands of tons of material to slide into the river. One of the most notable of these slides is mapped in the SW. ¼ sec. 8. A large creek flowing through the southeastern part of this township, leaving it in sec. 24, has a wide valley well covered with grass and is peculiar because of the large number of seeps and springs it contains. At many places along this stream there are pools 10 or 12 feet deep. The general covering of glacial drift in the southern part of this township is not thick enough to affect the form of the surface.

The rocks exposed in the sections on Missouri River consist of sandy shale and sandstone, together with thin beds of carbonaceous shale and lignite. There is probably about 200 feet of the Fort Union formation beneath the lowest beds exposed in this township.

The lowest bed of lignite that crops out in the township is bed CC, which was measured at locations 788, 806, and 809. At location 788 4 feet of lignite was measured above the water of Missouri River in September, 1912. Owing to the height of the water a complete section could not be measured. It was reported, however, that the lignite bed at this place is more than 6 feet thick and is mined during the winter when the water is low and the river frozen. This measurement is believed to be on bed CC, which was mapped for 15 miles in the township immediately to the east. Sections 806 and 809 are shown on Plate XXVI. The next higher bed of lignite is bed DD, which averages 2 feet 8 inches in thickness and was measured at locations 796, 797, 804, 805, 807, 808, and 813. At locations 796 and 797 bed DD carries 1 foot 9 inches of lignite. Other measurements of

this bed are shown on Plate XXVI. Its quality as well as its thickness is variable. Bed EE has an average thickness of 2 feet 4 inches and is separated in this township from bed DD by about 35 feet of shale. It was measured at locations 781, 782, 784, 785, 787, 791 to 795, 799, 803, 810, 814, and 815. These sections, with the exception of those tabulated below, are shown on Plate XXVI.

Sections of lignite bed EE in T. 147 N., R. 90 W.

[In addition to those shown on Plate XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
787	SE. ¼ sec. 8	Lignite	1	11
793	SW. ¼ sec. 10	Lignite	2	1
810	SE. ¼ sec. 27	Lignite, impure	1	6
814	NE. ¼ sec. 25	Shale.		
		Lignite	1	
		Shale	3	
		Lignite		6
		Shale.		
815	NE. ¼ sec. 25	Lignite	1	4

Bed FF, which has an average thickness of 2 feet 11 inches, is separated from bed EE by 5 to 20 feet of shale. It seems probable that this bed is the upper part of bed EE of the township immediately to the east and that in this township it becomes separated from that bed by the increasing thickness of the shale parting. Bed FF was measured at locations 783, 786,[13] 789, 790, 798, 800, 801, and 802. (See Pl. XXVI.) A section measured at location 811, in sec. 19, may represent bed FF, although the correlation is uncertain. At this place a spring issues from an outcrop of lignite, and an incomplete section shows 4 feet 2 inches of lignite of good quality. In secs. 24, 25, and 36 a lens of lignite lies between bed DD and bed EE. It was measured at locations 813 and 815 and apparently becomes thicker toward the south. The lens is only 8 inches thick at location 815 and continues to thin northward from this point. Several beds of lignite higher in the geologic section were noted but are too thin to be of any value.

T. 146 N., R. 90 W.

The part of T. 146 N., R. 90 W., that lies within the Fort Berthold Reservation has very little relief. The streams flow in broad valleys that are partly filled with glacial drift. However, the glacial drift is so old that the surface is not materially modified by it.

[13] The two sections on Plate XXVI labeled 783 should be 783 and 786.

The rocks underlying the glacial drift carry lignite, although no exposed lignite beds were found within the township, and the strata that crop out are beds which for this field are high in the Fort Union formation. It is probable, therefore, that the township is underlain by the lignite beds that crop out in townships to the east, north, and west.

T. 147 N., R. 89 W.

That portion of T. 147 N., R. 89 W., that lies south of Missouri River includes in its northern half the flood plain of the river, which in places is several miles wide. A bluff that has an average height of about 40 feet and in the eastern and western parts is apparently a river-built terrace extends across secs. 18, 20, 21, 25, 26, and 27. In the central part the bluff is cut by gullies into badlands. In secs. 27, 28, 29, and 30 badlands are present. Above this terrace is a high grass-covered upland extending across the southern part of the township. The relief reaches a maximum of about 450 feet. The flood plain of Missouri River is well covered with underbrush and trees, whereas the badlands are only sparsely covered with grass and in many places are totally bare. On the upland grass is abundant.

The strata have a southwestward dip of less than 10 feet to the mile. Exposures of the rocks are few, owing to the fact that on the river flood plain they are buried many feet beneath alluvium, and on the upland they are covered with glacial drift. The drift, however, is thin and in many places consists of only a few boulders scattered on the surface. A mass of drift which has been baked by the burning of a lignite bed caps a ridge in the NW. ¼ sec. 28, at location 826.

The lowest bed of lignite that crops out in this township was found in the SE. ¼ sec. 21, at location 827. This bed, which is at about the same horizon as bed BB, contains 3 feet 5 inches of lignite. This is the only measurement on bed BB in this locality, but a bed at about the same horizon was mapped for considerable distances in T. 150 N., R. 94 W., along Bear Den Creek. Bed CC was measured at locations 818, 825, 829, and 839. At location 818, where the lignite is mined by stripping, the bed is 6 feet 10 inches thick, and although it contains some poor lignite it is probably the best source of lignite for local use. Other measurements of bed CC, which are given on Plate XXVI, show its average thickness to be 6 feet. The next higher bed of lignite, bed DD, which has an average thickness of 2 feet, was measured at locations 816, 819, 822, and 823. Section 822 is shown graphically on Plate XXVI. Other sections of bed DD are given in the following table:

Sections of lignite bed DD in T. 147 N., R. 89 W.

[In addition to that shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
816	SW. ¼ sec. 19	Lignite	1	8
819	SW. ¼ sec. 29	Lignite		10
823	SW. ¼ sec. 28	Sandstone.		
		Lignite	1	2
		Shale		8
		Lignite		2
		Shale		1
		Lignite		6
		Shale.		

A lens of lignite mapped for a short distance in this township and the one immediately to the west lies about 25 feet above bed DD and was measured at location 812. Here it contains 4 feet 8 inches of lignite, but both east and west of this place it pinches out rapidly.

The next higher valuable bed of lignite in this township is bed EE, measurements of which were obtained at locations 817, 820, 821, 823, 824, 828, and 830.[14] (See Pl. XXVI.) Bed EE is the highest bed of lignite exposed and has an average thickness of about 3½ feet in this township.

Sections of lignite bed EE in T. 147 N., R. 89 W.

[In addition to those shown on Pl. XXVI.]

No. on map (Pl. XXIX).	Location.	Section.	Ft.	in.
817	SW. ¼ sec. 19	Lignite	2	
823	SW. ¼ sec. 28	Lignite	3	2

T. 146 N., R. 89 W.

The part of T. 146 N., R. 89 W., which lies within the Fort Berthold Reservation is crossed by the valleys of Beaver Creek and a tributary of that stream, which heads in the township to the north. Between these valleys is a high ridge containing several prominent points, which are capped with standstone. The altitude of the highest point in this township is about 400 feet above that of the lowest part. Although the relief is great, the township is generally grass covered, and most of the slopes are gentle. The rocks are generally covered with glacial drift.

The glacial drift ranges in thickness from a few inches to 30 feet and is composed of pebbles of igneous and sedimentary rock of almost

[14] On Plate XXVI section 830 is incorrectly labeled 823.

every description. In places the fine material has been carried away by subsequent erosion, leaving only large boulders of crystalline rock. A few limestone boulders have been found pitted and honeycombed by weathering, but generally the granites predominate at the surface. Exposures of the underlying rocks are poor and widely separated. In secs. 3 and 4 high hills are capped with sandstone. Elsewhere exposures of the stratified rocks are confined to little cut banks along streams or in gullies. The only formation represented is the Fort Union. This formation is lignite-bearing wherever known, and in this township at least three beds of lignite were noted in its exposed portions, although difficulty was experienced in mapping them because of the grass-covered slopes and the scarcity of outcrops. The lowest bed exposed is bed CC, which has an average thickness of over 5 feet in this part of the field. Measurements of this bed were obtained at locations 836 and 837. (See Pl. XXVI.) Elsewhere in the township the outcrop of this bed is concealed, although it is probable that location 832 is on the outcrop of this bed also, as a small amount of clinker was found here. At the horizon of bed DD some large pieces of lignite were found on the surface at location 834, but owing to the swampy condition of the place no section of the bed could be obtained. The highest bed of lignite exposed is bed EE, which was noted at locations 831 (see Pl. XXVI) and 835. No measurement of thickness is given for location 835. At location 833, which is outside of the reservation, bed EE has been mined by stripping. The section at this place is as follows:

Section of bed EE at location 833, in the SW. ¼ sec. 14, T. 146 N., R. 89 W.

	Ft.	in.
Shale.		
Lignite		6
Shale	1	
Lignite	2	2
Bottom covered by slump.		
	3	8

T. 147 N., R. 88 W.

Only that portion of T. 147 N., R. 88 W., which lies southwest of Missouri River is described here. It comprises parts of secs. 19, 30, 31, 32, 34, and 35.

The greater part of this township includes the flood plain of Missouri River. The southwestern part of sec. 31 lies on a terrace which slopes gently toward the flood plain. Between the terrace and the flood plain is a bluff averaging 50 or 60 feet in height but not so abrupt as to cause exposures in very many places. The bluff and the terrace are generally grass covered, whereas the flood plain of the river is densely covered with undergrowth. In places it is swampy, indicating cut-off meanders of the old stream.

The surface is largely covered with recent alluvium. In places, however, the ground is composed of glacial drift, and only in a few localities do the sedimentary rocks appear at the surface.

One bed of lignite corresponding to bed CC in the township immediately to the south has been mapped in sec. 31 of this township and was measured at locations 840 and 841. In a coulee in the center of sec. 31 this bed has been burned on this outcrop. Section 840 is incomplete owing to weathering of the bed at this place, and only 1 foot 8 inches was found. Section 841, which is also incomplete, shows 4 feet of lignite. (See Pl. XXVI.)

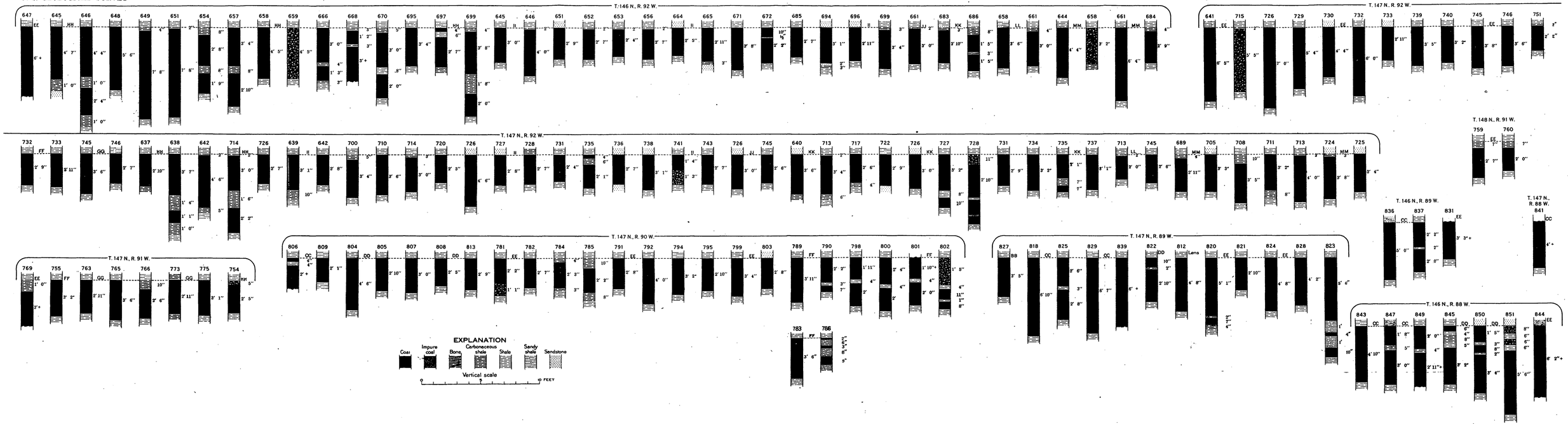
T. 146 N., R. 88 W.

The part of T. 146 N., R. 88 W., that lies within the Fort Berthold Reservation is rolling and generally grass covered. Beaver Creek flows through the western part from south to north and empties into Missouri River. Its valley is broadly U-shaped, and most of the slopes are gentle. The lower part of the stream for a mile or so contains flowing water the year around. Above this point the stream contains water in pools. Missouri River cuts the north line of the township in two places, but the entire width of the river does not come within the boundaries at any place. In secs. 4 and 5 bluffs 60 to 70 feet high are being rapidly undercut by the river, which is gradually moving its channel southward. A small tributary of Missouri River in sec. 4 heads in the highest hills in this township. It contains water in pools, from several springs, and in sec. 9 its valley is very steep-sided. It probably contains the best exposures of the rocks in this township.

The formation is generally covered with glacial drift from a few inches to 30 feet or more in thickness. Enough exposures were found, however, to indicate that the rocks lie nearly flat, with probably a slight dip to the northwest of less than 10 feet to the mile. The formation at the surface is the Fort Union and contains at least three beds of lignite in the exposed section in this township. The base of the exposed section is probably 160 feet above the base of the formation. The length of the stratigraphic section above Missouri River in this township amounts to about 225 feet, but a complete section could not be obtained owing to the cover of glacial drift or alluvium. Most of the strata are composed of sandy shale and sandstone with a few carbonaceous layers and a few beds of lignite.

The lowest bed of lignite mapped in this township, bed CC, crops out in sec. 5 in the bluff at the mouth of Beaver Creek on Missouri River, at location 847, where it contains 4 feet 8 inches of lignite. (See Pl. XXVI.) At this place the entire bed is not exposed, for the upper part has been eroded, and its surface is irregular and overlain by drift. At location 848, in sec. 4, the conditions

are similar and only 4 feet of this bed could be measured. The thickest known portion of this bed lies in the southern part of sec. 4 and the northern part of sec. 9. A section measured at location 849, in the SW. ¼ sec. 4 shows over 4 feet of lignite. (See Pl. XXVI.) Another section of this bed was obtained at location 843. Locations 846 and 852 are at the horizon of bed CC, but no section could be obtained at these places, and only fragments of lignite indicate its presence. Bed DD was measured at locations 845, 850, and 851. (See Pl. XXVI.) This bed is thicker and of better quality in this township than in the townships to the west. The highest bed of lignite exposed in this township is bed EE. It has been burned along the outcrop and causes a large amount of clinker. A section of this bed was measured at location 844, where it contains over 6 feet of lignite. (See Pl. XXVI.)



SECTIONS OF LIGNITE BEDS IN THE SOUTHERN PART OF THE FORT BERTHOLD INDIAN RESERVATION, NORTH DAKOTA

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY.