THE NEW SALEM LIGNITE FIELD, MORTON COUNTY, NORTH DAKOTA.

By EUGENE T. HANCOCK.

INTRODUCTION.

The lignite of North Dakota is a fuel of so low a grade, at least by comparison with the better coals of the Rocky Mountain region and the East, that it has attracted little attention, but with the difficulties of transportation that have been experienced in this country in recent years it becomes more and more important for localities that have undeveloped resources of even a poor quality to exploit them sufficiently to know their quantity and quality, so that when the need comes for utilizing the domestic supply it can be done intelligently and without needless waste. In order to accumulate information regarding such undeveloped resources of mineral fuel, the United States Geological Survey has been for a number of years making detailed examinations of many coal fields. Much of this work has been done primarily for the purpose of gathering data for the separation of the land into mineral and nonmineral classes as prescribed by the old coal-land law, but the Survey has also had in mind the need for information by the general public regarding the fuel resources of the country, and this need has been met by the publication of a number of papers describing certain coal fields. The present paper is one of this character.

The New Salem lignite field lies within the great lignite region of western North Dakota, northwestern South Dakota, and eastern Montana, on its southeastern margin. Some of these border fields contain less lignite than those lying in the interior portion of the region, for the reason that as the rocks lie in a great basin dipping slightly toward the center from all directions, the upper formations, which carry the larger lignite beds, are present in the interior and the lower formations, which carry thinner and more irregular beds, are found on the margin of the basin. In the New Salem field both groups of formations are present, and hence this field contains some thick beds and some thin ones.

As this field is on the southeastern margin of the greater region of lignite-bearing beds, it follows that in the areas lying farther to the

east and southeast the rocks are lower in the geologic scale and hence lie entirely below the lignite-bearing formations, and therefore it is useless to search for lignite in those areas.

Before 1912 the southeastern margin of the lignite field of North Dakota was known in a general way, but no exact information regarding it had ever been published. In 1912 E. R. Lloyd, of the United States Geological Survey, began the work of delimiting the field on its southeast side, and this work was continued during the summer of 1913. The region examined by Lloyd embraces an area

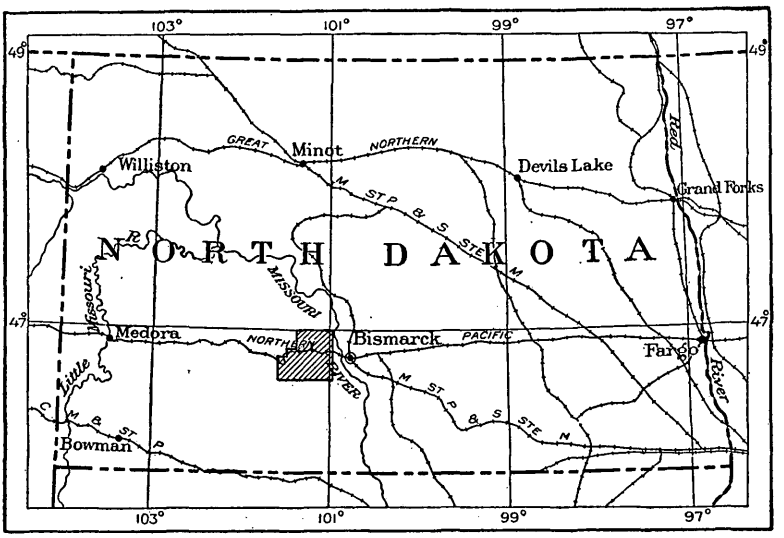

FIGURE 1.—Index map of North Dakota showing location of New Salem lignite field.

extending from the State line northeastward to the ninth standard parallel. It has an average width of about 4 miles and in general is bounded on the south and east by Cannonball River. Throughout this part of the field lignite was found to occur only locally and in thin beds. During the autumn of 1914 the geologic mapping was continued by the writer north of the ninth standard parallel throughout an area of about 600 square miles, in the west-central part of which is situated the prosperous town of New Salem. This area includes Tps. 137 to 140, Rs. 82 to 86, except 3½ townships in the northwest corner. Owing to the prominence of this town as a shipping point for a large agricultural community and as a center for the distribution of lignite [1] to the surrounding country, it is considered appropriate to refer to this area as the New Salem lignite field. The area surveyed in 1914 and included under this name is shown in figure 1.

[1] Since this report was prepared the mine at New Salem has been abandoned.

FIELD WORK.

The field examination upon which this report is based was made in August, September, and October, 1914, by Raymond C. Moore, Delbert Williams, Sidney Swanker, Frank Bunn, and the writer. The work was done under the direct supervision of M. R. Campbell, to whom the writer is indebted for many valuable suggestions. Information was contributed by many of the residents of the field; and as it is impracticable to make individual mention of these courtesies, acknowledgments can be made only in this general way.

The geologic examination was made primarily with a view of classifying the land and of determining the amount of lignite which it contains. An attempt was made to ascertain the extent and thickness of the different lignite beds from a study of their outcrops, supplemented by such data as could be obtained concerning lignite encountered in sinking wells. The mapping was done with the plane table, telescopic alidade, and stadia rod. By their use the outcrop of each lignite bed was accurately mapped wherever the bed is exposed, but where it is concealed by the overburden, as it is almost invariably, the outcrop was determined upon the basis of known elevations combined with a knowledge of the structure of the bed.

The township plats of the General Land Office were used as base maps for the field work and for the construction of Plate V. Most of the land corners are not difficult to find, as they are on well-established fence lines or in the public highways, many of which are laid out on the section lines. The original locations of the corners are generally marked by mounds and pits, covered with unusually dense prairie grass.

The land net, on a scale of 2 inches to the mile, was transferred to the plane-table field sheet directly from the township plats. With the exception of the stadia traverse of the outcrops of the lignite beds, all locations incident to the geologic mapping were made by triangulation. The mapping was controlled horizontally by land corners, together with conspicuous surface features carefully tied into section or township corners. Vertically the mapping was controlled by elevations taken directly from the Northern Pacific Railway profile, and the elevations were carried north and south by means of vertical angles.

PREVIOUS PUBLICATIONS.

That portion of southwestern North Dakota including Cannonball River and its tributaries has long been known to be a part of the great lignite region of the Dakotas and eastern Montana. The presence of what was supposed to be "stone coal" (lignite) was recognized in the vicinity of Mandan during the explorations by Lewis

and Clark in 1804–1806. They first noted lignite on the left bank of the Missouri about 20 miles above the mouth of Cannonball River.[2] Nearly every succeeding expedition added something of interest, but it was not until the explorations of the geologist F. V. Hayden, under the direction of Lieut. G. K. Warren, that any attempt was made to prepare and publish a geologic map of the region.[3]

In 1874 an expedition under the command of Gens. Custer and Ludlow, accompanied by N. H. Winchell, geologist, made a reconnaissance trip to the Black Hills, crossing the Cannonball River field on the way.[4]

The Geological Survey of North Dakota has published during recent years several articles relating to the lignite fields of the State. The region including Cannonball River and its tributaries, however, has received little attention owing to the more fully developed territory to the north and west. A. G. Leonard,[5] State geologist, has recently described several sections exposed on Cannonball and Heart rivers in Morton County. The Cannonball member is described by Lloyd and Hares.[6]

The Cannonball River lignite field, which was examined by E. R. Lloyd[7] in 1912 and 1913, joins and partly overlaps the lignite field described by A. G. Leonard.[8]

GEOGRAPHY.

COMMERCIAL RELATIONS.

The main line of the Northern Pacific Railway crosses the New Salem lignite field in an east-west direction near its central part. Wagon roads throughout the field follow the section lines except in the vicinity of the principal streams, where the land is so rough as to render this impracticable. The principal towns on the Northern Pacific Railway in this field are Sweetbriar, Judson, New Salem, and Almont. Owing to the complete system of public roads, one or another of these towns is readily accessible from almost every part of the field. The entire field is well settled and is supplied with adequate postal facilities.

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[2] Lewis, Meriwether, and Clark, William, Original journals, vol. 1, p. 200, New York, Dodd, Mead & Co., 1904.

[3] Hayden, F. V., Notes explanatory of a map and section illustrating the geologic structure of the country bordering on the Missouri River from the mouth of the Platte River to Fort Benton: Acad. Nat. Sci. Philadelphia Proc., vol. 9, pp. 109–116, 1858.

[4] Winchell, N. H., Report of a reconnaissance of the Black Hills of Dakota made in the summer of 1874 by William Ludlow, pp. 22 et seq., 1875.

[5] Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, pp. 507–547, 1911.

[6] Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geology, vol. 23, pp. 523–547, 1915.

[7] U. S. Geol. Survey Bull. 541, pp. 243–292, 1914.

[8] U. S. Geol. Survey Geol. Atlas, Bismarck folio (No. 181), 1912.

SURFACE FEATURES.

The New Salem lignite field lies in the Great Plains physiographic province, and hence it is devoid of trees except a few along the streams. Nearly all the drainage from this field empties into Heart River and eventually reaches Missouri River near Mandan. Big Muddy and Sweetbriar creeks are the principal affluents of Heart River. All these streams and many of their smaller tributaries contain either running water or water in holes throughout the year.

The field as a whole exhibits three rather distinct types of surface features. The feature most characteristic of the region is the very gently rolling prairie interrupted here and there by high boulder-covered ridges and small isolated buttes. (See Pl. I, *A*, and Pl. IV, *B*.) Throughout this rolling upland the highways commonly follow the section lines, the country is rather thickly settled, and the wide expanse of prairie land is marked by numerous broad fields of wheat, oats, flax, rye, or barley.

The alluvium along the principal streams gives rise to a second type of surface not wholly unlike that described above but much less extensive. These almost flat but gently sloping valley bottoms range from a quarter of a mile to a mile in width and contain a very productive soil.

Upland areas thoroughly dissected into badlands by numerous streams extend from the alluvial flats back into the country for several miles and constitute the third type of surface features. Districts characterized by surfaces of this type are suitable principally for grazing.

GEOLOGY.

STRATIGRAPHY.

GENERAL CHARACTER OF THE ROCKS.

The Fort Union formation, which occurs in the lower part of the Tertiary system (Eocene series) and which contains most of the valuable lignite in the Dakotas and eastern Montana, lies at the surface throughout a little more than half of the New Salem lignite field. It is underlain by a group of beds which are now tentatively classified as probably of early Tertiary age and are referred to the Lance formation. The upper 250 or 300 feet of this formation is very different in character from the underlying beds, which are more typical of the Lance. The underlying portion is composed of alternating beds of shale and sandstone, which, when eroded, give rise to badlands. Fossil leaves collected near the top of the lower part of the Lance indicate that it is of fresh-water origin, and they have been identified by F. H. Knowlton as belonging to the Fort Union flora. The upper 250 to 300 feet of the formation, on the other hand,

contains the remains of a marine fauna which until recently has not been recognized in this part of the stratigraphic section. The part of the formation containing this fauna has been mapped separately and is designated the Cannonball marine member of the Lance formation. It forms the surface rock throughout most of the eastern part of the field. It is reasonably certain, although there are no rock outcrops, that lower Lance beds occur at the surface throughout the extensive flat area on Little Heart River, in the southeastern part of the field. A collection of fossil leaves obtained about 20 feet above the alluvial flat in the NE. ¼ sec. 31, T. 138 N., R. 83 W., and determined as Fort Union species by Knowlton indicates the presence of lower Lance beds on either side of Heart River as far north as that place.

The Quaternary period is represented in this field for the most part by glacial boulders and by alluvial material along the principal streams. The stratigraphy is shown by the accompanying table.

Tertiary and Quaternary formations in New Salem lignite field, N. Dak.

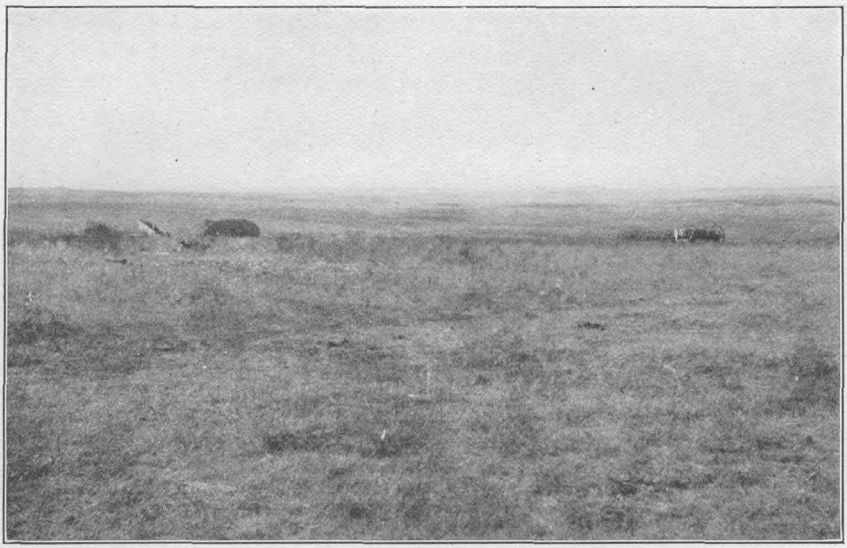
System.	Series.	Formation.	Character.	Thickness (feet).
Quaternary.			Alluvium, glacial boulders, and till.	
Erosional unconformity.				
Tertiary.	Eocene.	Fort Union formation.	Massive light-yellow sandstone, sandy and clay shale, black carbonaceous shale, and lignite.	250–350
Tertiary(?).	Eocene(?).	Lance formation.	Cannonball marine member, predominantly fine-grained, soft, unconsolidated sandstone, with alternating light-yellow and darker bands. Subordinate amount of light-yellow to dark-yellow and gray sandstone in lenticular beds.	200–300
			Undifferentiated Lance, dark shale, yellow sandstone.	400–525
Cretaceous.	Upper Cretaceous.	Fox Hills sandstone.	Not exposed.	

The New Salem lignite field is merely a northern extension of the Cannonball River lignite field. In the report on that field Lloyd [9] describes briefly the formations exposed from the Fox Hills sandstone to the White River formation. A somewhat detailed description of the marine member of the Lance formation and its bearing on the Lance-Laramie problem appears in a recent paper by E. R. Lloyd and C. J. Hares,[10] and its fauna has been described by T. W. Stanton.[11]

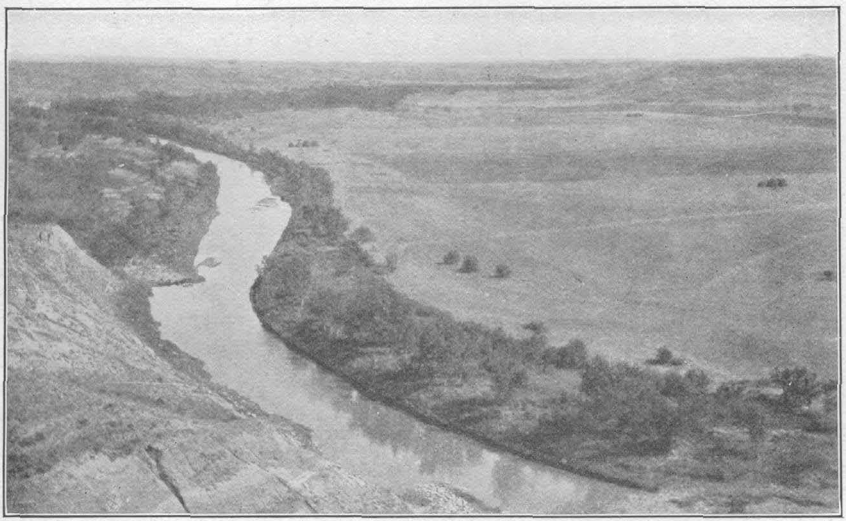
[9] Lloyd, E. R., The Cannonball River lignite field, Morton, Adams, and Hettinger counties, N. Dak.: U. S. Geol. Survey Bull. 541, p. 243, 1914.

[10] Jour. Geology, vol. 23, pp. 523–547, 1915.

[11] The fauna of the Cannonball marine member of the Lance formation: U. S. Geol. Survey Prof. Paper 128, pp. 1–66, 1920 (Prof. Paper 128–A).

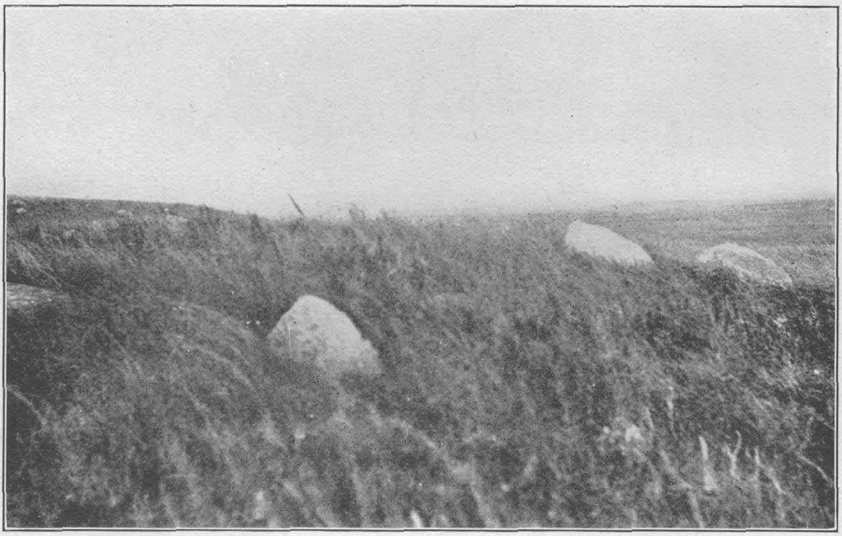


A. LEVEL UPLAND IN THE VICINITY OF NEW SALEM, N. DAK., LOOKING EAST.

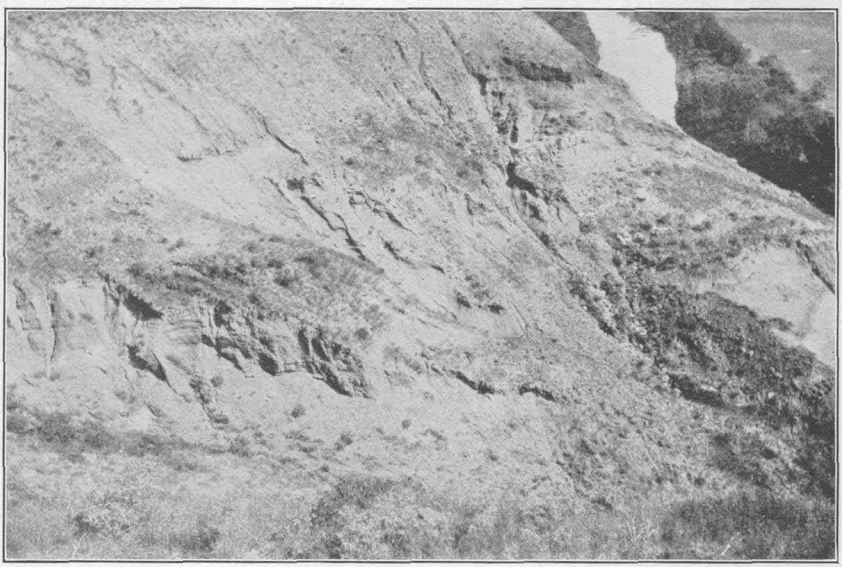


B. VALLEY OF HEART RIVER IN T. 138 N., R. 83 W., N. DAK.

Level upland in the distance.



A. LARGE GLACIAL BOULDERS ON UPLAND IN SEC. 17, T. 138 N., R. 84 W., N. DAK.



B. CANNONBALL MARINE MEMBER OF LANCE FORMATION IN BLUFF OF HEART RIVER, SEC. 10, T. 138 N., R. 83 W., N. DAK.

TERTIARY (?) SYSTEM.

LANCE FORMATION.

Lower part of the Lance formation.—The lower beds shown in the stratigraphic section measured in secs. 25 and 36, T. 137 N., R. 84 W., are believed to represent a transition from the underlying fresh-water beds into the marine member of the Lance formation. These beds not only have a striking resemblance to the Fort Union beds, but they contain numerous fragments of silicified wood, and one silicified log fully 2 feet in diameter was observed. Aside from the above-mentioned collection of leaves, which were determined by F. H. Knowlton to be Fort Union species, no fossils were obtained in this field from the lower part of the Lance formation. Fragmentary vertebrate remains were found in this part of the Lance in the Cannonball River field, farther south,[12] abundant dinosaur and turtle bones were found in several places in the Standing Rock Indian Reservation,[13] and a few collections of dinosaur bones have been made near the mouth of Cannonball River.[14]

Cannonball marine member.—The Cannonball marine member comprises the upper 200 to 300 feet of the Lance formation. It is exposed in many of the cut banks on Heart River, as shown in Plate II, *B*, and at numerous points on Sweetbriar Creek. Within the area described in this report it has yielded the following invertebrate fossils, identified by T. W. Stanton:

Nucula planimarginata Meek and Hayden.
Yoldia scitula Meek and Hayden.
Leda mansfieldi Stanton.
Glycimeris subimbricata Meek and Hayden.
Trigonarca? hancocki Stanton.
Arctica ovata (Meek and Hayden).
Dentalium pauperculum Meek and Hayden.
Lunatia obliquata Hall and Meek.
Anchura perveta Stanton.
Pyrifusus (Neptunella) newberryi Meek and Hayden?
Fasciolaria? (Mesorhytis) dakotensis Stanton.
Turricula? contorta Meek and Hayden.
Ringicula dubia Stanton.
Cylichna scitula Meek and Hayden?
Lamna cuspidata Agassiz.

[12] Lloyd, E. R., and Hares, C. J., op. cit., p. 528.

[13] Calvert, W. R., and others, Geology of the Standing Rock and Cheyenne River Indian reservations, North and South Dakota: U. S. Geol. Survey Bull. 575, pp. 21–22, 1914.

[14] Stanton, T. W., Washington Acad. Sci. Proc., vol. 2, p. 250, 1909. Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, p. 524, 1911.

The following section includes the lower part of the Fort Union formation, the Cannonball marine member of the Lance, and the uppermost beds of the lower part of the Lance:

Section measured from the NW. ¼ sec. 36, T. 137 N., R. 84 W., to the NE. ¼ sec. 30, T. 137 N., R. 83 W.

	Ft.	In.
Fort Union formation:		
Sandstone, yellow, hard; forms "rim rock"	1	
Shale, yellow, sandy	3	
Shale, sandy; contains unios and gastropods		6
Sandstone, light yellow, mainly unconsolidated but with an occasional resistant layer	27	
Lignite (location 56 on accompanying map)	4	8
Sandstone, yellow, soft, unconsolidated; contains a few layers of darker-yellow hard sandstone	16	
Sandstone, yellow	6	
Shale, light gray	10	
Shale, dark bluish drab, sandy	11	
Shale, light gray, sandy, grading upward into almost pure white shale	21	
Shale, carbonaceous		9
Lignite, impure		8
Lignite		9
Shale, carbonaceous	1	
Sandstone, white, hard	6	
Concealed	5	
	114	4
Cannonball marine member of Lance formation:		
Sandstone, light yellow, soft	3	
Sandstone, white, shaly	1	6
Sandstone, brown, shaly	1	6
Sandstone, white, coarse grained, cross-bedded	2	
Sandstone, soft, shaly	35	
Sandstone, light gray, thin bedded	1	
Sandstone, buff, soft, shaly	27	
Sandstone, light bluish gray, becoming browner near the top; contains numerous hard yellowish-brown sandstone concretions	32	
Sandstone, hard, forming a "rim rock"; fossiliferous; contains numerous dark-brown disklike concretions	2	
Sandstone, brown, shaly, soft; contains numerous thin bands of yellow very fine grained sandstone typical of Cannonball marine member	32	
Sandstone, yellow, hard, resistant, forming "rim rock"	1	
Sandstone, gray, with occasional yellow bands, very fine grained, texture uniform throughout	16	
Sandstone, hard, discontinuous; in places contains almost perfectly spherical concretions ("cannon-balls")	1	

	Ft.	in.
Cannonball marine member of Lance formation—Continued.		
Sandstone, soft, fine grained, made up of alternating light-yellow and dark-gray to black bands; contains a few yellowish-brown iron-stained concretions; typical of Cannonball marine member	26	
Sandstone, hard, forming a "rim rock"; contains numerous iron-stained concretions	1	6
Sandstone, yellow to buff, soft	2	
Sandstone, soft, fine grained; contains yellow and dark bands typical of Cannonball marine member	5	
Sandstone, white to light yellow, hard	2	
Sandstone, soft, fine grained; consists of light-yellow bands interlaminated with dark bands	12	
	203	6
Lower part of Lance formation:		
Sandstone, very hard; in places contains numerous concretions and fragments of silicified wood; a silicified log 2 feet in diameter was observed at one exposure	3	
Sandstone, soft, shaly, fine grained; made up of alternating light-yellow and dark bands	22	
Sandstone, white; contains numerous concretions	2	
	27	
Total thickness	344	10

The following section, though less detailed than the section just given, serves to illustrate the character of the Cannonball marine member of the Lance formation in another part of the field:

Section of the Cannonball marine member of the Lance formation, containing possibly a part of the lower Lance, measured in a cut bank on the north side of Heart River in sec. 10, T. 138 N., R. 83 W.

	Feet.
Top of Cannonball marine member of Lance formation.	
1. Partly concealed, but the few exposures indicate soft gray sandy shale	75
2. Sandstone, brown, very hard and resistant, forming a well-defined shelf; in places very fossiliferous, containing marine shells	4
3. Sandstone, yellow, soft, unconsolidated	15
4. Sandstone, fine grained, soft, unconsolidated, consisting of yellowish-brown bands alternating with darker bands and containing lenticular masses of sandstone. The entire mass has a characteristic somber hue	43
5. Sandstone, similar to No. 4, but the belt is of lighter color	45
6. Sandstone, similar to No. 4. Part of this may be lower Lance	115
	297

The top of the section given above marks the contact between the Cannonball marine member of the Lance formation and the overlying Fort Union formation.

These sections show that the Cannonball marine member is composed predominantly of fine-grained soft, more or less unconsolidated sandstone made up of light-yellow bands alternating with darker bands and including a subordinate amount of light to dark yellow and gray sandstone that commonly occurs in lenticular beds.

Several collections of marine invertebrate fossils were made in the Cannonball member in the New Salem field during the season of 1914, and the species have been identified by T. W. Stanton as belonging to the modified Fox Hills fauna.

TERTIARY SYSTEM.

FORT UNION FORMATION.

The Fort Union formation occurs at the surface throughout the northern and western parts of the field. The upper part of the formation as originally laid down has been removed by erosion. The maximum thickness of the remaining part is 350 feet. The formation consists mainly of massive light-yellow sandstone, sandy and clay shale, black carbonaceous shale, and lignite. The lignite beds occur throughout, but those of greatest economic importance lie above the lower 100 feet of the formation. The sandstone in the Fort Union is as a rule more resistant than that of the Cannonball marine member and gives rise to a gently rolling upland, whereas the soft unconsolidated sandstone of the underlying marine member is extensively cut by small streams, giving rise to a much more uneven surface. The relatively resistant sandstone of the Fort Union formation occurs as outliers throughout the eastern part of the field and rises above the general surface in the form of buttes.

The age of the Fort Union is attested by six collections of fossil leaves and 23 collections of invertebrates taken from different parts of the field and identified as of Fort Union age. The invertebrates, identified by T. W. Stanton, are as follows:

Unio sp. fragments.
Corbula mactriformis Meek and Hayden.
Viviparus sp.
Campeloma multilineata (Meek and Hayden).
Campeloma sp.
Viviparus retusus Meek and Hayden.
Viviparus leai Meek and Hayden.
Goniobasis nebrascensis Meek and Hayden.
Campeloma producta White.
Unio priscus Meek and Hayden.
Viviparus trochiformis Meek and Hayden.
Thaumastus limnaeformis Meek and Hayden.

The following fossil plants were identified by F. H. Knowlton:

Leguminosites arachioides Lesquereux.
Platanus sp.
Sapindas sp.?
Aralia? sp.
Populus cuneata Newberry.
Populus amblyrhyncha Ward.
Glyptostrobus europaeus (Brongniart) Heer.
Taxodium occidentale Newberry.
Viburnum sp.
Platanus, probably P. raynoldsii Newberry.
Sequoia nordenskioldi Heer?
Gigantic leaf, probably Ficus.
Sapindus affinis Newberry.
Sapindus grandifoliolus? Ward.
Celastrinites? sp.

STRUCTURE.

Throughout the greater part of the field there is a slight dip of 5 to 10 feet to the mile toward the northwest. This very low northwesterly dip is modified, however, by numerous local irregularities

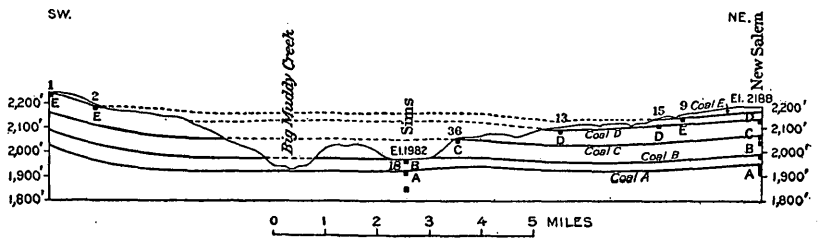


FIGURE 2.—Structure section through New Salem and Sims, N. Dak., showing the Fort Union formation. The numbers refer to corresponding numbers on the map (Pl. V).

of the strata, which become apparent only where it is possible to traverse clearly defined beds, such as beds of lignite or sandstone or fossil-bearing beds. In the course of the geologic mapping it became evident that there is a very gentle syncline (see fig. 2) whose axis trends in a northwesterly direction from the point where Big Muddy Creek crosses the south line of the field to the northeast corner of T. 138 N., R. 86 W. It is also evident from the elevations obtained on definitely traced beds that there is a region of minor uplift extending from sec. 34, T. 139 N., R. 85 W., south and east to the vicinity of the northeast corner of T. 138 N., R. 82 W. Evidence of the abovementioned major structural features is afforded by the observed dips, some of which clearly indicate still other minor irregularities in the strata. The lignite beds in T. 137 N., Rs. 83 and 84 W., dip southwest at a rate of 5 to 8 feet to the mile. Those in T. 137 N., R. 86 W., dip very gently in the direction of Big Muddy Creek. There is, however, an appreciable northward dip of 2 to 3 feet in 100 feet at the

Ramsland mine, near the north edge of sec. 6. Again, the lignite beds mapped in secs. 4, 5, and 6, T. 138 N., R. 85 W., appear to dip southwestward at the rate of about 50 feet to the mile. In general, the beds at the old Dakota Products Co.'s mine near New Salem dip very gently toward the northwest, and a similar dip was observed in the lignite beds mapped in the north row of townships in this field.

Figure 2 represents graphically the apparent syncline noted in the lignite beds in the western part of the New Salem field. The cross section extends from New Salem through Sims into sec. 7, T. 137 N., R. 86 W. The elevations and distances between the beds have been plotted to scale. Owing to insufficiency of the data, however, it can not be stated certainly that the correlation as indicated from New Salem to Sims is correct, and it is quite possible that the bed which crops out at Sims is bed A instead of bed B. All observed dips in the coal beds place the axis of the syncline just north and east of Sims. Bed E, in the New Salem section, has probably been removed by streams or by glacial action, and glacial materials have taken its place.

LIGNITE.

ORIGIN AND DISTRIBUTION.

No lignite beds were seen in the Cannonball member of the Lance formation and only one bed in the undifferentiated portion of the Lance formation below it in the New Salem field. The valuable beds of lignite are confined to the upper 200 or 300 feet of the Fort Union formation. There are few exposures of lignite, owing to the thick mantle of soil which is almost everywhere present, and for this reason it is extremely difficult to correlate lignite beds exposed at widely separated localities.

Early in Fort Union time swamps were formed over wide areas and large quantities of vegetal matter accumulated in them. The accumulation of this organic material and its burial under water, out of contact with the atmosphere, resulted in the formation of lignite.

There are only a few places in this field where erosion has been sufficient to expose a lignite bed continuously for more than a few hundred feet. The geologist's work in mapping the beds therefore consists mainly of searching for the few isolated exposures, most of which have been made by stripping, and of correlating the beds on the basis of elevation, in conjunction with an interpretation of the structure. In certain localities, as for example in T. 137 N., R. 86 W., and in the area of Fort Union rocks in T. 137 N., R. 83 W., the individual lignite beds could be traced with little difficulty. In general, this is equivalent to saying that wherever it was possible to determine the stratigraphic position of a lignite bed from its relation to the

base of the Fort Union, reasonably accurate correlation was possible, but for the beds stratigraphically higher in the Fort Union, where the mantle of soil is deep and where a knowledge of the structure is more or less vague, the most carefully made correlations are more or less doubtful. The exposures of lignite in the New Salem field are believed to represent five beds. The term lignitic horizons, in all probability, would more nearly represent the true conditions, as the beds are known to be very lenticular. For convenience of description, however, these beds are here referred to in ascending order as beds A, B, C, D, and E. The approximate distance of each bed above the base of the Fort Union formation is as follows:

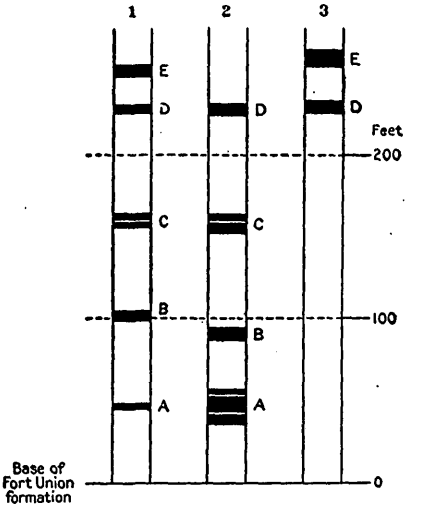


FIGURE 3.—Sections showing positions of lignite beds in Fort Union formation in New Salem lignite field, N. Dak. 1, Average section for the field; 2, section measured in air shaft of mine in sec. 7, T. 139 N., R. 85 W., 2¼ miles northwest of New Salem; 3, section in shaft and drill hole at abandoned mine of Dakota Products Co., New Salem.

A, 45 feet; B, 100 feet; C, 155 feet; D, 230 feet; E, 254 feet. Figure 3 represents graphically the distances between the various beds and shows the correlation of these beds with those exposed in a mine at New Salem and a mine 2½ miles northwest of New Salem.

The thickness of each bed at various places is shown on Plate III, and the location of each of the sections is shown on the accompanying map (Pl. V.) Two lignite beds in the Fort Union formation were mapped in T. 137 N., R. 83 W. The lower bed (bed B) occurs about 100 feet above the base of the formation, and the upper one (bed C) about 55 feet higher. Bed B was also mapped throughout a large area west of Heart River, and a lower bed that was measured at several places in the southwest quarter of T. 138 N., R. 85 W., and in sec. 4, T. 137 N., R. 85 W., was correlated with bed B. Three

beds were mapped in T. 137 N., R. 86 W. The lowest bed is exposed only at location 43,[15] in sec. 25. The next higher bed occurs at about the horizon of bed B, and the highest bed, which is well exposed in sec. 6, was correlated with bed E.

The exposures of lignite in the vicinity of Sims are thought to represent two beds. The lower bed is supposed to be bed B, and the upper one, which is about 100 feet above it, is designated bed C.

The exposures of lignite in New Salem Township and in the northern part of the township lying immediately south are thought to represent three separate beds, the lower one of which is correlated with bed C at Sims. The upper beds are 55 and 77 feet above bed C and accordingly are designated beds D and E, respectively.

In the vicinity of Judson, in the northeastern part of the field, exposures of lignite observed at several places about 50 feet above the base of the Fort Union formation are believed to represent bed A. Exposures of lignite which occur higher in the formation are correlated upon the basis of structure and elevation with beds C, D, and E. In addition to these beds in the Fort Union formation, there is a lignite bed near the top of the lower undifferentiated part of the Lance formation in which lignite is being mined at present in T. 137 N., R. 82 W. This bed is probably from 200 to 300 feet below bed A of the Fort Union formation.

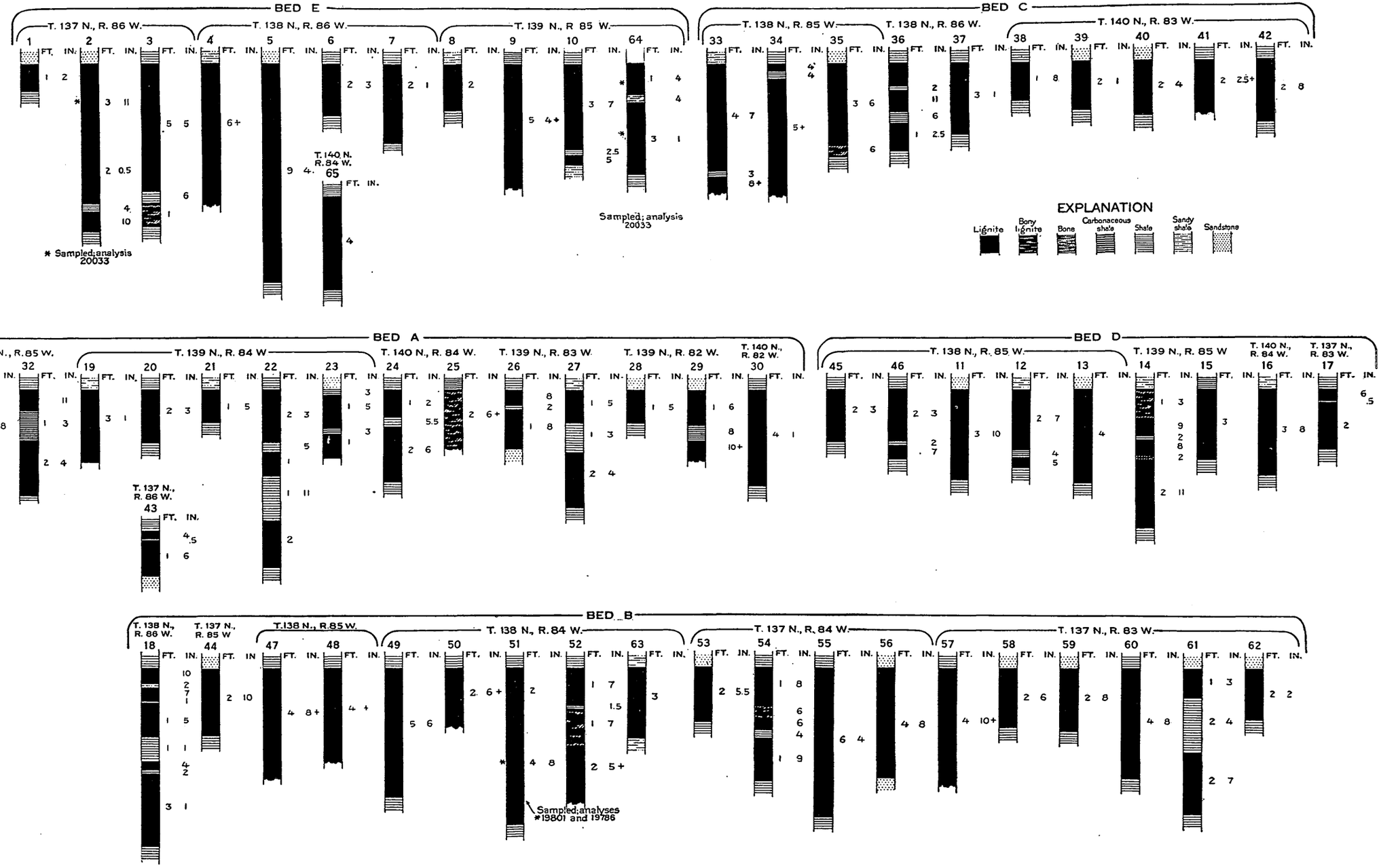
The lignite beds are considered in detail in the descriptions of individual townships.

PHYSICAL PROPERTIES.

The lignite of the New Salem field is similar to that from other parts of North Dakota. Most of the unweathered lignite has a dull luster, and much of it a tough, woody texture. It is very dark brown, and the powder and streak are brown to yellow. Careful examination of the woody parts shows considerable variation in color, luster, and texture. Dark-brown lignite having a comparatively dull luster contains numerous small lenses of bright black lignite, ranging from a thin film up to layers an inch or more in thickness. In certain places the luster is dull, the woody texture is lacking, and the lignite contains a large percentage of noncombustible material or ash.

When fresh lignite, which usually contains about 40 per cent of moisture, is exposed to the air it loses a considerable percentage of this moisture, shrinks, and soon breaks up into small pieces of irregular form. This tendency of lignite to fall to pieces on exposure is a serious handicap to the development of the mining industry, because it prevents long-distance shipment in open cars. The neces-

[15] Numbers refer to corresponding numbers on the map.



SECTIONS SHOWING THICKNESS, POSITIONS, AND NAMES OF LIGNITE BEDS IN NEW SALEM FIELD, MORTON COUNTY, N. DAK.

sity for paying transportation charges on its high content of water is also a serious drawback to the development of the lignite industry.

In lignite of the best quality the weathered surfaces are black and have a bright, vitreous luster, even though the unweathered lignite is brown and has a dull luster. Where the woody texture is not developed the lignite weathers into thin plates or laminae, and the same property has been observed in certain of the low-rank subbituminous coals. The weathering of different varieties of lignite is so characteristic that the examination of the weathered face of an exposed section may afford a better conception of the variations in character within the bed than an examination of the fresh material.

CHEMICAL PROPERTIES.

In order to determine the chemical composition of lignite it is necessary to take mine samples, and as lignite changes not only in physical condition but chemically on exposure to the air, it is necessary that these samples be as fresh as possible. Three such mine samples were taken during the examination of the New Salem lignite field, in accordance with the regulations of the United States Geological Survey, which in brief are as follows: A channel is cut across a clean, fresh face of lignite from roof to floor of the mine, all partings that are thrown out in mining being excluded. The material thus obtained is broken sufficiently fine to pass through a one-half inch screen, and the sample is reduced by quartering to about 4 pounds. This is placed in a galvanized can, sealed, and sent immediately to the chemical laboratory of the Bureau of Mines at Pittsburgh, Pa., for analysis.

The analyses of these samples are shown in the accompanying table. With them are included for comparison the analyses of four samples taken by E. R. Lloyd in the Cannonball River lignite field, of three samples collected by A. L. Beekly in 1909 from small strip pits in the valley of Cedar Creek in T. 129 N., R. 88 W., and of seven representative samples of lignite from producing mines in widely separated parts of North Dakota. To these analyses are added those of two subbituminous coals, from Montana and Wyoming, and two eastern bituminous coals, from Ohio and Pennsylvania. These last four coals have a market in the New Salem field, and a comparison of their heating value with that of the local lignite is of great interest and importance.

The accompanying table shows each analysis in four forms, marked A, B, C, and D. Analysis A represents the composition of the lignite as it is taken from the mine. This form of analysis should not be used in comparing one coal or lignite with another, because the amount of moisture in the sample as it is taken from the mine depends

to a certain extent upon local conditions, and consequently analyses of different samples of the same lignite expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. Analysis C represents the lignite after all the moisture has been theoretically eliminated. Analysis D represents the lignite after all moisture and ash have been theoretically removed. Forms C and D are determined from the others by recalculation.

Analyses of coal samples from the New Salem lignite field, N. Dak.

[Made at the Pittsburgh laboratory of the Bureau of Mines; A. C. Fieldner, chief chemist.]

Laboratory No.	Name.	Location.				No. on map (Pl. V).	Letter in fig. 4.	Air-drying loss.	Form of analysis.	Proximate.			Ultimate.						Heating value.	
		Quarter.	Section.	T. N.	R. W.					Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units
20033	Dakota Products Co.'s mine, near New Salem.	SW.	15	139	85	64	A	32.7	A	38.5	27.6	26.6	7.28	1.31	7.03	39.22	0.60	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
19801	Local mine.....	S. ½	32	138	84	51	.....	31.5	A	38.6	26.8	26.7	7.9	.66	.....	.....	.....	.....	3,585	6,450
									B	10.4	39.1	39.0	11.5	.97	.....	.....	.....	.....	5,230	9,420
									C	.....	43.7	43.5	12.8	1.07	.....	.....	.....	.....	5,835	10,500
									D	.....	50.1	49.9	.....	1.23	.....	.....	.....	.....	6,695	12,050
19786	Ramsland mine.....	NW.	6	137	86	2	B	24.9	A	36.1	27.7	30.3	5.9	.41	.....	.....	.....	.....	3,875	6,980
									B	14.9	36.9	40.4	7.8	.54	.....	.....	.....	.....	5,165	9,300
									C	.....	43.3	47.5	9.2	.64	.....	.....	.....	.....	6,065	10,920
									D	.....	47.7	52.3	.....	.70	.....	.....	.....	.....	6,680	12,020

Analyses of coal samples from fields furnishing coal in competition with the New Salem lignite.

Laboratory No.	Name.	Location.				Letter in fig. 4.	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.					Heating value.	
		Quarter.	Section.	T. N.	R. W.				Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.
14542	Nipper & Monroe's mine, near Haynes, N. Dak.	NW.	16	129	94	.....	14.5	A	32.6	30.6	28.5	8.3	1.53	.....	.....	.....	.....	4,085	7,360
								B	21.2	35.8	33.3	9.7	1.79	.....	.....	.....	.....	4,780	8,600
								C	.....	45.4	42.3	12.3	2.27	.....	.....	.....	.....	6,070	10,920
								D	.....	51.8	48.2	.....	2 59	.....	.....	.....	.....	6,920	12,460
14544	Pinkham mine, 9 miles northeast of Haynes, N. Dak.	NW.	36	130	94	.....	15.3	A	32.4	30.9	28.1	8.6	1.49	.....	.....	.....	.....	4,070	7,330
								B	20.2	36.5	33.2	10.1	1.76	.....	.....	.....	.....	4,805	8,650
								C	.....	45.7	41.6	12.7	2.21	.....	.....	.....	.....	6,025	10,850
								D	.....	52.4	47.6	.....	2.53	.....	.....	.....	.....	6,900	12,420
14729	Jones mine, near Leith, N. Dak.....	SE.	12	133	88	.....	27.1	A	36.2	29.8	25.3	8.70	.68	6.76	39.45	0.59	43.82	3,730	6,700
								B	12.5	40.8	34.8	11.93	.93	5.15	54.11	.81	27.07	5,105	9,190
								C	.....	46.7	39.7	13.63	1.07	4.29	61.81	.92	18.28	5,830	10,500
								D	.....	54.0	46.0	.....	1.24	4.97	71.56	1.07	21.16	6,750	12,150
17537	Kolbank mine, near Leith, N. Dak.....	NE.	7	133	87	.....	16.6	A	34.7	29.9	24.9	10.5	1.50	.....	.....	.....	.....	3,775	6,800
								B	21.7	35.8	29.9	12.6	1.80	.....	.....	.....	.....	4,530	8,150
								C	.....	45.7	38.2	16.1	2.30	.....	.....	.....	.....	5,785	10,410
								D	.....	54.5	45.5	.....	2.74	.....	.....	.....	.....	6,895	12,410
7841	Mine of A. L. McCord, Cedar Creek, N. Dak.	NE.	5	129	88	.....	19.3	A	32.1	25.6	31.7	10.6	1.19	.....	.....	.....	.....	3,790	6,820
								B	15.8	31.8	39.2	13.2	1.48	.....	.....	.....	.....	4,695	8,460
								C	.....	37.8	46.6	15.6	1.75	.....	.....	.....	.....	5,580	10,040
								D	.....	44.8	55.2	.....	2.07	.....	.....	.....	.....	6,615	11,910
7839	Surface prospect, Cedar Creek, N. Dak....	SW.	1	129	88	.....	21.1	A	33.1	25.5	36.1	5.3	.69	.....	.....	.....	.....	4,150	7,470
								B	15.2	32.4	45.7	6.7	.87	.....	.....	.....	.....	5,255	9,460
								C	.....	38.2	53.9	7.9	1.03	.....	.....	.....	.....	6,200	11,160
								D	.....	41.5	58.5	.....	1.12	.....	.....	.....	.....	6,735	12,120
7842	Surface prospect, Cedar Creek, N. Dak....	SE.	4	129	88	.....	23.1	A	32.5	27.1	34.6	5.8	.37	.....	.....	.....	.....	4,030	7,250
								B	12.2	35.3	45.0	7.5	.48	.....	.....	.....	.....	5,240	9,430
								C	.....	40.1	51.3	8.6	.55	.....	.....	.....	.....	5,965	10,740
								D	.....	43.9	56.1	.....	.59	.....	.....	.....	.....	6,525	11,750
1935	Mine of Washburn Lignite Coal Co., Wilton, N. Dak.	.....	1	142	80	C	32.3	A	40.5	27.1	27.4	5.0	.76	.....	.....	.....	.....	3,690	6,640
								B	12.2	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	12,210

1971	Mine of Consolidated Coal Co., Lehigh, N. Dak.	.....	8	139	95	D	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
19367	Mine of U. S. Reclamation Service 3 miles northeast of Williston, N. Dak.	.....	7	154	100	E	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	6,695	12,060
14485	Scranton mine of Charles Liddell, Scranton, N. Dak.	SW.	24	131	100	.....	22.5	A	34.8	31.1	26.0	8.1	.66	.....	.....	.....	.....	3,840	6,920
								B	15.9	40.1	33.5	10.5	.85	.....	.....	.....	.....	4,960	8,920
								C	.....	47.7	39.8	12.5	1.01	.....	.....	.....	.....	5,890	10,610
								D	.....	54.5	45.5	.....	1.15	.....	.....	.....	.....	6,730	12,120
33069	Beulah mine, Mercer County, N. Dak	.....	25	144	88	F	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
32444	Hebron Fire & Pressed Brick Co.'s mine, Hebron, Morton County, N. Dak.	.....	.....	140	90	G	11.1	A	28.1	31.1	31.4	9.41	1.15	5.97	44.58	.59	38.30	4,075	7,340
								B	19.0	35.1	35.3	10.59	1.29	5.32	50.16	.66	31.98	4,585	8,260
								C	.....	43.3	43.6	13.06	1.60	3.97	61.89	.82	18.66	5,660	10,190
								D	.....	49.8	50.2	.....	1.84	4.57	71.19	.94	21.46	6,510	11,720
31705	Conon mine of J. F. Casteel, Burlington, Ward County, N. Dak.	.....	.....	150	84	H	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
12005	Monarch mine of Wyoming Coal & Coke Co., Monarch, Sheridan County, Wyo.	SE.	24	57	85	I	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
29004	Mine A of Roundup Coal Mining Co., Roundup, Musselshell County, Mont.	.....	22	8	25 E.	J	3.5	A	13.6	32.8	45.5	8.05	.70	5.56	61.98	.98	22.73	5,935	10,690
								B	10.5	34.0	47.2	8.34	.72	5.37	64.20	1.01	20.36	6,150	11,070
								C	.....	38.0	52.7	9.31	.81	4.69	71.70	1.13	12.36	6,870	12,360
								D	.....	41.9	58.1	.....	.89	5.17	79.06	1.25	13.63	7,575	13,630
7712	Hocking Valley, Ohio.....	.....	.....	.....	.....	K	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
23097	Pittsburgh coal, East Millsboro, Fayette County, Pa.	.....	.....	.....	.....	L	1.2	A	2.5	35.7	53.6	8.17	1.76	5.19	76.15	1.49	7.24	7,885	13,650
								B	1.4	36.1	54.2	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

20033. From mine of Dakota Products Co. (location 64), half a mile northeast of New Salem; collected by E. T. Hancock October 23, 1914, about 2,540 feet N. 20° W. of the mine mouth. The lignite bed is in the Fort Union formation and ranges from 4 feet 6 inches to 6 feet in thickness. At the point of sampling the top of the bed was not exposed, and the sample included that part of the upper bench worked, 1 foot 4 inches thick, and the bottom bench, 3 feet 1 inch thick.

19801. From a local mine (location 51) operated by farmers in the S. ½ sec. 32, T. 138 N., R. 84 W.; collected by E. T. Hancock September 7, 1914, at a point about 70 feet N. 15° W. of the shaft. The lignite bed is in the Fort Union formation and is 6 feet 8 inches thick, but only the lower 4 feet 8 inches of the bed was sampled.

19786. From Ramsland open-pit mine (location 2), in the NW. ¼ sec. 6, T. 137 N., R. 86 W.; collected by E. T. Hancock August 24, 1914. The lignite bed is in the Fort Union formation and at the point of sampling has a thickness of 6 feet 9½ inches, but only the upper 3 feet 11 inches of the top bench was sampled.

14542. From Haynes lignite bed in the Nipper & Monroe mine, 3½ miles northeast of Haynes; collected by E. R. Lloyd July 30, 1912, in entry about 630 feet nearly due east of the mine mouth

14544. From Haynes lignite bed in mine of William Pinkham, about 9 miles northeast of Haynes; collected by E. R. Lloyd July 30, 1912, in main entry about 225 feet south of the mine mouth.

14729. From Haynes (?) lignite bed in Jones mine of J. T. Dunn, about 2 miles west of Leith; collected by E. R. Lloyd September 7, 1912.

17537. From Haynes (?) lignite bed in Kolbank mine of Simon Pederson, about 1½ miles southwest of Leith; collected by E. R. Lloyd July 10, 1913.

7841. From McCord mine (strip pit), on the north side of Cedar Creek, in the NE. ¼ sec. 5, T. 129 N., R. 88 W., about 8 miles northeast of Morristown, S. Dak.; collected by A. L. Beekly in 1909.

7839 and 7842. From prospect pits on the south side of Cedar Creek, T. 129 N., R. 88 W.; collected by A. L. Beekly in 1909. They are from the same bed as sample 7481.

1935. From mine of Washburn Lignite Coal Co., Wilton, McLean County, N. Dak.; collected by M. R. Campbell August 3, 1905, 1,750 feet from shaft.

1971. From mine of Consolidated Coal Co. at Lehigh, Stark County, N. Dak.; collected by M. R. Campbell August 5, 1905, 1,900 feet from the mine mouth.

19367. From mine of United States Reclamation Service 3 miles northeast of Williston, Williams County, N. Dak.; collected by F. A. Herald August 16, 1911, 1,225 feet east of the mine mouth.

14485. From Harmon (?) lignite bed in Scranton mine of Charles Liddell, Scranton, Bowman County, N. Dak.; collected by C. J. Hares June 30, 1912, from face of east entry, 1,000 feet from mine mouth.

33069. From Beulah mine, Beulah, Mercer County, N. Dak.; collected by A. J. Collier October 6, 1919, in ninth entry north.

32444. From Hebron mine of Hebron Fire & Pressed Brick Co., Hebron, Morton County, N. Dak; collected by B. W. Dyer March 13, 1919.

31705. From Conon mine of J. F. Casteel, Burlington, Ward County, N. Dak.; collected by John G. Schoning March 28, 1919.

12005. From Monarch mine of Wyoming Coal & Mining Co., Monarch, Sheridan County, Wyo.

29004. From mine A of Roundup Coal Mining Co., Roundup, Musselshell County, Mont.

7712. From Hocking Valley, Ohio.

23097. From East Millsboro, Fayette County, Pa.; a typical Pittsburgh coal.

The percentage of moisture in all lignites is very high. The percentage of sulphur shown in the analyses of lignites from this field is higher than that in the lignites of some parts of the plains basins, but it is not so high as that in coals of other regions. The sulphur occurs in the form of nodules or balls of pyrite and marcasite, which are distributed along joints and bedding planes.

In the analyses of samples from the New Salem and Cannonball River lignite fields and some of the others given in the above table the volatile matter was determined by the "modified method," which involves a preliminary heating of the lignite before it is subjected to a temperature sufficiently high to drive off the volatile matter.° The modified method prevents the sputtering and the attendant mechanical loss of particles of the sample which are caused in the standard method where the higher heat is applied at once. The loss accompanying the standard method affects chiefly the fixed carbon, so that when the modified method is used the determined percentage of that constituent is generally higher, in some analyses as much as 20 per cent.

COMPARATIVE HEATING VALUE.

Most of the users of lignite are little concerned about the percentage of sulphur in the lignite 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 general use in manufacturing plants.

Many think it best to foster home industries even at the cost of some sacrifice, but to most persons the deciding factor regarding a fuel as well as any other commodity that they may be needing is that of economy, and economy in the purchase of fuel means generally getting the 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 is essential in order to determine which kind of coal 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 page 17 will enable anyone to make a direct comparison of the various coals and lignites there listed, and in fact their comparative values may be expressed in dollars and cents.

Figure 4 shows graphically the heating value of certain of the coals and lignites whose analyses are given on pages 17–19. These analyses have been selected because they were made from samples that were collected in working mines and so had suffered no deteriora-

tion from exposure to the weather. For convenience in reference these will be designated A, B, C, etc., as shown in the diagram. A and B represent samples from the New Salem field; C to H lignite from adjacent fields of North Dakota; I and J subbituminous coals from Wyoming and Montana; and K and L two well-known and high-rank coals from the East that are frequently shipped into this region by way of the Great Lakes. These letters are also shown in the table of analyses.

The line marked " pure coal " shows the comparative heating value of the several 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

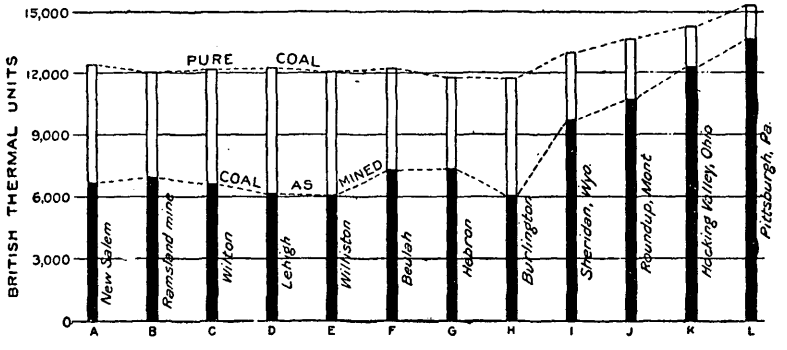


FIGURE 4.—Graph showing the heating value of North Dakota lignite as compared with that of other coals with which it may have to complete.

as follows: A, D, F, C, B, E, G, H. In other words, the New Salem lignite is intrinsically a little better than any other lignite here considered. The " pure coal " line ascends rapidly to the right, reaching its highest point at L. This shows that the best coal here considered is the Pittsburgh coal, and that both this and the Hocking Valley coal of Ohio are superior in heating value to the subbituminous coals of Wyoming and Montana.

The comparison just made is interesting, but it has no practical value because it refers to pure coal and not to the coal in the consumer's bin. The line marked " coal as mined " shows the comparative heating value of the same group of coals in approximately the condition in which they are consumed. This line shows much greater variations than the " pure coal " line 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: G, F, B, A, C, D, H, E. The Hebron mine produces the best lignite,

with Beulah a close second and Ramsland third. Here again the subbituminous and bituminous coals stand higher than the lignites, and the difference between them is more marked than it is on the "pure coal" line. The reason for this is mainly the fact that the high-rank coals contain little moisture, whereas lignite is heavily charged with moisture.

The relative heating values are proportional to the British thermal units in the analyses showing coal "as received." Thus, the heating value of New Salem lignite compared with that of Pittsburgh coal is as 6,700 is to 13,650; or, expressed in another way, if New Salem lignite sells for $5 a ton the consumer could afford to pay $10.20 for Pittsburgh coal. If he could buy Pittsburgh coal for less than $10.20 it would be cheaper than the lignite at $5. If New Salem lignite costs $5 a ton the real value of the other lignites and coals shown in the diagram is as follows:

Comparative value of certain coals.

New Salem lignite	$5.00
Ramsland lignite	5.05
Wilton lignite	4.96
Lehigh lignite	4.60
Williston lignite	4.44
Beulah lignite	5.40
Hebron lignite	5.45
Burlington lignite	4.49
Sheridan subbituminous coal	7.20
Roundup subbituminous coal	7.95
Hocking Valley bituminous coal	9.15
Pittsburgh bituminous coal	10.20

MINING.

At the time the field work was done the only mine in operation was that of the Dakota Products Co., at New Salem.[16] This mine, which is considered in the description of T. 139 N., R. 85 W., was almost a continuous producer, while practically all the other local mines are operated for only a short period each year and only on a very small scale.

The Dakota Products Co.'s mine was operated almost entirely to supply the local demand for lignite. The tonnage mined during the fall and winter greatly exceeded that produced during the spring and summer, but the average daily output for the year was reported to be about 110 tons. Some of the lignite was consumed in New Salem and some was hauled in wagons directly from the mine to the farms of the surrounding country. A considerable quantity was also

[16] This mine has since been abandoned, but in 1919 the Consolidated Lignite Collieries Co. was opening a new mine in sec. 7, about 3 miles northwest of New Salem.

shipped by rail to the small towns on the Northern Pacific Railway and from them distributed by wagons.

It has apparently been the custom throughout this field for two or more farmers to combine and by means of plows and scrapers remove the cover from a bed of lignite. After the covering is removed the lignite is broken up by some convenient method and shoveled directly into wagons. With very few exceptions the local lignite mines represented on the accompanying map (Pl. V) are openings of this character. They are generally referred to as "open-pit mines" or "strip pits," and the process of removing the overburden is known as "stripping." In most of them only a few hundred square feet of the lignite bed has been removed, but exceptionally—for example, at the large open pits at locations 2, 3, 4, and 5, about 3½ miles southwest of Almont—several thousand square yards of the beds have been stripped and mined out.

The lignite beds in this field are almost without exception underlain by a dense bluish-gray clay shale, which is nearly impervious to water. Such material is a very serious obstacle to open-pit mining, for after the covering is removed and a portion of the lignite is mined out the open pit readily fills with water. Many of the open pits can not be drained without the expenditure of considerable additional labor. This difficulty could be avoided by selecting for stripping some point on a slope where the pit could be more easily drained. Too often the place chosen for stripping is determined by certain signs of lignite, such as black material brought up by burrowing animals, without the slightest regard for the possibility of draining the pit after it is made. Owing to a heavy rainfall early in the season of 1914, practically all the open pits in the New Salem field were partly filled with water, a condition which made it very difficult in many places to measure the thickness of the lignite beds.

The ground water moves downward until it reaches the impervious clay shale and then flows laterally, eventually reaching the surface in the form of springs. In opening drift mines it is advantageous to determine the local conditions of structure and then locate the mine in such a manner that the entry will follow the gradual rise of the beds, which in most localities is sufficient to furnish natural drainage.

One of the most serious obstacles to underground mining in this field is the character of the overlying shale, which is so weak that it can not be used as a roof. It is therefore necessary in many places to leave a portion of the lignite to form the roof, a necessity which prevents the mining of any but the thicker beds by this method.

A general estimate of the amount of coal present in the New Salem field may be obtained after a study of the stratigraphic sections

given for each township. Taking an average of the mean thicknesses of coal beds for each township gives 3.03 feet as a uniform thickness for the entire field. On the assumption that 1 square mile of lignite 1 foot thick contains 1,152,000 short tons, a thickness of 3.03 feet for the New Salem field will give it a coal content of approximately 2,068,000,000 short tons.

DESCRIPTION BY TOWNSHIPS.

The lignite beds in each township are described in order, beginning with the lowest. All places where lignite beds were examined and many places where lignite was reported to be present were accurately located, and their positions are shown on the maps by location numbers. The lignite sections measured at these points are correspondingly numbered, and it is by means of these numbers that reference is made from the text to the map (Pl. V) and to the plate of graphic sections (Pl. III).

T. 137 N., R. 82 W.

The most conspicuous topographic feature in T. 137 N., R. 82 W., is the prominent ridge composed mainly of glacial boulders which occupies a portion of secs. 13, 14, 23, and 24. All the northern part of the township is a gently rolling upland underlain by the Cannonball marine member of the Lance formation. Most of the south half is considerably lower than the northern upland and is almost flat, and although there are no rock exposures, it is probably underlain by the lower part of the Lance formation. Most of the drainage from the township empties into Little Heart River. With the exception of the small boulder-covered tract mentioned above, the entire township is well adapted to agriculture. No exposures of lignite were observed.

T. 138 N., R. 82 W.

With the exception of an area of about 10 square miles in the southeast corner, T. 138 N., R. 82 W., drains into Heart River. The surface of the township, except a narrow belt adjacent to Heart River and Sweetbriar Creek, is a gently rolling prairie well suited to agriculture. The very fertile alluvium along the principal streams is admirably adapted to general farming, and the deeply dissected belt adjacent to it is utilized mainly for grazing.

Nearly all of the township is occupied by the Cannonball member of the Lance formation. The lower sandstones of the Fort Union formation cap some of the highest buttes, which occur principally in the southwestern and northeastern parts of the township. No outcrops of lignite were seen, and none were reported.

T. 139 N., R. 82 W.

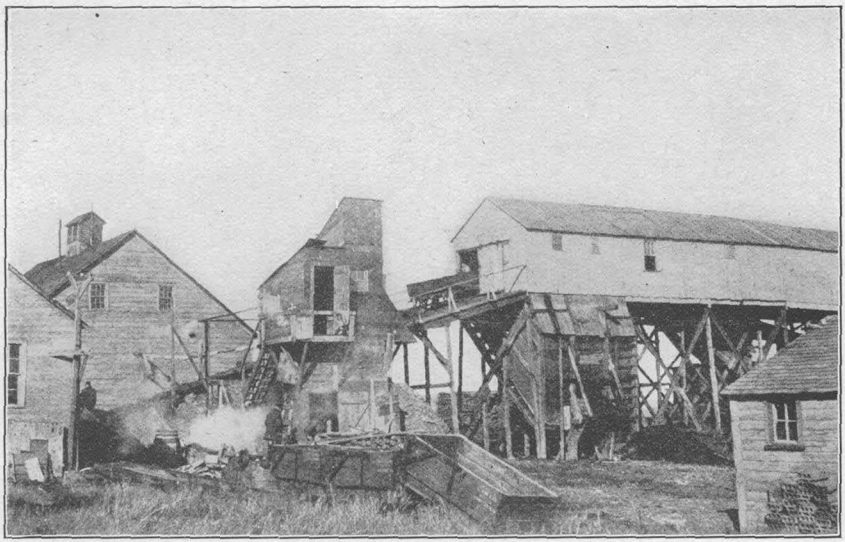
Heart River flows across the southeastern part of T. 139 N., R. 82 W., and receives the drainage from all except the north tier of sections. In general the eastern and southeastern parts of the township are moderately rough, owing to the extent to which the numerous small streams have eroded the soft shale. The northwestern part, on the other hand, is a rolling prairie. The alluvial flat along Heart River and the moderately level upland are devoted to general farming; the rougher portions of the township are utilized mainly for grazing. The township is crossed by the main line of the Northern Pacific Railway, on which grain elevators have been erected at short intervals, bringing the producers into close touch with the markets.

The Fort Union beds have been eroded so that the underlying marine member of the Lance formation is exposed throughout about two-thirds of the township. The comparatively high upland in the northwestern part is composed of the lower beds of the Fort Union formation.

Only one bed of lignite was observed in this township. From its position with reference to the base of the Fort Union formation it was designated bed A. The bed was measured in an open pit at location 29, in sec. 10, where it was found to consist of at least two separate benches of lignite separated by 8 inches of black carbonaceous shale. The upper bench measured 1 foot 6 inches, but all except the upper 10 inches of the lower bench was under water and its full thickness could not be ascertained. It was reported, however, to have a total thickness of 3 feet. What is probably the same bed was seen in an old prospect in the SW. ¼ sec. 15. Its position was also indicated by a "burn" in the SW. ¼ sec. 9, and the bed was measured in the road at location 28, in sec. 8, where it was found to contain only 1 foot 5 inches of lignite. What is believed to be the same bed is also exposed near the east line of sec. 12 of the township immediately west. As the bed at that place appeared to contain only 10 inches of lignite, the line of traverse was not continued west of location 28.

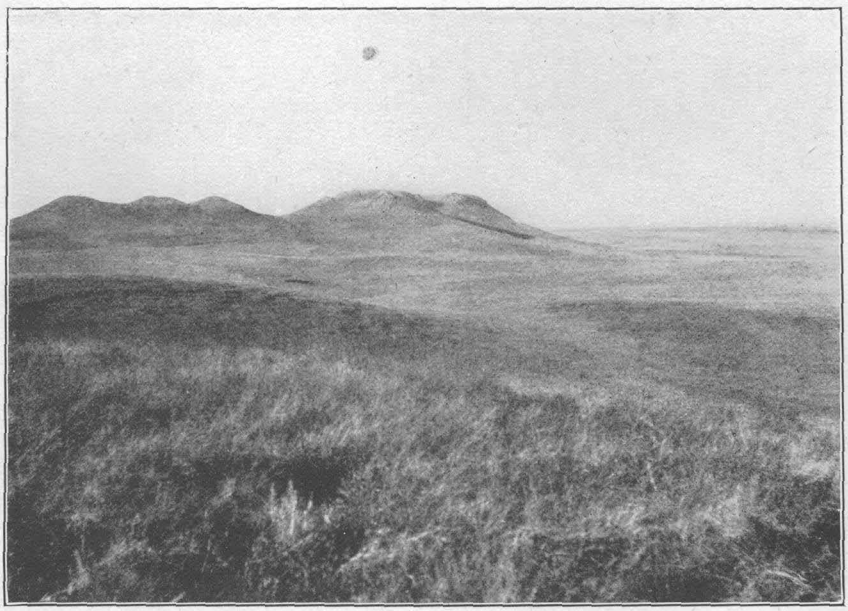
T. 140 N., R. 82 W.

The drainage of T. 140 N., R. 82 W., goes eastward into Missouri River, which lies from 2 to 3 miles east of the township. Otter Creek drains much the larger part of the township. All of the eastern part is underlain by the Cannonball marine member of the Lance formation; the western part is occupied by the lower beds of the Fort Union. The portion of the township underlain by the Lance formation has a very uneven surface. The slopes are not steep,



A. DAKOTA PRODUCTS CO.'S MINE NEAR NEW SALEM, N. DAK.

This mine has been abandoned.



B. CROWN BUTTE, ON UPLAND IN SEC. 31, T. 140 N., R. 82 W., N. DAK., LOOKING NORTHEAST.

however, so that the valleys and much of the upland are well adapted to farming. South of Square Butte Creek the edge of the Fort Union formation is marked by a rather steep escarpment, and below the escarpment for a distance of half a mile to a mile the land is deeply dissected. The portion of the township which is occupied by the Fort Union formation maintains a somewhat higher altitude and has a much more even surface than the other portion. In places there are prominent hills or buttes, as they are called in this country, standing distinctly above the surrounding plain. One of the best examples is Crown Butte, shown in Plate IV, *B*.

A single bed of lignite was found in this township, and from its relation to the base of the Fort Union formation it was identified as bed A. At location 30, in the NW. ¼ sec. 17, the bed contains 4 feet 1 inch of good lignite overlain by black carbonaceous shale and underlain by gray clay shale. This bed does not appear to be of much value for any considerable distance north of location 30, for the section measured in the NE. ¼ NW. ¼ sec. 9 includes only a few thin streaks of lignite. The bed was at one time extensively mined for local use near the southeast corner of sec. 20, but the workings have been abandoned and allowed to fill with water. What was taken to be the same bed is exposed in a spring about 600 feet east and a little north of the southwest corner of sec. 29. The thickness of the bed at this place is reported to be 1 foot 6 inches. No further exposures of this bed were observed during the geologic mapping. On Plate V the broken line in secs. 19, 30, and 31 indicates the probable position of bed C, which in this township is entirely grass-covered.

T. 137 N., R. 83 W.

The most prominent surface feature in T. 137 N., R. 83 W., is the high drainage divide which crosses near the middle of the township in a north-south direction. This divide is roughly coincident with the area underlain by the rocks of the Fort Union formation. The shale and soft sandstone of the Cannonball marine member of the Lance formation west of the divide are deeply dissected by numerous small streams, and in consequence the area is extremely rough and, except for the alluvial flats along Heart River, is ill adapted to general farming. The area occupied by the same member east of the divide, on the other hand, slopes off gently to the lowland. It is gently rolling, whereas the area mapped as lower Lance is almost perfectly flat. The part of the township east of the divide is well adapted to general farming.

Two noteworthy beds of lignite are exposed in this township and from their stratigraphic positions were designated beds B and D. Their outcrops are shown on Plate V, and the sections measured at

short intervals are represented graphically on Plate III. By referring to sections 57, 58, 59, 60, 61, and 62 it will be seen that the lower bed (bed B) ranges in thickness from 2 feet 2 inches to 4 feet 10 inches. The rock overlying this bed is commonly a light-colored soft sandstone, and that underlying it is commonly a clay shale. The upper bed (bed D) was found only at location 17, near the northwest corner of sec. 30, and at an old prospect in the SE. ¼ sec. 20. At location 17 the bed contains 2 feet 6 inches of lignite with a ½-inch shale parting 6 inches from the top. At the old prospect in sec. 20 the bed contains 2 feet 6 inches of very much weathered lignite.

T. 138 N., R. 83 W.

Heart River crosses T. 138 N., R. 83 W., in a series of great meanders from the SE. ¼ sec. 31 to the SE. ¼ sec. 13. The alluvial flat in which the river flows and which ranges from a quarter to half a mile in width (Pl. I, *B*) includes some of the most fertile agricultural land in the township. As in other parts of the field, the rich flood plain of the river is bordered on either side by a belt of country from half a mile to a mile in width in which numerous side streams have deeply intrenched themselves in the soft sandy shale of the Lance formation. This belt is better suited for grazing than for general farming. It gradually merges into the gently rolling upland, which if not entirely underlain by the Fort Union beds is characterized by small isolated buttes that are merely outliers of that formation. No lignite was seen or reported in this township.

T. 139 N., R. 83 W.

With the exception of a narrow belt along the east edge, T. 139 N., R. 83 W., drains into Sweetbriar Creek. Although this township is traversed by a great many drainage channels, most of the valleys are comparatively shallow, and general farming can be carried on nearly everywhere. Sweetbriar Creek and its numerous tributaries have gradually eroded away the overlying Fort Union beds, exposing the underlying sandstone and sandy shale of the Lance formation throughout most of the south half of the township. This broad valley of erosion gradually merges into the upland occupied by the Fort Union formation. The flatness of the upland is indicated by the paucity of drainage channels and also by the fact that most of the public highways follow the section lines. The small settlement known as Sweetbriar, on the main line of the Northern Pacific Railway, affords an excellent market and shipping point for the surrounding region.

The only exposures of lignite seen in this township are on bed A at locations 26 and 27, in sec. 4. The details of the sections measured

at these points are represented in Plate III. It is reported that a well in the NE. ¼ SE. ¼ sec. 3 passed through 4 feet of lignite at a depth of about 40 feet. From the elevation of the surface at that place the lignite bed as reported is 12 feet lower than the lignite at locations 26 and 27 and in all probability represents the same bed.

T. 140 N., R. 83 W.

A drainage divide that is not at all conspicuous as a surface feature crosses T. 140 N., R. 83 W., from the southwest corner of sec. 6 to the southeast corner of sec. 24. This divide separates the drainage which flows north and east into Square Butte Creek from that which flows south into Sweetbriar Creek. The only rocks exposed in this township are those of the Fort Union formation. In contrast with the dissected belt along Heart River the entire township is a gently rolling upland prairie, suitable for general farming. It is well settled, and with few exceptions the main wagon roads follow the section lines.

Owing to the evenness of the surface it is extremely difficult to find exposures of lignite, but measurements of a bed were obtained at locations 38, 39, 40, 41, and 42. As shown on Plate III, the bed is thin, not exceeding 2 feet 8 inches in thickness at any of these locations. From the elevation of the lignite at these places it is reasonable to assume that they represent the same bed, which, upon the basis of its stratigraphic position, is assumed to be bed C. A 4-foot bed of lignite is exposed in an open pit at location 65, in the NE. ¼ SE. ¼ sec. 13 of the township immediately west, and in all probability represents a higher bed, but no exposures of the upper bed were observed in this township.

T. 137 N., R. 84 W.

The drainage from the western part of T. 137 N., R. 84 W., flows westward and empties into Beaver Creek; that from the eastern part flows eastward and empties into Heart River. The divide between the two drainage systems crosses the township in a north-south direction about a mile west of its middle line. The soft sandstone and sandy shale of the Lance formation on either side of Heart River back for a distance of 1½ or 2 miles are deeply dissected by numerous side streams, and in consequence this badland is used mainly for grazing. A well-defined flood plain from a third to half a mile in width extends along Heart River and includes some of the most fertile land in the township. The deeply dissected belt on either side of the river valley gradually merges into the gently rolling upland, which is underlain by the lower beds of the Fort Union formation. The lower part of the Lance formation extends up

Heart River for a distance of about 4 miles and crops out in a narrow belt between the alluvium and the upper or Cannonball member of the Lance. The exposures of lignite in this township are all believed to represent the same bed, which, on the basis of its stratigraphic position, is correlated with bed B in the township immediately east. The sections measured at locations 53, 54, 55, and 56 show a bed of lignite ranging from 2 feet 5½ inches to 6 feet 4 inches in thickness. The details of the sections are graphically represented on Plate III. A bed of lignite 80 inches thick at location 51, in sec. 32, T. 138 N., R. 84 W., is from its elevation believed to be the same bed.

T. 138 N., R. 84 W.

From the west-central part of T. 138 N., R. 84 W., the streams flow north into Sweetbriar Creek, east into Heart River, and south into Beaver Creek. Fort Union beds crop out in about two-thirds of the township, and that portion has a gently rolling surface well adapted to agriculture. Some of the area underlain by the Cannonball marine member of the Lance formation is extensively cut up by deep gullies and is suited only for grazing. It shows in many places steep grass-covered ridges with buttes of the Fort Union formation rising abruptly above the general surface. A large part of the township is covered by a mantle of glacial till with pebbles and boulders ranging from coarse gravel to boulders the size of a small house. Certain tracts are so thickly covered with the glacial drift as to be useless for anything but grazing.

Only one bed of lignite of economic importance was observed in this township. This bed ranges from 3 feet to 6 feet 8 inches in thickness, and it is believed to be bed B, the same as the one mapped in the township immediately south. The details of the measurements made at locations 49, 50, 51, 52, and 63 are represented graphically on Plate III. Where the thickness of the bed was found to be below the classifiable limit of 28 inches it is not represented graphically. Thus at location 70, in sec. 1, bed B measures only 2 feet 3 inches; at location 71 it appears to be represented by two thin streaks of carbonaceous shale; and at a point near the west line of sec. 15 it contains only 1 foot 3 inches of lignite. A bed of lignite 1 foot 10 inches thick was measured near the bottom of the valley in the NE. ¼ sec. 6. No other exposures were observed, and owing to the local northeasterly dip it was impossible to correlate the bed with any of the other beds mapped.

T. 139 N., R. 84 W.

In T. 139 N., R. 84 W., Sweetbriar Creek and its northern tributary have lowered their beds enough to expose the Lance formation only in a small tract in the southeastern part of the township. A

narrow belt along the contact between the Fort Union and the Cannonball member of the Lance formation is in many places very rough, owing to the presence of numerous small gullies. The eastern part of sec. 12, parts of secs. 35 and 36, and some other tracts are covered with glacial boulders (Pl. II, *A*). Such tracts are ill adapted to general farming but can be utilized to good advantage for grazing. The flood plains along the principal streams and most of that portion of the township which is underlain by the Fort Union formation are well adapted to general farming. The main line of the Northern Pacific Railway crosses this township from east to west. The little town of Judson, situated on the railway about a mile south of the center of the township, affords a market and shipping point for the crops raised in the surrounding region.

A bed of lignite was observed at location 23, in sec. 2, and at locations 19, 20, 21, and 22, in secs. 29 and 30. As shown in Plate III, the bed at these locations contains from 1 foot 5 inches to 5 feet 8 inches of lignite, but the thicker section is badly broken by partings. These exposures are all believed to be on the lowest bed observed in the field, namely, bed A.

T. 140 N., R. 84 W.

T. 140 N., R. 84 W., except a small tract in the northeastern part, is drained by the branches of Sweetbriar Creek. The entire township is occupied by rocks of the Fort Union formation. It comprises a portion of the gently rolling upland prairie that forms the divide between Sweetbriar and Square Butte creeks. The extent to which the public highways are able to follow the section lines expresses the evenness of the surface. The amount of land in this township at present being farmed is indicated by the more or less uniform distribution of farm houses.

The few exposures of lignite that occur in this township are believed to represent at least three different beds. The bed exposed at location 25, in sec. 31, and at the two open pits at location 24, in sec. 34, occurs only a short distance above the base of the Fort Union formation, and accordingly it is assumed to be bed A. This bed, as shown in Plate III, is 4 feet 1½ inches thick, including a parting 5½ inches thick, at location 24, but at location 25 the part exposed is only 2 feet 6 inches thick and consists of bony lignite. The 3-foot 8-inch bed of lignite exposed in the open-pit mine at location 16, in sec. 16, is believed to be bed D, whereas the 4-foot bed of lignite exposed in the open pit at location 65, near the east line of sec. 13, is at a position stratigraphically somewhat higher and was accordingly correlated with bed E.

Lignite is said to have been found in several wells in this township. For example, a 4-foot bed of lignite is reported in the log of

a well a few hundred feet southeast of the house in the SE. ¼ NE. ¼ sec. 14, at such a depth that its elevation is 2,147 feet, or the same as that of the lignite at location 65. Some lignite is also reported in the log of a well near the house in the SW. ¼ SE. ¼ sec. 2, at such a depth that the elevation is 2,180 feet, but the thickness of the bed could not be ascertained. Furthermore, 6 feet of lignite is reported in the log of a well near the house in the SW. ¼ NW. ¼ sec. 10, at such a depth that it would have an elevation of 2,095 feet. The elevation of the bed in the well is so near that of the bed in the open-pit mine in sec. 16 that it seems probable that they are the same. What appears from its elevation to be the same bed is reported to occur at a depth of 35 feet in a well near the house in the NE. ¼ SE. ¼ sec. 12, T. 140 N., R. 85 W. This 7-foot bed of lignite, reported to have been "dug through," was found to have an elevation of 2,082 feet.

T. 137 N., R. 85 W.

The most conspicuous topographic feature in T. 137 N., R. 85 W., is the relatively high divide which separates the Big Muddy Creek drainage system from that of Beaver Creek. Each of these streams flows in very striking meanders, and each has a well-defined flood plain, which includes some of the most fertile land in the township. That of Big Muddy Creek averages about three-quarters of a mile in width, but that of Beaver Creek has a width of less than a quarter of a mile. Bordering the flood plain of each stream is a belt of badlands which has been deeply dissected by numerous small streams and which is better adapted for grazing than for general farming. The badland belt gradually merges into the gently rolling upland prairie. The Cannonball member of the Lance formation is exposed throughout most of the south half of the township, and the Fort Union or lignite-bearing formation occupies practically all of the north half.

The exposures of lignite that were examined are believed to represent two separate beds, which, from their relation to the base of the Fort Union formation, are assumed to be beds A and B. The lower, or bed A, is of very little value, containing in the NE. ¼ sec. 4 only 1 foot 6 inches of very poor lignite. Even for immediate local use this bed has been abandoned. The upper bed is represented by a number of very striking "burns" on the west side of the ridge. The lignite is exposed only at the side of the main road in sec. 10 (location 44), where, as shown in Plate III, it is 2 feet 10 inches thick. Bed B in T. 137 N., R. 86 W., is represented by a thin band of lignite from 3 to 7 inches in thickness. In order to determine the dip of the rocks the thin lignite bed was traversed throughout that township, as well as in secs. 19 and 30 of this township.

T. 138 N., R. 85 W.

A high ridge covered by a thick mantle of glacial boulders extends from north to south through T. 138 N., R. 85 W., and separates it into two almost equal parts. A somewhat less prominent parallel ridge lies immediately east of Beaver Creek.

This township is occupied throughout by the lignite-bearing Fort Union formation. Exposures of lignite were observed at a number of places, but owing to the local irregularity of structure (see p. 12) it is extremely difficult to correlate them. According to what appeared to be the most reasonable interpretation the different sections represent beds A, B, C, and D. It is highly probable that the two beds exposed in sec. 4 (locations 12 and 34) are the same as the beds exposed in sec. 8 (locations 11 and 33), as the upper bed was traced from one to the other area by means of a succession of "burns." The very appreciable dip toward the southwest may cause the lower one of these two beds (bed C) to dip beneath the two streams and to reappear in sec. 12, T. 138 N., R. 86 W.

Bed A is exposed at locations 31 and 32, in sec. 33; location 66, in sec. 29; and location 67, in sec. 30. At location 31, as shown in Plate III, it has a thickness of 3 feet 8 inches, and at the open-pit mine at location 32 the principal bench of lignite measures 2 feet 4 inches, but above it there is an 11-inch bed of lignite separated from the main bed by 15 inches of carbonaceous shale. This bed has been mined at one or two other places near by, but the mines were long ago abandoned, and the old openings have caved so badly that the bed could not be measured. Bed A is reported to have a thickness of 4 feet on the line between secs. 28 and 33, but a measurement could not be obtained. At location 66, in sec. 29, bed A is 2 feet 3 inches thick, and at location 67, in the SE. ¼ sec. 30, 1 foot 9 inches.

Bed B is more than 4 feet thick at locations 47, in sec. 28, and 48, in sec. 26, at each of which the bottom of the bed was under water and the entire thickness could not be ascertained. At location 68, in sec. 30, the bed measured 1 foot 9 inches, and at location 69, 1 foot 10 inches. It is apparent, therefore, that bed B in traversing the township from sec. 21 to sec. 26 ranges in thickness from 1 foot 9 inches to 4 feet 8 inches or more.

The principal exposures of beds C and D occur in secs. 4, 5, 6, 8, and 18. At locations 33, 34, and 35 bed C ranges in thickness from 3 feet 6 inches to more than 5 feet. The bottom of the bed being under water at locations 33 and 34, it was impossible to ascertain the true thickness at either place. The variation in thickness of bed D from 2 feet 3 inches to 4 feet is clearly shown by sections 11, 12, 13, 45, and 46 on Plate III. The lignite beds in this vicinity are being mined at locations 11, 12, and 13.

In addition to the surface exposures, lignite is reported to have been discovered in wells at several localities in this township. For example, 2 feet of good lignite is reported in the log of a well near location 46. According to another report 9 feet of lignite occurs at a depth of 10 feet in the NE. ¼ NW. ¼ sec. 26. Its elevation is about 2,090 feet, or 24 feet below that of bed B at location 48, in sec. 26, so that the lignite as reported may represent bed A. A lignite bed from 3 to 4 feet thick is reported to occur in the NW. ¼ NE. ¼ of the same section. A 7-foot bed of lignite is said to have been found at a depth of 35 feet in the SW. ¼ NE. ¼ sec. 14.

T. 139 N., R. 85 W.

The south half of T. 139 N., R. 85 W., includes a portion of the gently rolling upland between the valley of Big Muddy Creek and that of Sweetbriar Creek, and hence the southeast quarter of the township drains into Sweetbriar Creek, and the southwest quarter into the Big Muddy. The main line of the Northern Pacific Railway crosses the township in an east-west direction a short distance south of its middle line. New Salem, an enterprising town which is situated on the railway almost exactly in the center of the township, affords a market and shipping point for the surrounding territory. The south half of the township is occupied throughout by the lignite-bearing Fort Union formation. The few exposures of lignite observed during the geologic mapping are believed to represent only two beds, which on the basis of their probable stratigraphic position are assumed to be beds D and E. The lignite sections measured on the upper bed, or bed E, which has a maximum thickness of over 5 feet, are represented graphically on Plate III under Nos. 8, 9, and 10. Location 9, near the south line of sec. 21, marks an old abandoned mine. Considerable lignite was at one time mined here, but of late years the drift has been allowed to become partly filled with water. The lignite bed is overlain by 8 inches of black carbonaceous shale beneath a bed of sandy clay. Between the roof and the water there is 5 feet 4 inches of lignite. The extent of the lignite below the water could not be determined, but as the water does not cover the rails and in all probability the rails were laid on the floor of the bed the thickness of the bed is but little more than that given above. South of location 9 this bed is represented by a number of red "burns" almost to the northwest corner of sec. 33. The bed appears to get thinner toward the south, for at location 8, in sec. 33, it is only 2 feet thick.

The lower bed (bed D) at location 14 is 22 feet lower than the upper bed at location 8. The bed is about 5 feet thick. The details of the measurement made are shown on Plate III. At location 15,

in sec. 21, the bed contains 3 feet of lignite, but the top of the bed is not well defined owing to an admixture of sand and clay.

The section measured at location 10, in sec. 34, shows two separate benches of lignite separated by 2½ inches of black carbonaceous shale. For convenience of classification this bed was correlated with the upper bed (bed E) on the west side of the divide, but owing to the local dips observed in the township immediately south the correlation is very uncertain.

The mouth of the main slope (Pl. IV, *A*) of the Dakota Products Co.'s mine is at location 64, about half a mile northeast of New Salem. The mine consists of a slope which goes down from the surface in a direction a few degrees south of west for a distance of nearly 200 feet. From the lower end of the slope the main haulageway is reported to run about N. 20° W. for a distance of 2,900 feet. The air shaft was sunk 2,500 feet from the lower end of the slope. Throughout this distance the bed has been mined out on either side for a considerable distance back from the main haulageway. At the time of visit, however, the mining was confined to an area from 200 to 400 feet north and west of the air shaft. The lignite bed where it has been mined ranges in thickness from 4 feet 6 inches to 6 feet. The analysis of a sample taken about 2,540 feet N. 20° W. of the mouth of the mine is shown under laboratory No. 20033 on page 17. At the point of sampling the bed consists of two benches separated by 4 inches of bone. The upper bench has a thickness of over 1 foot 4 inches, and the lower bench a thickness of 3 feet 1 inch. The sample represents the two benches of lignite. The lignite at the point of sampling is underlain by gray clay shale. The roof is reported to be very irregular, varying from clay shale to sandstone, and vice versa, in passing from one room to another in the mine. Though a rather pronounced north to west dip was reported for the mine in general, yet in places a local easterly dip was observed. As a result of borings made at intervals of 250 feet the lignite bed is reported as thickening toward the northwest.

Two other lignite beds are reported to occur below the bed which was being mined at the time of this investigation. The upper bed is said to have a thickness of 6 feet and to lie 121 feet below the surface. The lower bed is reported to have a thickness of 15 feet and to lie at a depth of 212 feet. The lignite bed then being mined is only 16 feet lower than the bed exposed at the old mine at location 9, in sec. 21. In view of the general northerly dip in the mine and the small difference in elevation between the two places mentioned, it is highly probable that the beds are either the same or very near together stratigraphically. There being no exposures of bed E north of location 10, in sec. 34, the position of the outcrop of the bed as mapped

was determined on the assumption that the lignite bed that was being mined is bed E.

In the autumn of 1919, according to a report by A. J. Collier, of the United States Geological Survey, the Dakota Products Co.'s mine had been abandoned and all equipment removed. Before the property was abandoned, however, a shaft was sunk to a depth of 235 feet in search of beds below the one formerly mined, and a bed of lignite is reported to have been found at the bottom of this shaft, consisting of 7 feet of "black jack" or carbonaceous shale and 2 feet of clay overlying 9 feet of lignite. Northwest of New Salem, in the SW. ¼ sec. 7, the Consolidated Lignite Collieries Co. was opening a mine on an 8-foot bed of clear lignite which probably can be correlated with that formerly mined near New Salem. The following section, based on information gained in sinking an air shaft above the 8-foot bed and a well near its outcrop, was reported by Charles Westmark, the mine foreman:

Section of lignite beds in sec. 7, T. 139 N., R. 85 W., northwest of New Salem.

	Ft.	in.
Sand.		
Lignite	9	6
Clay	20	
Lignite, bed mined	8	
Clay	60±	
Clay and sand	170	
Clay	10	
Lignite, "solid coal" (bed A?)	19	
Clay.		
	296±	

T. 137 N., R. 86 W.

T. 137 N., 86 W., occupies a portion of the divide between Big Muddy Creek and Heart River. Most of the western part of this township is a moderately high rolling prairie which is well settled and adapted to general farming. Almont, a station on the main line of the Northern Pacific Railway about three-quarters of a mile north of the north line of the township, is accessible by means of a fairly complete system of wagon roads and affords favorable market facilities.

Erosion has not advanced far enough to expose the Lance formation in a very large area, so that the Fort Union or lignite-bearing formation underlies almost the entire township.

The best bed of lignite observed in this township is exposed in secs. 5 and 6. From all appearances, however, the bed is lenticular. The details of the several measurements made on the bed are represented graphically under section Nos. 1, 2, 3, and 6, of Plate III. Location 2 marks the position of the Ramsland open-pit mine. The lignite bed was sampled at that point, and the results of the analysis

are shown under laboratory No. 19786 in the table on page 17. Where the bed was sampled it measured 6 feet 9½ inches, which included a 4½-inch bench of brown shale 10 inches from the bottom. A very pronounced northerly dip of 2 to 3 feet in 100 feet was observed in the bed where the overburden had been removed. At location 3, a few hundred feet to the northeast, the same bed has a total thickness of 6 feet 11 inches. The lower 12 inches of the bed contains many thin streaks of impure lignite, and this is separated from the main bed by 6 inches of sandy carbonaceous shale. The strata are well exposed at location 1, in sec. 7, and from all appearances the 14-inch bed there exposed represents the bed worked in the Ramsland mine. If it does, the bed not only thins rapidly but rises 46 feet in passing from location 2 to location 1. The lignite bed represented by the sections given above is correlated from its stratigraphic position with bed E as mapped farther north and east.

Location 43, in sec. 25, marks an exposure on a lignite bed which was correlated with bed A on account of its close proximity to the base of the Fort Union formation. At this location the bed measures 1 foot 10½ inches and has a ½-inch parting 4 inches from the top. Bed B in this township is thin and has a characteristic fossil bed immediately above it. Although the lignite varies in thickness only from 3 to 7 inches, the bed was traversed throughout the township for the purpose of determining the dip of the rocks.

T. 138 N., R. 86 W.

Unlike many of the other townships in this field, T. 138 N., R. 86 W., includes a large area of low valley land. The drainage either empties directly into Big Muddy Creek or enters it through its principal tributary near the township line, in the SE. ¼ sec. 35. Some of the most fertile soil occurs on the alluvium of the principal streams. The township is fairly well settled, and the inhabitants have the advantage of unusual market and shipping facilities. The main line of the Northern Pacific Railway, after leaving New Salem, swings south and follows the valley of Little Muddy Creek almost to the south line of this township. It then enters the valley of Big Muddy Creek and continues its northwesterly course. Sims, for some time a thriving lignite-mining town and a source of supply for the railway, is in the northern part of sec. 14. Almont, another shipping point, is in the NW. ¼ sec. 35. This township is occupied throughout by the lignite-bearing Fort Union formation.

A rather valuable bed of lignite has been uncovered at locations 4 and 5, in the SE. ¼ sec. 31. At location 4 about 10 feet of sandy shale has been removed, exposing the bed throughout an area about 75 feet wide and 250 feet long. The basin formed by the removal of the lignite was partly filled with water. Six feet of lignite was

exposed, but the amount of the bed below the water could not be ascertained. At location 5, on the north side of the valley, the lignite has been uncovered and mined throughout an area about 100 feet wide and 250 feet long. At one point in the open pit the lignite bed was found to have a thickness of 9 feet 4 inches. These two sections are represented on Plate III. This same bed was measured at locations 1, 2, and 3, in secs. 6 and 7, T. 137 N., R. 86 W., and is described in the section on that township. The "burns" shown in secs. 29, 30, 32, and 33 of this township are believed to represent this same bed of lignite burned on the outcrop.

The principal commercial development of lignite in the township is in the vicinity of Sims. For a time considerable lignite was mined at Sims by the Northern Pacific Railway Co., but of late years the supply of higher-grade coals farther west has caused the abandonment of the lignite as a fuel, so at present most of the old openings are badly caved and partly filled with water. The correlation of the lignite beds in the vicinity of Sims with those of the township to the east is very difficult, owing to the lack of exposures and the rather unusual dips observed in secs. 4, 5, 6, and 8 of that township. It seems probable, however, that the lignite bed exposed at location 18, in sec. 23, and also at the two old mine openings on the opposite side of the valley is bed B. This bed, as shown on Plate III, consists of two benches, an upper bench containing 2 feet 4 inches and a lower bench containing 3 feet 5 inches of lignite, but both benches are broken by shale partings so that they are not particularly promising. It was impossible to measure the bed at either of the old mine openings east of location 18. It is reported, however, that in the process of mining a 4-foot bed of lignite was cut some distance above the mined bed. The log of a deep well drilled at Sims,[17] as given from memory by the driller, shows three "coal" beds having thicknesses of 8 feet, 5 feet, and 5 feet, respectively, within a depth of 130 feet. It also shows a 5-foot bed at a depth of 330 feet and a 6-foot bed at a depth of 710 feet. The writer is not inclined to place much dependence on such a well log, for two reasons—the log was reported from memory, and it is difficult, in a well boring, to distinguish between good lignite and impure lignite or even black carbonaceous shale. As the lignite beds in this field are very lenticular, it may be that there is at Sims an unusual development of lignite near the base of the Fort Union formation. However, as there is some doubt regarding the dips, the lignite bed at location 18, in sec. 23, might represent either bed A, B, or C. It is suggested that the reported 5-foot bed of lignite at a depth of 330 feet may be in the lower Lance, at or near the

[17] Darton, N. H., Preliminary report on artesian water in a portion of the Dakotas: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, pp. 662–669, 1896.

EXPLANATION

- Alluvium
- Glacial drift
- Fort Union formation
- Cannonball marine member of Lance formation
- Lower part of Lance formation
- Outcrop of lignite bed. Figures refer to sections on Plate XXXVII or in text
- Outcrop of lignite bed concealed
- Lignite bed burned at outcrop
- Lignite mine
- Local lignite mine
- Government land corner found
- Lignite reported in wells
- Roads on section lines indicated by broken lines

1 0 1 2 3 4 5 MILES

64 DAKOTA PRODUCTS CO MINE

New Salem

Judson

Sims

Almont

Rosebud

Harmon

Saint Vincent

Sweetbriar Creek

Heart River

Little Heart River

Apple Creek

Muddy

NORTHERN PACIFIC

T. 140 N.

T. 139 N.

T. 138 N.

T. 137 N.

R. 86 W. R. 85 W. R. 84 W. R. 83 W. R. 82 W.

Engineer Reproduction Plant, U. S. Army, Washington Barracks, D.C.

Geology by E. T. Hancock

GEOLOGIC MAP OF THE NEW SALEM LIGNITE FIELD, MORTON COUNTY, NORTH DAKOTA

SHOWING OUTCROPS OF LIGNITE BEDS AND LOCATION OF MEASURED SECTIONS

1921

horizon of the lignite mined on Little Heart River in T. 137 N., R. 81 W., south of Mandan.[18]

A lignite bed believed to be bed C was measured at the old mine at location 36, in sec. 12, where it consists of three separate benches, as shown in Plate III. Near the northeast corner of sec. 11, however, the same bed contains only 1 foot 5 inches of good lignite overlain by 7 inches of lignitic shale and underlain by gray clay shale. What appeared to be the same bed was noted at location 37, in sec. 3, and found, as shown on Plate III, to contain 3 feet 1 inch of good lignite.

Lignite was noted at other places in the township, but generally the beds are thin and do not promise to be of much value. An 18-inch bed of lignite caps the small hill in the SW. ¼ NW. ¼ sec. 33. Two thin beds of lignite were measured in the buttes at locations 6 and 7, in the NW. ¼ sec 22. At location 6 the beds are separated by an interval of 21 feet and the lower bed measures 2 feet 3 inches and the upper 1 foot 4 inches. At location 7 the lower bed contains 2 feet 1 inch of lignite, but the upper bed has thickened to 3 feet 5 inches. The log of a well near the house in the NW. ¼ NW. ¼ sec. 22 reports 3 feet of lignite. The 19 inches of lignite exposed on the north slope in the SE. ¼ sec. 9 in all probability represents one of the beds noted above. A prominent "burn" about 45 feet stratigraphically below this bed seems to occur at about the same horizon as an 18-inch bed of lignite measured in the east bank of the creek in the SW. ¼ NW. ¼ sec. 4.

[18] Leonard, A. G., U. S. Geol. Survey Geol. Atlas, Bismarck folio (No. 181), p. 6, 1912.