LIGNITE IN THE FORT BERTHOLD INDIAN RESERVATION N. DAK., NORTH OF MISSOURI RIVER.

By MAX A. PISHEL.

INTRODUCTION.

The area here described is that part of the Fort Berthold Indian Reservation, N. Dak., which lies north of Missouri River, the northern part being in Mountrail County, the southern part in McLean County, and a few square miles in the extreme northeast corner in Ward County. The area is triangular in shape, the greatest dimensions being from north to south about 35 miles and from east to west about 39 miles. The broadly curving course of Missouri River forms the irregular hypotenuse of the triangle. The part of the Missouri from the mouth of Shell Creek northwestward to the reservation line is known as the Big Bend because of the almost perfect semicircle which the river makes here, hence the area between this part of the Missouri and the north boundary line of the Fort Berthold Indian Reservation is called in this paper the Big Bend district.

The field is reached most easily by a branch line of the Minneapolis, St. Paul & Sault Ste. Marie Railway, which crosses the northeast corner of the area and terminates at Plaza, just north of the reservation. This branch connects with the main line at Drake and with the Northern Pacific Railway at Bismarck. Several other railway companies have made surveys in this area, and it is certain that another railway will tap this section of the country shortly after the reservation is opened for settlement. At certain seasons of the year steamboats ply between river ports on the Missouri.

During the field season of 1908 a Geological Survey party under Carl D. Smith made a reconnaissance survey of this area for the purpose of ascertaining for the Reclamation Service whether or not it contained beds of lignite available for fuel for pumping plants, and the results of the examination were published the following year.[1] As the larger part of the area was at that time unsurveyed, the present writer was detailed during the field season of 1910 to locate the outcrops of the lignite beds with reference to section lines, which had meanwhile been surveyed, and to collect such other data as would be valuable for use in classification of the lands prior to throwing them

[1] Smith, C. D., The Fort Berthold Indian Reservation lignite field, North Dakota: Bull. U. S. Geol. Survey No. 381, 1910, pp. 30-39.

open to entry. In the field the writer was assisted by R. J. Johnson, who served as rodman and assisted in prospecting for coal.

The outcrops of the lignite beds were mapped with plane-table, telescopic alidade, and stadia rod. As a rule the lowest workable bed was traced by stadia traverse; and the upper beds, where less than a mile distant from the lowest, were sketched by triangulation. If the outcrops of the upper beds were more than a mile away from the outcrops of the lower bed they were also traced by stadia traverse. Where a lignite bed was not continuously exposed, a preliminary level line was carried forward from the last known exposure and a contour sketched at the elevation of the bed at the last known exposure. When the next exposure was found the position of the bed between the two outcrops was inferred with the aid of this contour. As the strata are practically horizontal, rarely dipping more than 1°, it was found, especially along the bluffs, that the contour line almost invariably coincides with the actual position of the outcrop. Traverses were tied to section corners, at the most every 2 miles, and at other places where convenient. The land surveys, being new, are well marked, and corners were found wherever looked for.

In this report are embodied the results obtained by the writer, supplemented by data from the notes of Smith's party. The accompanying map (Pl. XIII, p. 184) was compiled from field sheets and shows only the most important cultural and drainage features and the main geologic facts in connection with the occurrence of lignite. Plate XII (p. 184) contains numerous sections showing the thickness and character of the lignite beds. The numbers of the sections correspond to locations on the map. In building up the base map the length of the land lines given on the Land Office township plats was assumed to be correct.

TOPOGRAPHY.

Surficially the area is a rather smooth plain, through which the larger streams have cut broad valleys, usually from 1 to 2 miles in width and bounded by bluffs. At some points these bluffs are abrupt and of badland character; but at others, especially near stream junctions, they are comparatively low with grassy slopes. Although the area is in the region once covered by the continental ice sheet, glacial potholes and other features resulting directly from glacial action are rare. It can not be denied, however, that the receding ice sheet has had a decided effect on the present topography of the region, giving it, in general, a rather smooth appearance. Large terraces found between Shell Creek and Missouri River, just within the north boundary of the reservation, suggest the idea that in preglacial time Missouri River cut across this bend, finding an outlet down what is now the valley of Shell Creek, which for 10 miles from its mouth is exceptionally wide, at most places over 4 miles.

GEOLOGY.

STRATIGRAPHY.

Fort Union formation.—The rocks outcropping in this area are largely shale, sandy shale, and shaly sandstone, containing beds of lignite at various horizons. Sandy shale and shaly sandstone are predominant. The strata belong to the so-called "yellow beds" of the Fort Union formation and are of Tertiary age. The rocks at a distance have a somber aspect, reminding one of the Lance formation outcropping just below the "yellow beds" in eastern Montana. They differ, however, in that the Lance is decidedly cross-bedded and very lenticular, whereas the beds in this area are rather continuous and cross-bedding is not so common. This difference is most readily discerned in the lignite beds, as the sandy shale and shaly sandstone are difficult to trace on account of their tendency to weather and slump, so that in many places the contacts between the members are obliterated.

The continuity and uniformity of deposition of the beds in this field are shown by measurements of the distance between the lignite called bed 1 and that called bed 2 in the Big Bend district. In sec. 31, T. 151 N., R. 93 W., this distance measured by stadia is 230 feet; over 6 miles away in sec. 32, T. 152 N., R. 93 W., it is 225 feet as measured with a hand level. The distance measured with hand level halfway between these two places is 216 feet. An example of a fair degree of uniformity in other beds is the yellow sandy shale immediately below bed 2. In sec. 18, T. 150 N., R. 91 W., and sec. 20, T. 150 N., R. 92 W., it is 26 feet thick. In sec. 6, T. 150 N., R. 93 W., it is represented by 17 feet of fine-grained yellow sandstone underlain by 10 feet of gray carbonaceous shale.

The soft, shaly sandstone is composed entirely of fine material and is locally indurated; it contains at places irregular concretion-like masses slightly darker than the surrounding material. Glacial bowlders of foreign material, both igneous and sedimentary, are scattered over the entire field, but evidences of a drift sheet, except for a preglacial gully in sec. 5, T. 147 N., R. 88 W., which will be mentioned later, were not found. The surficial covering, which appears to be a mixture of till and ordinary hill wash, was rarely found to be more than 10 feet thick, either on the ridges or out in the flats.

Several measurements of the exposed strata were made at various places in the field and 400 feet was the maximum thickness obtained. The writer is of the opinion that there is exposed in the area a total thickness of not more than 600 feet of strata. Lignite beds more than 30 inches in thickness were found in scattered localities at six different horizons, but at no one place were there found more than three beds each over 30 inches thick.

The following columnar sections give an idea of the character of the coal-bearing rocks. The first is a general section of the Big Bend district. The part above bed 2 was taken in sec. 20, T. 150 N., R. 92 W.; the part between beds 1 and 2 was measured in the SE. ¼ SE. ¼ sec. 6, T. 150 N., R. 93 W.; and bed 1 and the strata below were measured in the NW. ¼ SW. ¼ sec. 31, T. 151 N., R. 93 W. This is a good representative section and shows practically all the strata outcropping in the district. North of the reservation, just outside the fence along the bluffs, at least 200 feet of strata could be added to the top of this section, the hills there being about 300 feet high and bed 3 lying nearly at the foot of them. However, as these upper rocks have no bearing on the geology inside of the reservation, no section of them was made, and all the writer can say is that they are composed largely of sandstone and sandy shale. The second section was taken in secs. 9 and 10, T. 147 N., R. 89 W., and represents characteristics of the strata in the southeast part of the reservation.

General section of the Big Bend district.

	Ft.	in.		Ft.	in.
Shale, somber	30		Sandstone, gray, shaly	17	
Lignite, bed 3	3		Shale, carbonaceous, with lignite streaks	11	
Shale, gray, sandy	8		Lignite		5
Concretions, yellowish, clay ironstone	2		Shale, sandy, grayish yellow	3	
Shale, gray	25		Sandstone, gray, soft	17	
Shale, sandy, yellowish gray	23		Lignite		8
Sandstone, soft, gray, shaly	4		Sandstone, brown, shaly	6	
Shale, yellowish, well stratified	6		Lignite	1	
Shale, carbonaceous, with lignite lenses	3		Shale, gray, sandy	45	
Shale, gray, somber	3		Sandstone, grayish tan	10	
Shale, yellowish drab, sandy	3		Sandstone, yellowish gray	10	
Lignite, bed 2	4	6	Shale	1	
Shale, yellowish, sandy	27		Lignite	4	3
Lignite	1		Shale, sandy	4	
Shale, sandy, gray	25		Shale	1	
Shale, carbonaceous		4	Lignite	2	11
Sandstone, soft, gray, shaly	25		Shale, carbonaceous		7
Shale, carbonaceous	3		Lignite	3	6
Shale, gray	3		Clay and sand	75	
Shale, carbonaceous	2		River level.		
				414	2

Section in the vicinity of the Armstrong district.

	Ft.	in.		Ft.	in.
Shale, yellowish, sandy	42		Shale, gray, clayey	12	
Sandstone, yellowish	5	3	Shale, drab, with ironstone concretions	31	2
Shale, gray	15	8	Shale, carbonaceous	1	
Lignite	2	3	Lignite, bed 2	6	11
Shale, sandy, gray	15	8	Shale, grayish, drab	8	
Lignite with dirt	3	2			

Section in the vicinity of the Armstrong district—Continued.

	Ft.	in.
Shale, yellowish brown, sandy	3	
Sandstone, yellowish brown, sandy	5	
Shale, gray	12	
Shale, carbonaceous, with lignitic particles		7
Lignite	1	4
Shale, carbonaceous	2	
Shale, gray, sandy	4	
Shale, yellowish drab	6	
Shale, carbonaceous, with lignitic lenses	1	
Shale, brownish drab	3	
Sandstone, light yellowish, making a bluff	10	6
Shale, greenish gray	4	
Sandstone, yellowish, rusty, soft, clayey	8	
Shale, greenish gray, sandy	4	
Sandstone, greenish gray, sugary	15	
Sandstone, yellowish brown, with large elongated clay-ironstone concretions	12	
Sandstone, gray, sugary	31	
Lignite, bed 1*a*	5	11
Shale, somber, sandy, with flat, thin clay-ironstone concretions	22	
Lignite	1	9
Clay, gray	1	4
Lignite	2	7
Clay, somber, sandy	14	5
Alluvium to river level	60	(?)
	373	6

Glacial drift.—The whole area, except along the steep bluffs, is covered with sod, underneath which is a few feet of soil. This, together with the fact that the area is near the terminal moraine of the Wisconsin drift, led people to believe that a mantle of drift covered the whole area except in the badlands. Indeed it has generally been thought that the area was almost entirely overlain by glacial drift; yet, so far as the writer knows, no one has ever made a definite statement concerning the thickness of the drift at any place, and certainly the entire area is not drift covered. The writer has seen drift material in the SW. ¼ sec. 5, T. 147 N., R. 88 W., in a partly filled preglacial gully, this material being composed largely of a heterogeneous mass of igneous bowlders and sand. The gully is about 50 feet deep and only about half filled with drift, the flats on both sides of the gully apparently having no glacial material on them. A prospect hole dug by the writer in a very gently sloping plain, away from any streams or bluffs, in the SE. ¼ sec. 19, T. 152 N., R. 89 W., showed only 2 feet of clay underneath the sod and above the lignite, but this 2 feet of clay did not have the appearance of glacial clay, being entirely devoid of glacial bowlders. A well dug by the railroad company at Plaza, near the northeast corner of the same township, is said to be 73 feet deep through clay beneath which is 2 feet of lignite. Whether the clay is glacial clay or "yellow beds" the writer does not know.

On the whole it is probable that glacial drift covers the flats of the eastern and northeastern part of the reservation and perhaps the tops of the broad divides farther west, but the writer is of the opinion that very little drift, if any, covers the slopes toward the

larger streams, and that although the topography of the area has been shaped by the overriding of the continental glacier, the material itself, being largely sand, has nearly all been carried away, leaving only a few scattered bowlders too large to be moved.

STRUCTURE.

Broadly speaking, the area is structurally a flat syncline with minor flexures and small undulations, the dip at no place being more than 2½°. The lowest points of the major syncline are at Elbowoods and near the mouth of Rising Water Creek, and the highest points are in the extreme eastern and western parts of the field. The structure is most easily studied by noting the elevations of the lignite beds with reference to water level in Missouri River. For example, following bed 2 westward from the east boundary of T. 147 N., R. 87 W., it dips in a southwesterly direction as far as sec. 12, T. 147 N., R. 88 W. Here it lies 130 feet above the level of Missouri River; thence westward to the west line of the township the strata are horizontal, beyond which there is a gradual rise until bed 2 reaches a height of 200 feet above water level in sec. 9, T. 147 N., R. 89 W. Thence it dips very slightly westward as far as sec. 6 of the same township, from which it slopes in a southwesterly direction, reaching its lowest point just northeast of Elbowoods in sec. 27, T. 148 N., R. 90 W., where it is only about 100 feet above river level. North of this lowest point the rocks are partly covered with soil and vegetation, so that a definite statement concerning the dip of the strata can not be made. The writer is of the opinion, however, that a low anticline is located between Elbowoods and Rising Water Creek. This creek follows the pitching axis of a synclinal trough, which near its mouth brings bed 2 almost to the same altitude as at Elbowoods. Just north of Rising Water Creek, in sec. 7, T. 149 N., R. 90 W., a decided southerly dip was observed. Farther north however, near the north line of the township, the strata are horizontal. No perceptible dips were noted from there northward, exposures being very rare. In sec. 12, T. 151 N., R. 91 W., a northeast dip was noted, but in secs. 19, 20, 29, and 30, T. 152 N., R. 89 W., the dips are unmistakably toward the south. On the west side of Shell Creek the general dip is northeast, with local dips in other directions. Generally speaking, all of the larger creeks are in synclinal valleys which appear to be of preglacial origin.

THE LIGNITE.

PHYSICAL AND CHEMICAL CHARACTER.

The lignite is dark brown to brownish black in color. It is strongly laminated parallel to the bedding and has an irregular, or in some specimens conchoidal fracture. Contrary to what might be expected, it weathers to a pitchy black, so that on a dry-weathered surface it looks like subbituminous coal, except that the fine woody structure is not destroyed and can always be detected with the naked eye, indicating that the lignite is derived largely from remains of trees and heavy vegetation. Like most lignite, when exposed to the atmosphere it checks, falls to pieces, and breaks into small irregular fragments with pitchlike luster and brown streak. Near the bottom and top of some of the beds, but more commonly near the bottom, silicified wood has been found. Although the strata in this field have not undergone much folding, jointing is present to some extent. If the lignite bed is underlain by an impervious layer these joints serve as a reservoir for water, and if the bed is slightly inclined they serve as a course along which water travels. As a result springs and seeps can be found on the outcrop of lignite beds at many places. This was especially noted at a place called Coal Springs, in sec. 16, T. 152 N., R. 92 W., where water issued in a rather good-sized stream from one of these joint crevices. Here and there mineral resin was found, as was also mineral charcoal, the latter usually with the dirtiest lignite.

A sample of lignite was taken for analysis at Coal Springs, in the NE. ¼ NW. ¼ sec. 16, T. 152 N., R. 92 W. (For thickness of lignite bed see No. 110, Pl. XII.) Although the lignite was not absolutely fresh, it is considered a fair representative sample of the lignite of this general region. The analysis as made by the Bureau of Mines is given below.

Analysis of lignite from Fort Berthold reservation.

[A. C. Fieldner, chemist in charge. Laboratory No. 11294. Air-drying loss, 33.70 per cent.]

	As received.	Air-dried.	Moisture free.	Moisture and ash free.
Moisture	41.0	11.0	.....	.....
Volatile matter	24.9	37.5	42.2	47.5
Fixed carbon	27.5	41.6	46.7	52.5
Ash	6.6	9.9	11.1	.....
Sulphur	.44	.67	.75	.84
Calories	3,265	4,925	5,535	6,230
British thermal units	5,880	8,870	9,970	11,220

The lignite is tough and in hardness compares well with other lignites. When struck with the pick or hammer it sounds decidedly

dull. It burns with a long red flame and leaves a white ash and no clinkers, except under a boiler or forced draft, where a considerable amount of clinker is produced.

NATURAL BURNING.

The tracing of the beds of lignite is somewhat facilitated but the measurement of their thickness is hindered by the large amount of burning which they have experienced in this region, clinker being produced along the outcrop where the burning took place. It is interesting to note that as a rule clinker beds are found along bluffs and rarely in flats, for which two reasons may be assigned: First, the lignite does not so readily catch fire where the outcrop lies in a flat, and, second, after it is ignited and has produced clinker it is more resistant to erosion and therefore not so likely to become part of a flat. The clinker beds are composed almost entirely of burned material which before burning lay directly above the lignite, the strata below being as a rule very little affected. The explanation of this is apparent when watching a burning lignite bed. After the lignite has caught fire and part of the bed has burned out, the overlying strata, if not too massive nor too thick, will break off and fall as loose rock on top of the burning lignite. This loose material is then burned to clinker in all gradations from slightly baked yellowish or reddish clay or sand to a fused mass, the degree of fusion depending on the heat generated and the physical and chemical composition of the strata. The thickness of the clinker and the amount of fused material is a good index of the character of the coal bed burned, the thicker and purer the bed the heavier and more completely fused being the clinker produced; but, as the amount of fusion depends also on the composition of the rocks and the amount of air available for draft for the fire, the condition of the clinker is not an absolute criterion.

ACTION OF WATER ON THE LIGNITE BEDS.

As has been mentioned previously, much silicified wood is found in the lignite beds of this region. Some of the fossilized tree trunks are partly carbonized and partly silicified; in fact, there are present all gradations from lignite to silicified wood. Just at what stage of metamorphism the tree trunks and roots were silicified can not be stated with exactness, but the writer is of the opinion that it happened either just before the bog or swamp began to form, or after it had been covered with strata and elevated again above water level. Two reasons can be given why it did not take place during the bog or swamp stage. First, silicified wood is found not in the middle, but rather near the bottom or top of the bed, and, second, according to H. Stremme,[1] peat bogs do not contain any acids or alkalies which dissolve out the hydrocarbons. Stremme states that the chemical con-

[1] Stremme, H., Zeitschr. prakt. Geologie, vol. 18, No. 10, Oct., 1910, p. 389.

stituents found in peat bogs, which turn blue litmus paper red and heretofore have been considered humic acid and detrimental to the forming of peat, are in reality colloids and rather beneficial to the formation of peat. Furthermore, a peat bog or swamp is usually so situated that the water in it is stagnant or has very little flow, so that if chemical action should take place at any time no new solvent would be added and action would soon cease.

That a large amount of the hydrocarbons is carried out of the coal bed during the lignite stage of the coal is a matter of fact. While tracing the lignite beds in the region under discussion the writer was very much impressed by the relatively large amount of soluble bituminous matter which is carried out of the lignite beds in springs. Every spring and seep noticed by the writer in this locality, and they numbered up into the hundreds, came from a lignite bed. Only a very few of them are apparently free from this soluble bituminous matter. Some of the spring water, especially that from the larger springs, is only slightly discolored, but the water issuing from the smaller springs and seeps is decidedly dark brown in color. The writer could not detect any odor given off by the water. However, a slight sour taste was perceptible. That this brown substance is held in solution and not in suspension is proved by the fact that the water allowed to stand in pools becomes browner by concentration and no precipitate is formed. Only after the evaporation of the water is residue left, when it can be seen on the bottom of the pools in the form of thin scales.

The writer does not know the exact chemical composition of this brown residue. However, it is his opinion that it is a hydrocarbon. According to C. F. Zincken,[1] lignite is readily attacked by alkalies, especially by KOH, and potassium ulmate is formed, which gives the solution a dark-brown color. He also states that the more the coal is advanced in the stage of bituminization the less it is attacked by alkalies and acids. Bituminous coal and anthracite are not attacked by alkalies of hypochlorite and only slightly by sulphuric acid. However, a mixture of sulphuric and nitric acids will change part of the coal to a substance resembling ulmic acid, which is precipitated by water. Here in this particular locality, where the strata are very gently inclined and the rocks above the lignite beds, owing to their sandy character, act more like sieves, the water percolates through the lignite very slowly and gives the solvents in the water a good opportunity to attack the soluble part of the lignite.

As the water in this general region is known to carry alkalies in solution and the coal is still in the lignite stage, it seems very probable that the dark-brown substance contained in the water of the springs in this region is leached out by alkalies.

[1] Zincken, C. F., Die Physiographie der Braunkohle, 1867, p. 10.

DISTRIBUTION OF THE LIGNITE.

Twelve beds of lignite were counted in the columnar section exposed in sec. 25, T. 150 N., R. 93 W., none of them less than 1 foot thick. Although there are six horizons at which lignite 30 inches or more in thickness is found, not more than three such beds have been found at any one place. In the region between Elbowoods and Rising Water Creek no lignite of economic value at present was found, and the writer feels confident, in the light of the few outcrops and the fact that clinker beds are entirely wanting, that no lignite bed 30 inches or more in thickness exists in this area in the strata above river level. The fields in which such beds are known—the Armstrong district and the Big Bend district—are thus separated by an area in which beds 30 inches thick or more are not known to occur.

Armstrong district.—The Armstrong district, so called because the village of Armstrong is located near its center, is that part of the Fort Berthold Reservation which stretches from Elbowoods to the east boundary of the reservation, lying mainly in T. 147 N., Rs. 87, 88, and 89 W., and T. 148 N., Rs. 89 and 90 W., but including portions of T. 147 N., R. 90 W., and T. 148 N., R. 88 W. It is bounded on the south by Missouri River and on the north by the flat between the Missouri and Rising Water Creek. The outcrops in this latter flat are so concealed by hill wash and vegetation that the locations of the lignite beds and their thicknesses are difficult to determine. There are three beds of lignite of 30 inches or over in thickness in the western part of T. 147 N., R. 87 W., but from the center eastward erosion has removed the uppermost bed entirely. For the sake of convenience in describing the lignites in this district, the lowest of these has been named bed 1*a*, the next higher bed 2, and the uppermost bed 3.

Bed 1a.—Starting at the east boundary of the field bed 1*a* lies about 150 feet above river level and is split into two benches with another thin bed of lignite 17 feet below it. The bed increases in thickness toward the west. An outcrop in the NE. ¼ NW. ¼ sec. 17, T. 147 N., R. 87 W. (No. 5),[1] which the writer considers to be that of bed *1a*, shows 5 feet of lignite, but neither the top nor the bottom was certainly determined—the bottom because the hole which the Indians made in taking out the lignite is filled with water, and the top because the prospect is at the edge of an alluvial flat and the bed is immediately overlain by alluvium. West of this place the strata dip southwest as indicated by the clinker remains of bed 2, and bed 1*a* goes under the alluvial flat which is prominent from Armstrong eastward. From section 14 to the west line of T. 147 N., R. 88 W., no perceptible

[1] Numbers in parentheses refer to graphic sections on Pl. XII and to their corresponding locations on Pl. XIII.

dip was observed on bed 2, which is here rendered very conspicuous by the clinker.

In the SW. ¼ SE. ¼ sec. 19, T. 147 N., R. 88 W. (No. 16), a lignite bed was measured which lies 125 feet below bed 2 and is considered to be bed 1*a*. This outcrop is 23 feet above river level.

The outcrop measured in the SW. ¼ NW. ¼ sec. 20 (No. 15) is 50 feet below bed 2, and is of the same bed as the outcrop in the NE. ¼ NW. ¼ sec. 16, T. 147 N., R. 87 W. (No. 3). This lignite bed, however, is very lenticular and is not considered of economic importance.

From the outcrop in sec. 19, T. 147 N., R. 88 W. (No. 16), up to the one in sec. 24, T. 147 N., R. 89 W. (No. 17), bed 1*a* rises 40 feet; thence westward it rises very little, having only very gentle undulations entirely across the township. In sec. 31, T. 148 N., R. 89 W. (No. 30), the westernmost exposure, in this district, of any coal having a thickness of 30 inches or more, bed 1*a* is 75 feet above the river level. In a bluff along the north line of sec. 1, T. 147 N., R. 90 W., the strata are most beautifully exposed and dip uniformly westward at 1½°. As there are several thin beds shown here one can not definitely state which is bed 1*a*. A uniform dip of 1½° would bring it below river level within 2,800 feet. As bed 2 also thins down to a thickness of less than 30 inches in this neighborhood, and is not exposed from here westward, no definite observations could be made regarding the dip of the strata. However, a dip of 1° W. in sec. 25, T. 148 N., R. 90 W., indicates clearly that the lowest place in the fold lies west of this point and bed 1*a* must lie at a considerable depth below river level.

Bed 2.—In the northeastern part of T. 147 N., R. 87 W., bed 2 lies high up under the flats which are so conspicuous in this particular locality and is not exposed. However, from the center of the township west to within 3 miles of Elbowoods it can be traced almost continuously by its clinker beds. Sections were taken wherever the lignite bed was favorably located. Throughout this district the clinker left by bed 2 is heavy, indicating a rather thick bed or pure lignite, perhaps both.

A badland bluff in sec. 19, T. 148 N., R. 90 W., has 50 feet of strata exposed near the horizon of bed 2 and what is thought to be bed 2 is only 8 inches thick. The strata here lie horizontally.

The badland bluffs in secs. 11, 12, and 14 T. 148 N., R. 91 W., expose 60 feet of strata. The yellow bed of sandy clay is undoubtedly the one near bed 2 so well exposed in the bluff just north of the Missouri and east of Elbowoods. In sec. 12 the lignite lies directly on this yellow sandy clay and attains a thickness of 3 feet, but this is decidedly local. From here northward no lignite outcrop was found until Rising Water Creek was reached.

Bed 3.—This bed is 60 feet above bed 2 as measured by stadia in sec. 6, T. 147 N., R. 87 W. As it lies rather close to the surface of the plain it is easily understood how it could be eroded at the tops of the anticlines and only present in the trough of the synclines. For that reason it is found only in the western part of T. 147 N., R. 87 W. In the SE. ¼ SW. ¼ sec. 6 (No. 8) it lies 25 feet below the top of the bluff. Although the bottom of the minor syncline in this district lies near the west line of sec. 13, T. 147 N., R. 88 W., erosion progressed in such a way that even there the cover reached barely a thickness of 50 feet. The map (Pl. XII) shows that in this particular locality comparatively large areas are burned out completely. Inasmuch as the plain slopes toward Sixmile Creek and the strata are horizontal in secs. 4, 9, and 16, T. 147 N., R. 88 W., bed 3 is eroded in this locality. In this plain it is impossible to trace the outcrop, the surface being covered by hillwash and vegetation.

West of Sixmile Creek, near the south quarter corner of sec. 3, T. 147 N., R. 89 W. (Nos. 22 and 22*a*), two thin beds of lignite were found above bed 2, a 38-inch bed 45 feet above it and a 27-inch bed 63 feet above it. No other measurements of these beds were obtained to the east, between this place and Sixmile Creek. On the north side of the divide, however, clinker beds indicate the position of the lower of the two beds. In the columnar section made by C. D. Smith's party in 1908, in sec. 32, T. 148 N., R. 89 W., the distance between bed 2 and the next higher bed, which is here 4 feet thick, is only 34 feet, and the distance to the next higher is 8 feet, indicating a thinning of the strata. In view of this fact it is rather difficult to tell which of these two beds is the equivalent of bed 3 as found east of Sixmile Creek. In the NE. ¼ sec. 36, T. 148 N., R. 90 W. (Nos. 32 and 33), the distance between bed 2 and the next higher is 15 feet. The latter bed is less than 30 inches thick here.

West of Sixmile Creek the beds above bed 2 are not shown on the map. South of the divide between Missouri River and Sixmile Creek the bluffs are quite steep, and when mapped the outcrop of this bed almost coincides with that of bed 2. The outcrop north of the divide was not traced, the slope being so flat that an attempt would have resulted in only an approximation to the truth.

Big Bend district.—In this district the lowest bed containing 30 inches or more of coal has been named bed 1, the next highest bed 2, and so on. In sec. 13, T. 150 N., R. 93 W. (No. 69), 20 feet above bed 2, another bed is 30 inches or more thick and this thickness persists for about 2 miles westward, from there on west being less than 30 inches. This bed the writer named bed 2*a*. Between this and bed 3 is a distance of 50 feet in sec. 10, T. 150 N., R. 93 W. In the bluffs northeast of Weidman's ranch the distance between the horizons of bed 2 and bed 3 is 60 feet. Although the upper bed can not

be traced successfully from this part of the field into bed 3, which outcrops in T. 150 N., R. 93 W., the writer named it bed 3, as it is very near the position of the last-mentioned bed and very similar to it.

As the beds of lignite east of Shell Creek and north of Rising Water Creek appear to be continuous west of Shell Creek, and as they are thought to belong to one and the same lignite basin, the writer treats the field as a unit and calls it Big Bend district, although it is cut in two by Shell Creek. In this district there are exposed four lignite beds 30 inches or more in thickness. The 14-foot bed reported by C. D. Smith[1] on the west side of the Missouri opposite Weidman's ranch is so low in the stratigraphic column that it is not exposed north of the river. These four beds are not all of economic value at any one place along the outcrop. (For comparison as to the position of these coal beds in this district with those in the Armstrong district see columnar sections on p. 173.)

Bed 1.—This is the lowest bed with a thickness of 30 inches or more exposed on the north side of the river and has been traced from sec. 16, T. 150 N., R. 93 W. (No. 77), northward into sec. 27, T. 152 N., R. 93 W. (No. 107), where it disappears below the river. In sec. 17, T. 150 N., R. 93 W. (No. 78), the outcrop lies at the same altitude as that in the NE. ¼ SW. ¼ sec. 31, T. 151 N., R. 93 W. (No. 86), and is about the same distance from the horizon of bed 2. East of sec. 17, T. 150 N., R. 93 W., this bed is not known to be above 30 inches in thickness at any place. Another exposure of bed 1 was measured in the NE. ¼ SE. ¼ sec. 7, T. 150 N., R. 93 W. (No. 82). Here the bed is split into two thinner ones. From this point northward hill wash and terraces cover the bed so that no other section of it could be taken in this township. As seen from lignite sections 86 and 88 to 92 the bed increases in thickness toward the north. From Hoffman's place, in the SE. ¼ sec. 19, T. 151 N., R. 93 W., northward the bed is concealed under a river terrace, but as it is 6 feet 3 inches thick in the SW. ¼ SE. ¼ sec. 32, T. 152 N., R. 93 W. (No. 101), and increases in thickness northward in the southern half of T. 151 N., R. 93 W., the writer is of the opinion that it is over 30 inches in thickness between these points. One can not state definitely just what becomes of bed 1 toward the north. If the strata between bed 1 and bed 2 horizon are as constant here as they are in T. 150 N., R. 93 W., then according to a columnar section in the SW. ¼ sec. 14, T. 152 N., R. 93 W., bed 1 should be 70 feet below river level at the latter place. The writer measured 3 feet of good lignite at the water's edge, in the SE. ¼ NW. ¼ sec. 27 (No. 107). The top and bottom could not be determined, and consequently it is doubtful whether or not this out-

[1] Smith, C. D., The Fort Berthold Indian Reservation lignite field, North Dakota: Bull. U. S. Geol. Survey No. 381, 1910, p. 35.

crop is in place. In the NW. ¼ SW. ¼ sec. 27 (No. 106) 5 feet of good lignite were measured. A number of measurements were made by C. D. Smith's party in the year 1908 between the last-mentioned place and the south line of this township and all gave bed 1 as 30 inches or more in thickness.

Bed 2.—In the NW. ¼ SE. ¼ sec. 18, T. 149 N., R. 90 W., in the side of a bluff along the creek bank, a succession of rocks is exposed which is very similar to the exposure in sec. 14, T. 148 N., R. 91 W. Although the former exposure is 50 feet lower in altitude the writer is of the opinion that the yellow sandy clay at both places is identical. Following the lignite beds northward from Rising Water Creek an increase in quality of the lignite and thickness of the bed can be noticed, and in the prospect in the NW. ¼ NW. ¼ sec. 6, T. 149 N., R. 90 W. (No. 47), it is undoubtedly of such quality that it can be worked with profit. From there northward good exposures may be had until the northwest corner of sec. 30, T. 150 N., R. 90 W., is reached; thence northward outcrops are very scarce, but as bluffs continue all along, the position of the bed can be mapped with a certain degree of accuracy. There is an outcrop in the SW. ¼ SE. ¼ sec. 36 (No. 56), and another in the SE. ¼ NW. ¼ sec. 24 (No. 57), in T. 151 N., R. 91 W., and both show the lignite to be over 30 inches in thickness. Bed 2 has no other exposure in this township or north of here on the east side of Shell Creek. In the SE. ¼ SE. ¼ sec. 12, T. 151 N., R. 91 W., there is a spring at about the horizon of this bed. As springs were not found along the bluffs except at coal horizons the writer concludes that this is the horizon of bed 2. Farther north bed 2 goes under the Shell Creek bottom.

West of Shell Creek in sec. 18, T. 150 N., R. 91 W. (No. 58), is an outcrop of bed 2. In the SE. ¼ NW. ¼ sec. 13, T. 150 N., R. 92 W., lignite was brought up by badgers at the horizon of bed 2, and again in the SE. ¼ SE. ¼ sec. 9. In the NW. ¼ sec. 16 (No. 59) an outcrop shows a similarity to that in sec. 18, T. 150 N., R. 91 W. (No. 58), which leads one to infer that they were taken on the same bed. Although the outcrop between the two places is not continuous, the writer concluded they were on the same bed from the fact that they are about equal in altitude and the succession of rock is the same at both places.

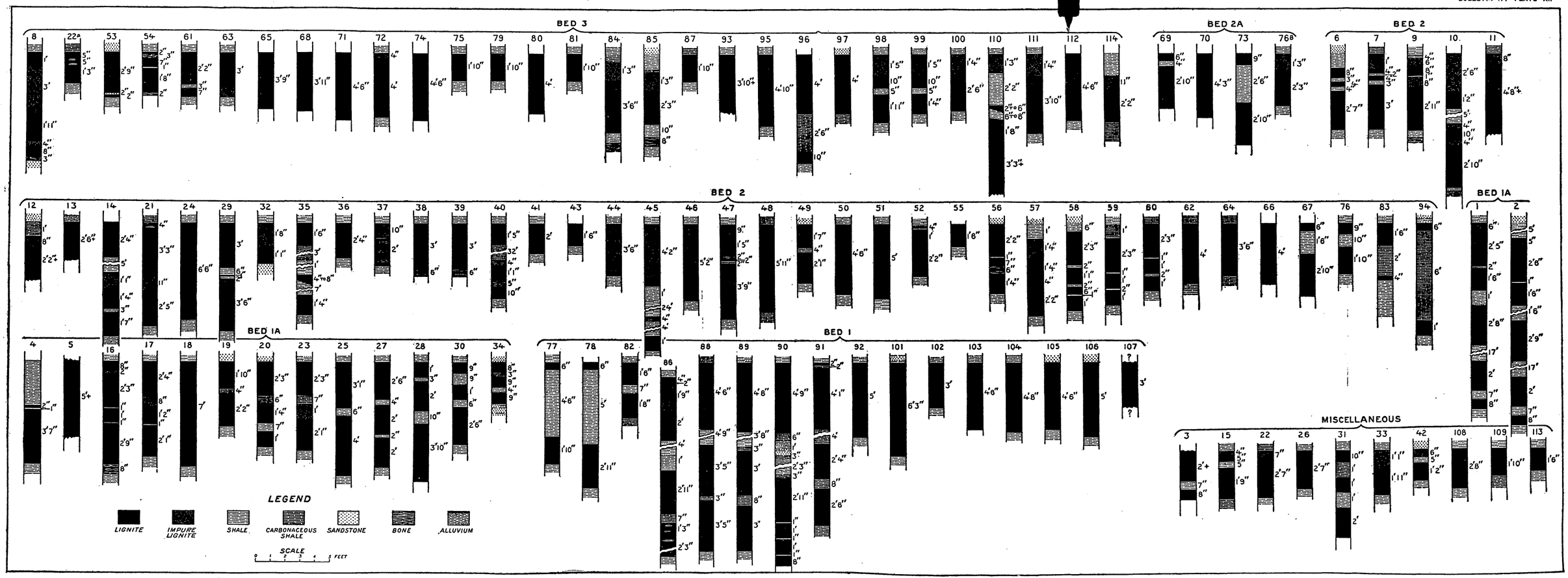
Good exposures may be had along bed 2 in secs. 19 and 20 of T. 150 N., R. 92 W. (Nos. 60, 62, 64, and 66), and along the bluffs in T. 150 N., R. 93 W. As will be noted from the sections given, this bed thins westward, so that in the SE. ¼ NE. ¼ sec. 16. T. 150 N., R. 93 W. (No. 76), it is less than 30 inches thick.

Bed 2a.—Twenty-five feet above bed 2 there was measured in the SW. ¼ SW. ¼ sec. 11, T. 150 N., R. 93 W. (No. 70), a bed 4 feet 3 inches thick. This was measured again in the NE. ¼ SE. ¼ sec. 10

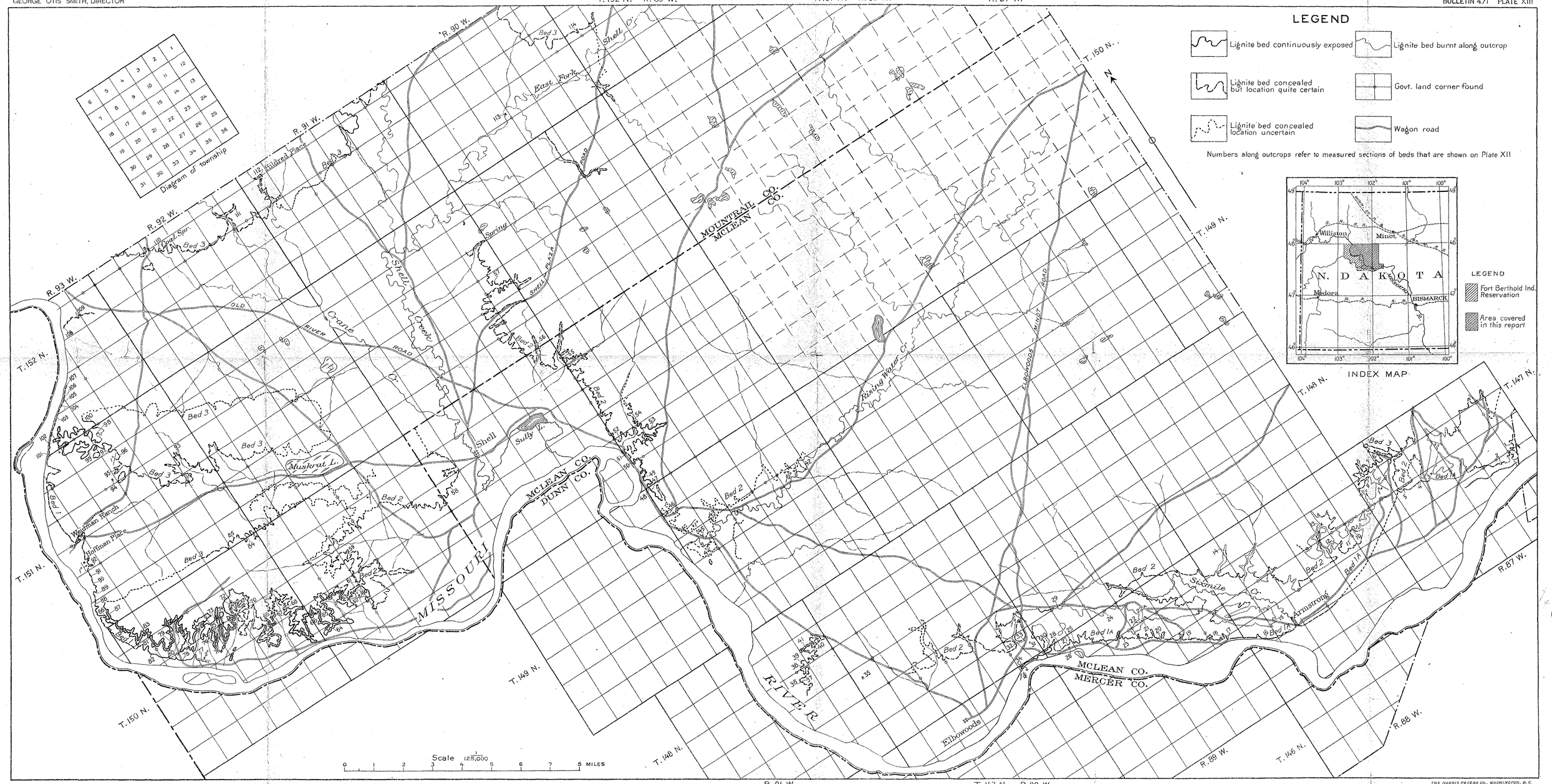
(No. 73) and the SE. ¼ NE. ¼ sec. 16 (No. 76b), and the sections are given in Plate XII. From those measurements it can readily be inferred that this bed is only of local extent. The measurement taken on a bed in the NW. ¼ SW. ¼ sec. 13 (No. 69) is on bed 2*a* in the opinion of the writer.

Bed 3.—Bed 3 is continuous and uniform in thickness over rather a large area. From the lignite sections (Pl. XII) it will be seen that this bed increases in thickness from the SE. ¼ NE. ¼ sec. 20, T. 150 N., R. 92 W. (No. 61), westward. At the latter place it is hardly of economic value, although 33 inches thick, as it is rather dirty near the base. Near the west line of T. 150 N., R. 92 W. (No. 65), this bed reaches its maximum thickness in this vicinity, whereas in a section measured in the SE. ¼ NE. ¼ sec. 16, T. 150 N., R. 93 W. (No. 75), it is only 1 foot 10 inches thick. Although C. D. Smith in an unpublished report gives this bed as 4 feet thick in sec. 8, T. 150 N., R. 93 W. (No. 80), the writer has not been able to find it more than 30 inches thick west of sec. 15 and is of the opinion that at the place reported by Mr. Smith it only thickens locally. In the NE. ¼ SW. ¼ sec. 36, T. 151 N., R. 93 W. (No. 85), and in the NW. ¼ NE. ¼ sec. 1, T. 150 N., R. 93 W. (No. 84), sections were taken on a bed. At the latter place the bed was found burning. The altitude of these two places and the character of the roof and floor of the bed lead the writer to think that it is bed 3. At several places to the east clinker beds were found near the horizon of bed 3, but how far east this bed continues and its thickness can be ascertained only by a series of drill holes. In the SW. ¼ NW. ¼ sec. 13, T. 151 N., R. 93 W. (No. 93), a lignite bed very similar to that in sec. 36 of this township was measured. No outcrops were found east of No. 93. However, a clinker bed was located in the SE. ¼ NE. ¼ sec. 15, which was thought to be caused by the burning of bed 3. A section was measured in the NW. ¼ SW. ¼ sec. 10 (No. 95), and again in the SE. ¼ SW. ¼ sec. 3 (No. 97), both on bed 3. At the last places mentioned bed 3 is considered the best in the field. Northward it changes in quantity and quality rapidly. The exposure in the SE. ¼ SW. ¼ sec. 3 (No. 97), has 4 feet of good lignite, whereas that in the NE. ¼ SE. ¼ sec. 4 (No. 99), contains only 2 feet 6 inches of good lignite, the upper part of the bed being very dirty. The same can be said of the outcrop in the SE. ¼ NW. ¼ sec. 3 (No. 98). A valley running northwest and southeast in the northern part of T. 151 N., R. 93 W., and also extending into the next township to the north, forms the northern limit of bed 3 on this particular outlier. The north boundary of the lignite bed in this locality is only approximately shown on the map, as no exposures were found.

Bed 3 was also measured at Coal Springs in the NE. ¼ NW. ¼ sec. 16, T. 152 N., R. 92 W. (No. 110), and in the SE. ¼ NW. ¼ sec.



SECTIONS OF LIGNITE BEDS IN FORT BERTHOLD INDIAN RESERVATION, N. DAK.



MAP OF THAT PART OF FORT BERTHOLD INDIAN RESERVATION, NORTH DAKOTA, LYING NORTH OF MISSOURI RIVER

By Max A. Pishel

13 of the same township (No. 111). Between these two outcrops no traces of an exposure could be found. The writer is of the opinion, however, that the lignite here is continuous. East of Crane Creek the outcrop of bed 3 runs along flats and nothing could be seen of it until the SW. ¼ NW. ¼ sec. 11, T. 152 N., R. 91 W., was reached. Here settlers had taken out lignite in the past, but the opening had afterwards caved in so that no section could be measured. A farmer near by, however, told the writer that the lignite bed is 2 feet thick. In an outcrop measured by the writer outside the reservation in the SW. ¼ sec. 6, T. 152 N., R. 90 W., a section of the lignite is as follows:

Section of lignite bed in SW. ¼ sec. 6, T. 152 N., R. 90 W.

	Feet.
Clay, sandy.	
Lignite	2
Lignite, dirty	1+
Bottom not reached.	
	3+

Going east of Shell Creek only a reconnaissance survey was made of T. 152 N., Rs. 90 and 89 W., and of T. 151 N., Rs. 90 and 89 W. In the SW. ¼ SE. ¼ sec. 19, T. 152 N., R. 89 W. (No. 114), bed 3 was measured and found to be very similar in section to the outcrop measured in the SW. ¼ sec. 6, T. 152 N., R. 90 W. In a dip slope with bed 3 near its top in secs. 11, 12, 13, 14, 23, and 24, T. 152 N., R. 90 W., and secs. 17, 18, 19, 30, and 31, T. 152 N., R. 89 W., lignite was brought up in badger holes. In the SE. ¼ SE. ¼ sec. 28, T. 152 N., R. 90 W. (No. 113), an outcrop with 18 inches of lignite was found. In the opinion of the writer this is below bed 3 and above bed 2.

Farther south traces of lignite were found in various places, but the outcrops were rather badly covered so that no section could be taken. The writer is of the opinion, however, that bed 3 is not of economic importance in this region.

USE OF THE LIGNITE.

In the past the only mining in this area was done by the Indians. More recently white settlers entered along the edge of the reservation and took out lignite at various places. The method of mining consists in finding a place where the cover is comparatively thin (say 4 to 6 feet) and not so thin that the lignite is made worthless by weathering. The cover is removed and the lignite taken out. At no place has underground mining been carried on, but the writer is of the opinion that it could be profitably done in many places. The greatest drawback in mining lignite extensively is its tendency to "slack" and fall to pieces when exposed to the atmosphere and the sun. For that reason it is almost impossible to ship it, especially during the

summer months. However, when kept away from the air and sunlight and in a cool place it apparently is affected very slowly. As it stocks so much better in the winter than in the summer, mining is practically carried on only during the winter months. Until briquetting of lignite is a commercial success it will be mined only for domestic uses and for local trade. At present there is little demand for lignite, as the country is very thinly settled, but the demand will increase as the population grows, and industries and factories spring up that can use the lignite shortly after it is mined.

Competition is another factor which limits the sale of lignite to local markets—that is, to the State of North Dakota—as people are willing to pay from $1 to $2 a ton more for Iowa and Illinois coals, which are not so dirty to handle and keep up a better fire.

The project which the Reclamation Service contemplates establishing in this area will necessitate pumping the water out of Missouri River. To do this, great quantities of fuel would be required and the lignite beds would be a cheap source of supply. In many places the lignite outcrops very close to the river's edge, so that it could be loaded directly on barges and taken up or down the river to the pumping stations.

According to a conservative estimate by the writer the amount of available lignite in that part of the Fort Berthold Indian Reservation north of Missouri is 1,819,953,682 tons.

Gas-producer tests have been made of North Dakota lignite and the results show that it is well adapted to this use.[1] In these tests the lignite compares rather favorably with some of the higher grades of coal, and should that method of utilizing fuel become more universally applied the extensive lignite fields will become a great source of wealth to the nation.

[1] Bull. U. S. Geol. Survey Nos. 290, 1905, pp. 135-139; 381, 1910, pp. 24-25.