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Geological Survey

ARTHUR G. LEONARD, STATE GEOLOGIST

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The Lignite Deposits of North Dakota

by

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LETTER OF TRANSMITTAL

State Geological Survey
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North Dakota Industrial Commission.

Gentlemen:

I submit herewith the joint report of the State Geological Survey and the School of Mines, University of North Dakota, on the lignite deposits of North Dakota. The investigations were carried on under a law passed by the legislature in 1919 which provided that "The Industrial Commission of North Dakota is hereby authorized to arrange with the Director of the State Geological Survey at the University of North Dakota to make a suitable survey of the coal lands within the state to ascertain their extent, character, location, etc., and with the Dean of the School of Mines for such special investigations of these deposits or the lignite as he may consider necessary to determine its character, value and adaptation to special uses, and the desirability of the state holding such lands."

The provision for this work was found to be much needed and highly desirable to provide for the proper classification, sale and title of state and individual lands. Prior to the passage of the above act the Geological Survey had been carrying on in connection with other work, as far as meagre funds would permit, a field study of the lignite deposits, and some of the results of this previous work are also included in the present report, so as to make it as complete as possible.

The volume not only contains a description of the lignite deposits by counties, but also articles on the general features of the coal beds and the formations containing them, together with a discussion of the origin of the deposits, the prospecting, development and evaluation of lignite lands; and the character, composition and uses of lignite, with numerous analyses and tests showing the special characteristics of the coal of different beds.

A new and important feature of these analyses is that the composition of the ash and the fusion point of the ash are included, both of which have a direct bearing on the utilization and commercial value of the lignite.

This report should prove of great value to the state in making better known its vast lignite resources and should help in their development.

Very respectfully,

A. G. LEONARD,
State Geologist.

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The Lignite Deposits of North Dakota

ARTHUR G. LEONARD

The lignite deposits are confined to the western half of the state where the workable beds are included within an area of approximately 28,000 square miles. The United States Geological Survey has estimated the area covered by lignite-bearing formations within North Dakota at 32,000 square miles, but in some of this area the veins are too thin to be workable. It is probable that the area of workable lignite would thus be reduced to 28,000 square miles, as represented on Plate 1.

The coal fields of North Dakota form part of a much larger area which covers most of eastern Montana, and extends north into Saskatchewan and south into Wyoming. The greater part of the lignite is of Tertiary age, and is thus geologically quite young, very much younger than the bituminous coal of Pennsylvania and the Mississippi valley states. It it because it was formed in comparatively recent times that the coal of this region is lignite rather than bituminous. There has not been time since the vegetation accumulated in the swamps and bogs of Tertiary time for the wood to undergo a greater change than that involved in the formation of lignite, and the woody material of the beds has not been buried long enough to lose more of its volatile constituents and thus become bituminous coal.

THE LIGNITE BEARING FORMATIONS

The lignite beds of North Dakota occur only in the Fort Union and Lance formations, and by far the greater number are found in the Fort Union.

In Bowman and western Slope counties and in several places in eastern Morton county workable beds of lignite are found in the Lance formation, but throughout much of the area covered by it, the latter is barren of coal with the exception of thin seams only a few inches thick.

The Lance formation, which lies below the Fort Union and is thus the older of the two, occupies a large area in south-central North Dakota, including eastern Morton and much of Grant and Sioux counties. It also covers a smaller area in the southwestern corner of the state, in western Bowman and Slope counties. The Lance formation consists of two distinct parts, a lower non-marine or fresh water portion

composed of sandstone and shale, and an upper marine member containing a fauna resembling that of the Fox Hills sandstone. In Bowman and Slope counties the upper part of the Lance is composed of non-marine beds containing lignite, and believed to be contemporaneous with the marine member occurring in Morton and Grant counties.[1]

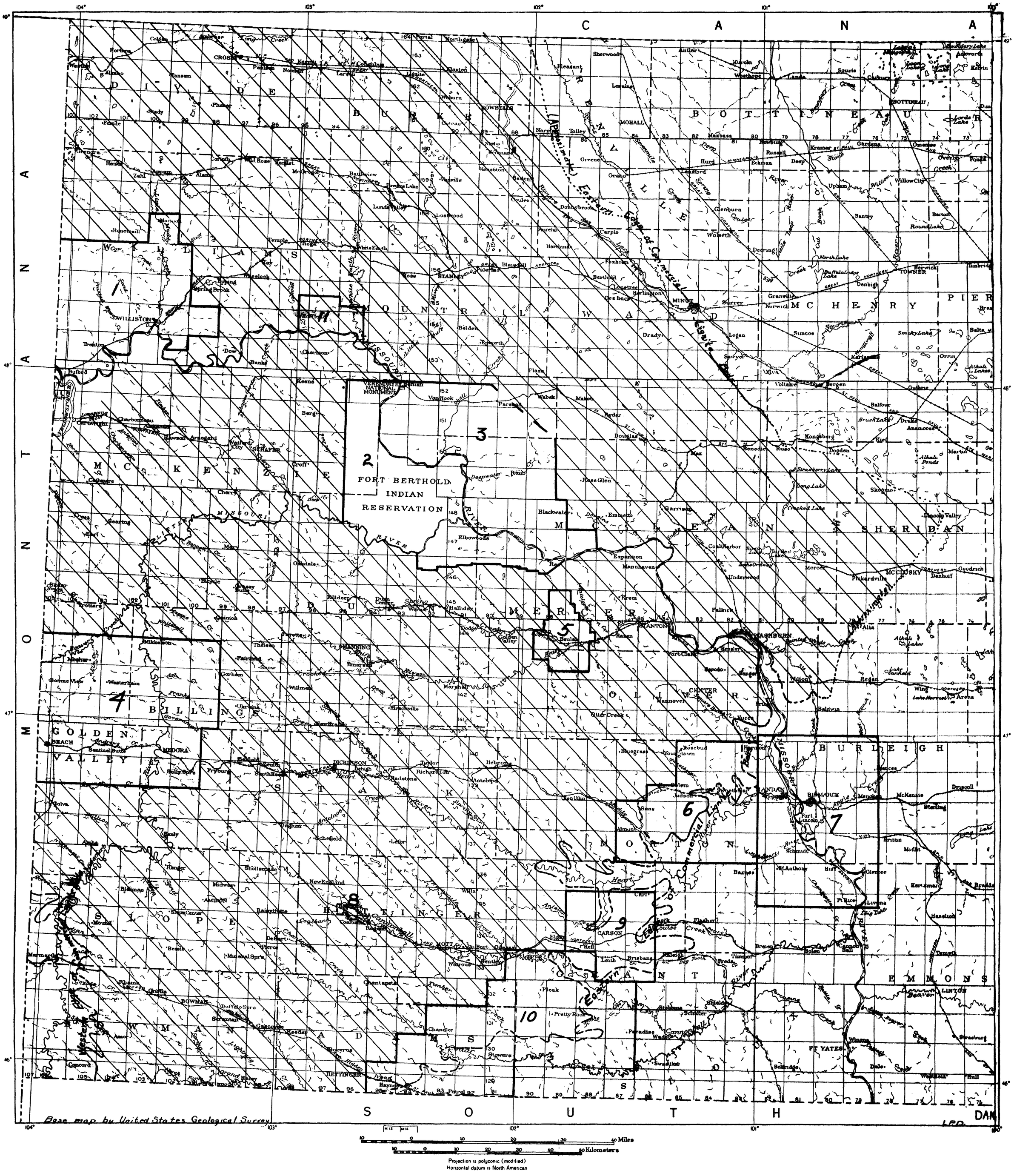
The Fort Union formation, which overlies the Lance, contains most of the coal beds of North Dakota. This formation is found only in the western portion of the state, where it occupies the greater part of the region outside the Lance areas. The Fort Union is a fresh water formation composed of clays and shales alternating with soft sandstones, and containing numerous beds of lignite. The prevailing colors of the shales and sandstones are light ash gray and yellow, and for the most part the formation is remarkably uniform in composition, color and general appearance. One of the conspicuous features of the Fort Union is the vast quantity of baked and fused rock, or clinker, (locally called "scoria") produced by the burning of the coal beds. The overlying shales and sandstones have been burned to a red or salmon pink color and in places completely fused to slag-like masses. This clinker caps many of the ridges and buttes of the region and outcrops for miles in the bluffs of the Missouri, Little Missouri, and other streams.

The Fort Union formation, which is early Eocene in age and thus belongs to the Tertiary system, contains an abundant flora, about 400 species of fossil plants having been described from this formation. It also has a fauna comprising both fresh water shells, fishes, turtles and the aquatic reptile *Champsosaurus laramiensis.*

In Billings and Golden Valley counties the Fort Union has a thickness of 1000 feet, while farther north in McKenzie county the formation reaches 1300 feet in thickness. Over much of the area covered by it many hundreds of feet of strata have been removed by erosion, and only in the higher buttes and divides of western North Dakota has the upper part of the formation been preserved.

The numerous lignite beds of the Fort Union are evidence that the region was occupied again and again by swamps, many covering hundreds and even thousands of square miles. These were probably formed by the partial filling of the lakes with sediment brought in by the rivers, thus converting them repeatedly into swamps. The coal-

[1]E. R. Lloyd and C. J. Hares, the Cannonball Marine Member of the Lance Formation of North and South Dakota and its bearing on the Lance-Laramie Problem; Jour. of Geology, Vol. 23, pp. 523-547, 1915.



MAP OF WESTERN NORTH DAKOTA, SHOWING THE AREA WITHIN WHICH LIGNITE BEDS OVER FOUR FEET THICK OCCUR

The ruled area is the portion of the lignite field covered by the work of the North Dakota Geological Survey.

Special and more detailed mapping by the State Geological Survey has covered the following areas:

5. Beulah-Zap District.
8. Havelock District.
11. East Side of Nesson Anticline.

The United States Geological Survey has mapped in detail the lignite beds in the following areas;

1. Williston area. Bulletin 531.
2. Fort Berthold Indian Reservation South of Missouri River. Bulletin 726.
3. Fort Berthold Indian Reservation North of Missouri River. Bulletin 471.
4. Sentinel Butte Lignite Field. Bulletin 341.
6. New Salem Lignite Field. Bulletin 726.
7. Bismarck Folio. No. 181.
9 and 10. Cannonball River Lignite Field. Bulletin 541.

forming vegetation growing in these swamps consisted, as determined by Thiessen,[2] very largely of coniferous trees, including varieties related to the Sequoia, cypress, juniper, and arbor vitae, together with some firs and spruces. The woody material of these trees, including trunks, stems, and branches, comprises roughly 75 to 85 per cent of the whole mass of the lignite. That the vegetation accumulated in some of these swamps for thousands and tens of thousands of years in indicated by the fact that several of the lignite beds have a thickness of 35 feet and others of over 20 feet. That the coal swamps recurred repeatedly in many parts of the region is proved by the presence in some vertical sections of as many as 15 or 20 lignite beds, the majority of them, it is true, of no great thickness. Among the lakes and swamps there grew many varieties of trees, including, according to Knowlton,[3] the poplar, oak, walnut, fig, elm, maple, birch, alder, dogwood, hickory, box elder, buckthorn, viburnum, witch-hazel, horse-chestnut, and bittersweet. Interspersed with these were scattered conifers and ginkgos. Thus during Fort Union time North Dakota and adjoining areas were covered with dense forests. Osborn thus describes the region as it was at this period: "Vast stretches of subtropical and more hardy trees were interspersed with swamps where the vegetation was rank and accumulated rapidly enough to form great beds of lignite. Here were bogs in which bog iron was formed. Amid the glades of these forests there wandered swamp turtles, alligators, and large lizards of the characteristic genus *Champsosaurus*."[4]

THE LIGNITE BEDS

Since the lignite beds are found from top to bottom of the Fort Union formation, and in Slope county occur also in the upper part of the Lance formation, they have a vertical range of 1200 to 1300 feet. Many outcrops show two or three thick coal beds within a vertical distance of 75 to 100 feet and in some of the higher bluffs bordering the Little Missouri and other streams a dozen or more are present, if the thin seams are included. In the Tepee Butte bluff, which is the highest occurring anywhere along the Little Missouri river, and is nearly opposite the mouth of Deep creek, 20 coal beds are scattered through a thickness of 584 feet of Fort Union strata. These beds range

[2]David White and Reinhardt Thiessen, "The Origin of Coal," Bureau of Mines Bull. No. 38, 1913, pp. 222.
[3]F. H. Knowlton, U. S. Geol. Survey Bull. No. 611, 1915, p. 59.
[4]H. F. Osborn, The Age of Mammals, p. 100.

in thickness from two inches to 12 feet, there being three over five feet thick.

The workable coal beds, or those over 4 feet in thickness, which are present in western North Dakota, are known to number no less than 100. Only a few of these are found in any one locality, and many occur at about the same horizon in the Fort Union, showing that a number of coal-forming swamps scattered over the entire Fort Union area were in existence at about the same time. Many of the different coal beds are therefore probably contemporaneous or nearly so.

In the badlands of the Little Missouri river the conditions are exceptionally favorable for the study of the coal deposits and the determination of the number of lignite beds. This is due in part to the bare slopes, affording a great number of outcrops, which make it possible to trace individual beds almost continuously for long distances, and in part to the northerly dip of the beds, which carries the lignite seams successively below river level as they are traced from south to north. Coal beds which in the southern part of the field, in Slope county, occur well above the Little Missouri, are seen when followed down the river to dip below the valley bottom, and higher beds appear in the bluffs. It has thus been possible to correlate and place in their relative positions in the vertical scale coal beds which outcrop in widely separated portions of the field. The number of coal beds over 4 feet thick in Slope, Billings and Golden Valley counties is known to be at least 22, not all of them present at any one point, but some occurring in one locality, and some in another. They range from 4 to 35 feet in thickness, and the aggregate thickness of these 22 beds is 192 feet.

In McKenzie county there are 15 to 20 coal beds over 4 feet thick, and in Dunn county 14 are known to be present. From three to five workable lignite beds are known to occur in each of the other coal producing counties. In most cases these lignite seams outcrop along the sides of the valleys, or in the buttes, and in general only those coal beds are known to be present which are near enough the surface to be exposed where streams have eroded their valleys through them. Occasionally the presence of deeper beds is learned from wells and drill holes.

The lignite beds vary in thickness from a fraction of an inch to 35 feet and over. Beds 6, 8, and 10 feet thick are common, half a dozen are known which have a thickness of 20 feet, and there are at least two with a thickness of 35 feet. The individual coal beds vary

in thickness from place to place and where traced for any considerable distance the seam may grow thinner and finally pinch out entirely. Again, a thick bed of lignite may be split up into several by clay seams or clay partings, so that a single bed in one place may be represented a few miles distant by three or more coal beds. This is often caused by the rapid thickening of thin clay partings in the lignite.

While most of the coal beds are nearly horizontal, they commonly have a gentle dip, and many are more or less undulating. In the western part of the state the beds in general dip toward the north and east, averaging from 5 to 50 feet per mile. The undulating character of certain beds is well shown where they outcrop in the bluffs of the Little Missouri; in places they disappear below river level, while a few miles distant they may rise 50 to 75 feet or more above the river.

Many of the individual coal beds cover large areas. One which is well exposed in the badlands of Billings and McKenzie counties has been traced along the Little Missouri valley a distance of 45 miles, and doubtless has an area of 1500 to 1800 square miles. Another lignite bed is known to extend no less than 50 miles along the Missouri and Little Missouri rivers and its area is probably not less than 2000 square miles. A third coal bed occurring in the badlands of the Little Missouri was traced 25 miles north and south and 24 miles east and west, and undoubtedly has an extent of over 1000 square miles. It ranges in thickness from 9 to 15 feet. Many lignite beds, particularly the thinner ones, are less persistent and the area covered by them is comparatively small. There is a great variation in the extent of the lignite beds as well as in their thickness.

BURNING OF THE LIGNITE BEDS

Many of the coal beds have burned out extensively and very few of the thicker ones have wholly escaped burning. Some were doubtless set on fire by man, others may have caught from prairie fires, but it seems probable that spontaneous combustion has been the chief cause. This burning of the coal beds has doubtless been going on for thousands and tens of thousands of years, ever since the erosion of the overlying strata brought them near the surface or exposed them in the bluffs and buttes. Once started, the fire slowly smoulders and works its way back farther and farther from the outcrop, the overlying clays settling down as the coal is consumed, and the cracks thus opened admitting fresh supplies of air. Thus a coal bed which is not too far

below the surface may continue to burn for scores and hundreds of years. As an example the Bowman coal bed of Bowman and Slope counties may be cited, this thick 35-foot bed having burned out over many townships, so that its former extent is known largely by the clinker it has formed. Where it is covered by any considerable thickness of shale and sandstone it does not seem likely that the lignite can burn very far back from the outcrop in the face of the bluff, since after the coal has been consumed the overlying materials would settle down and occupy its place, thus shutting off the air and smothering the fire. It is believed that those beds of lignite which have burned over many square miles, or over many townships, must have been near the surface, as they are today, when they were being consumed. (See Fig. 2, Plate II.)

The heat of the burning lignite has baked and changed the overlying clays, and either burned them to a red or pink clinker (locally called "scoria"), or entirely fused them into slag-like masses. (See Fig. 2, Plate III.) These clinker beds often have a thickness of 30 to 50 feet and are a very conspicuous feature not only of the badlands, but of the upland prairie as well. Some of the thick beds of clinker may have been produced by the burning of two or more lignite beds not many feet apart, the intervening clays having been baked and now forming a single layer. Not infrequently a bed of ash is found just below the clinker. (See Fig. 1, Plate II.) One such bed of light gray ash is a foot thick and another is 6 to 10 inches.

The coal of North Dakota is for the most part a brown lignite, though in some of the beds it is black and lustrous. It is generally conspicuously woody in appearance and exhibits clearly the grain of the wood. It breaks or splits readily along the grain, but is broken less easily in any other direction. Portions of flattened trunks and branches are often found in the lignite, looking not unlike the original wood, except for the brown color. An individual bed is frequently more woody in some portions than others, being made up of alternating layers of tough, brown lignite, and black, lustrous, brittle material.

One outcrop was observed in which the clay just below the lignite was filled with the roots of the trees which had formed the coal bed. These roots penetrated the clay 3 or 4 feet and some were several inches in diameter. While largely changed to coal they retained the appearance of roots.

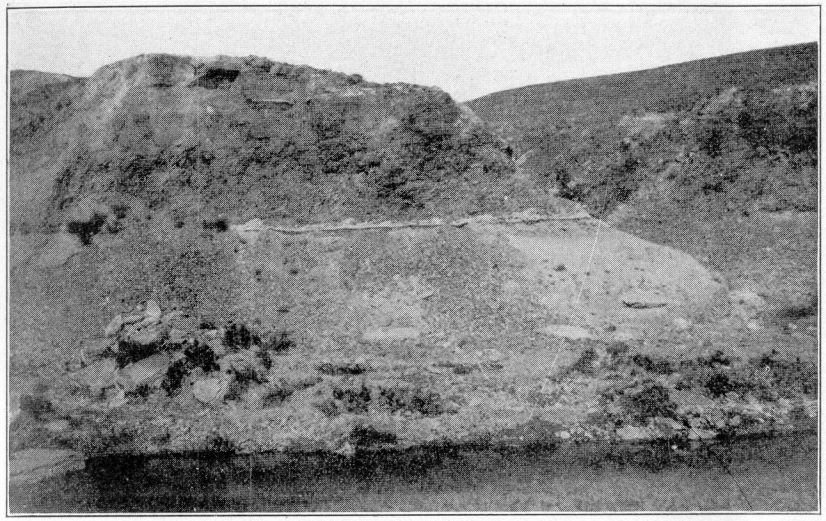


Fig. 1. Clinker formed by burning of the Coalbank coal bed near the Kouba mine. At base of clinker is a layer of white ash 4 to 6 inches thick.

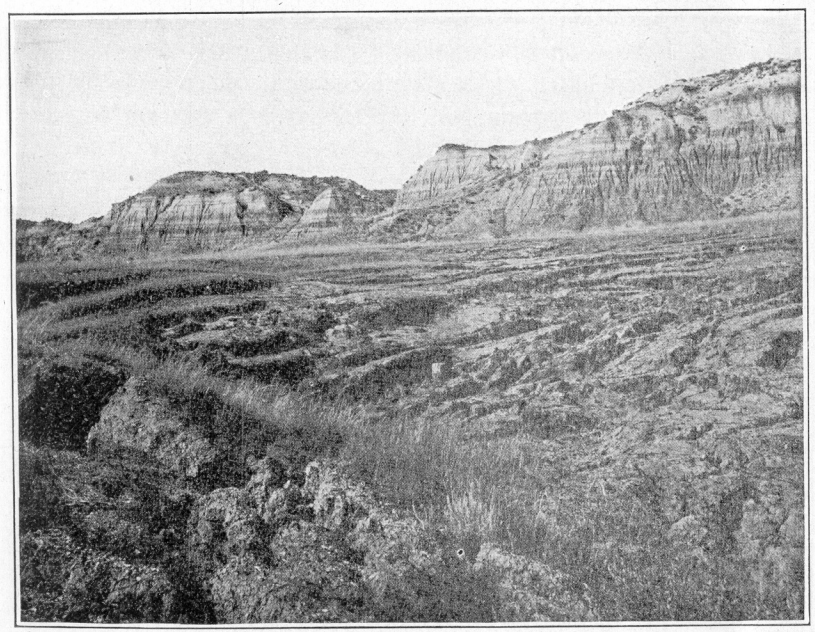


Fig. 2. Effects produced by burning of thick coal bed not far below surface. The clays overlying the coal have settled down many feet and the ground is broken by wide cracks from which the gases escape.

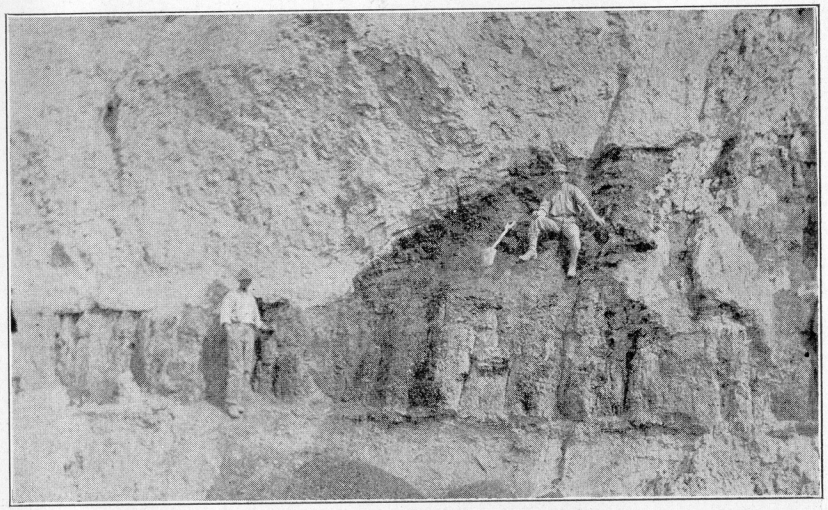


Fig. 1. Coal bed 12 feet 8 inches thick exposed on Red Wing creek, McKenzie county. The upper portion of coal has burned at the left, leaving only 4 feet of the bed. It is here covered by the clinker produced by the burning of the coal.

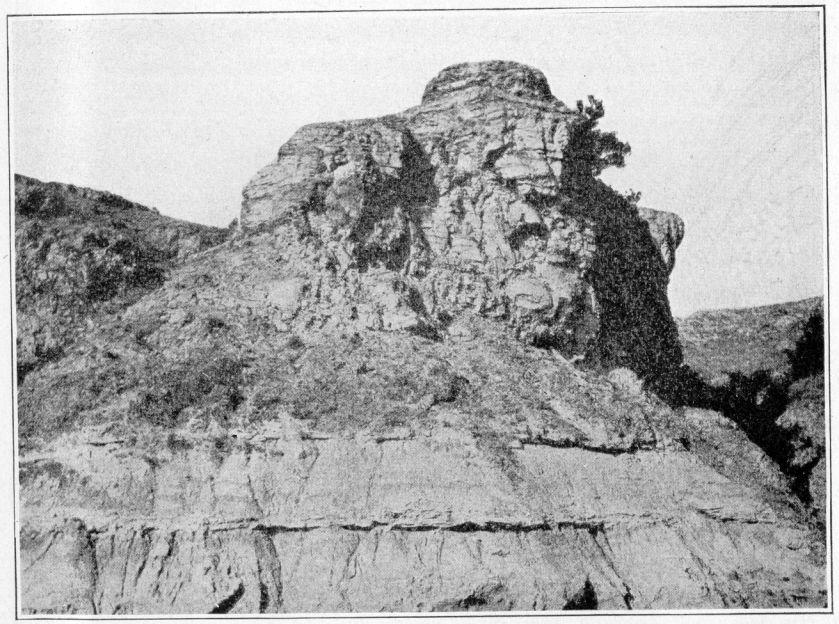


Fig. 2. A mass of clinker ("scoria") formed by the burning of a thick coal bed. Mouth of Deep Creek.

In many of the beds the lignite is cut by joint cracks which are vertical, or nearly so, and from 5 or 6 inches to a foot or more apart. These joints are usually very clear cut and regular.

ORIGIN OF THE LIGNITE BEDS

Recent microscopic studies of thin sections of North Dakota lignite have furnished interesting information regarding the materials composing the coal, and the kinds of plants which have accumulated to form the deposits.[5] The lignite consists largely of woody material, including trunks, stems and branches of trees, these comprising about 75 to 85 per cent of the whole mass. With possibly one exception the trees entering into the formation of the lignite are coniferous varieties related to the Sequoia (the big-tree of California), cypress, juniper, and arbor vitae, together with some firs and spruces.

The conditions under which the beds of lignite were formed are well stated by Thiessen as follows: "The writer believes that the conditions under which these coal beds were formed were much like those under which peat beds formed in certain wooded swamps in parts of Wisconsin and Michigan. In these swamps the growth of trees consists chiefly of white cedars, *Thuya occidentalis,* tamarack, *Larix laricina,* and black spruce, *Pica mariana,* in which the white cedar predominates. The growth is so dense that underneath them nothing but a thin mat of mosses, lichens, and liverworts, with an occasional herbaceous plant, is able to exist. The substratum, or peat bed, consists of logs and branches fallen in every direction over one another, either in a semimacerated condition or unmacerated, though much changed. The interstices of these are filled with a debris in which the macerated parts of stems and branches, cone scales, leaves, thalli of mosses and liverworts, pollen grains, and so forth, are plainly recognizable. Such a formation appears in all respects analagous to the lignite beds under discussion."[6]

HISTORY OF LIGNITE MINING

Lignite has doubtless been mined and used in western North Dakota by ranchers and others since the earliest settlement of the region, but the earliest mining of which there is any record was carried on by the Northern Pacific Railroad, which operated mines along its line as early as 1884. The mine at Sims was worked for many years

[5]David White and Reinhardt Thiessen, The Origin of Coal, Bureau of Mines Bull. No. 38, 1913.
[6]Ibid, p. 222.

and in 1888 there were two shipping mines, one at New Salem and another at Dickinson. By 1894 the number had increased to 8, and in 1900 the large Washburn mine at Wilton was opened. Several years prior to this the mines in the vicinity of Kenmare began operations.

It is difficult to give the number of mines that are being operated at the present time, the winter of 1923-24. Every year some mines are abandoned and new ones are opened up, so that the number is constantly changing. Then there are large numbers of small "mines" or openings where a little coal is mined for local use by those living in the vicinity. There are hundreds of such places where coal has been or is being taken from the outcrop or mined by stripping off the cover. The last State Mine Inspector's Report, for 1923, gives a list of 259 mines, but in this list many small country mines are not included. The number of good sized shipping mines in the state is constantly increasing.

The nine most important coal-producing counties named in the order of their production are as follows: Burleigh, Burke, Mercer, McLean, Williams, Adams, Ward, Stark, and Morton[7]

In 1922 North Dakota produced 1,057,823 tons of lignite, according to the figures of the State Mine Inspector, which are for the year ending October 21. The production as given by the United States Geological Survey, which is for the calendar year 1922 and hence includes the months of November and December, is 1,327,564 tons, valued at $3,513,000. In 1923 the production as given by the Mine Inspector was 1,435,605 tons, valued at $3,742,413. The figures of the United States Geological Survey for 1923 are not yet available.

THE QUANTITY OF LIGNITE IN NORTH DAKOTA

The quantity of lignite in North Dakota is so great that the supply may be considered as practically inexhaustible. Single beds whose extent and thickness have been determined are known to contain billions of tons.

As already stated, the lignite beds are confined to the western half of the state and are included within an area of approximately 28,000 square miles. The United States Geological Survey has estimated the area covered by lignite-bearing formations within North Dakota at 32,000 square miles, but in some of this area the veins are too thin to be workable. A careful measurement has recently been

[7]Fifth Annual Report of State Mine Inspector, 1923.

made of the area covered by the Fort Union and the Ludlow lignitic member of the Lance formation, and as near as can be determined, the workable lignite beds of North Dakota are confined to about 28,000 square miles. The eastern boundary of the field cannot be definitely located since a heavy mantle of drift covers the Fort Union in the central part of the state and it is not known just how far east the formation extends, but the area given above is believed to be approximately correct. (See Plate I.)

In a number of counties, where the streams have eroded deep valleys, many thick beds of coal are known to be present from their outcrops along these valleys. In Billings and Golden Valley counties the aggregate thickness of the workable coal beds, or those 4 feet thick or more, is over 100 feet, in McKenzie county it is at least 50 feet and it is about the same in Bowman and Slope counties. If we make the assumption that the aggregate thickness of workable coal beds within 300 or 400 feet of the surface is 16 feet, a very conservative estimate, and that this thickness underlies the entire area, the quantity of lignite in North Dakota is 516,000,000,000 tons. But if the deeper beds, as well as those less than 4 feet thick, were included, the total estimated tonnage would be considerably more than this.

The Prospecting, Development, and Evaluation of Lignite Lands in North Dakota

LEONARD P. DOVE

Owners and prospective owners of lignite land are interested in the mest methods of both exploration for lignite and how to arrive at a scientific opinion as to what the lands should be worth. The following information has been prepared from the best national authorities and from the experience of the writer. Often purely local factors enter into the problem of valuation so that any attempt at a scientific basis must be subject to some flexibility to allow for unusual conditions.

For those land owners who merely wish to know whether their land may be underlain with coal, local well drillers are important and invaluable sources of information. Usually a request to the State Geologist, University Station, Grand Forks, North Dakota, for reports on the region in which the land is located will bring the desired information if the region has been studied. The Director of the United States Geological Survey, Washington, D. C., may also supply desired information. It is the custom of the State Geological Survey to furnish gratis to a bonafide land owner any information on their particular lands, that may be on file and unpublished.

As the lignite industry has steadily grown it is natural that there be an increasing demand for more specific information about particular pieces of land. When it is remembered that approximately 28,000 square miles of the State of North Dakota is underlain with more or less lignite, detailed information on every square mile or subdivision will not be available for many years.

An experienced geologist can usually tell with a fair degree of certainty whether a particular traceable bed of coal underlies an area and can also tell within certain limits how deep it is, but there is no man or instrument known that can tell without exposures, boring or digging, the exact thickness of the coal or whether the quality is satisfactory. Gophers, badgers, and other burrowing animals often bring the "blossom" or weathered coal to the surface even when but little other evidence of coal may be present. The aid of these small prospectors should not be ignored.

Since most outcrops of coal are along the borders of stream valleys and banks where normal wash has exposed them, it is common to find the actual position of the coal bed in place very difficult to locate on account of slumps and creep. The Fort Union formation in which the lignite is found is made up in great part of uncemented and unconsolidated materials and hence slumps badly. Driving entries to open a coal bed from the side of banks should be directed by drill records, often easily and cheaply gotten to avoid the discrepancy of position of the coal bed and the slumping material.

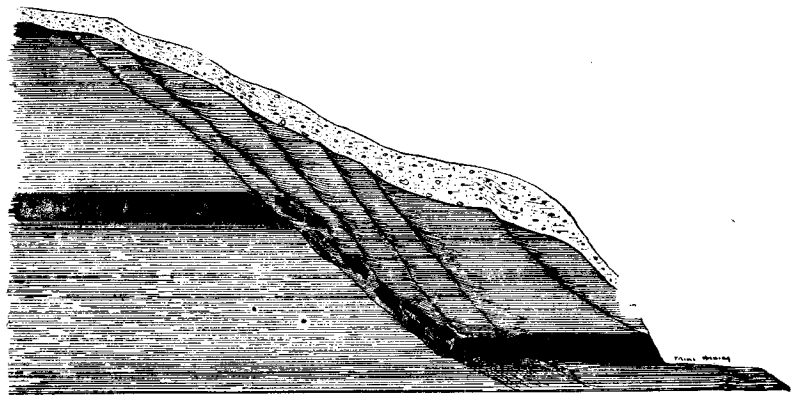


Fig. 1. Slumping has lowered the outcrop. Expensive surface equipment should not be built until drill records show the exact position of the coal.

For preliminary surveys the writer has found the following to be fairly safe to follow in judging the quality of lignite, where analyses are not available.

"In the best lignite the weathered surfaces are black and have a bright vitreous luster, even though in the unweathered condition the lignite is brown and has a dull luster. As the percentage of ash increases, the luster of the weathered surface is duller. The weathering of lignite of different grades is so characteristic that an examination of the weathered face of an exposed section will, in many cases, afford a better conception of the character of the lignite than an examination of the fresh lignite."[1]

The commercial value of a bed of lignite is conditioned by many factors, several of them depending on the geology of the land.

[1]U. S. Geological Survey. Bulletin 627, page 40.

GEOLOGICAL FACTORS

The most important geological factors are: (1) Depth of coal bed from the surface; (2) kind and nature of the material underlying and overlying the coal, or overburden; (3) thickness of the bed; (4) water and structure; (5) glaciation; (6) weathering and burning at the outcrop. A simple inspection shows that essentially every factor enumerated depends on accurate and reliable information derived from the drill or bore hole.

DEPTH OF THE COAL, OR OVERBURDEN

In general the amount of overburden that now covers the coal influences the value of the coal. The deeper it is in general the more it costs to reach it, if it must be mined by underground methods. A light cover is a decided advantage if it offers possibilities of being mined by stripping. In general the quality of lignite is affected by the kind of overburden. If the overburden is sand or a sandy shale and the bed lies well above valleys in side hills, weathering or slaking of the coal may proceed under 20 to 30 feet of cover, so that the coal may be rendered useless. However, even a few feet of dense clay or clay shale may protect the coal and the quality of the coal even under a light cover be fully as good as it is where the cover is 40 or 100 feet thick. Disregarding coal weathered at the outcrop, which may involve a width of a few feet to 100 or even 300 feet, there appears to be little difference in the heat or thermal value of coal from the same bed whether it be covered by 20 or 200 feet of overburden.

It is rare to find lignite, except where it is continually covered with water, that is of good quality unless the overburden is at least 15 feet thick. There is coal being mined in North Dakota by stripping from depths of 20 to 25 feet, that so far as any tests can show, is fully as good, burns as well and satisfies consumers equally as well as the same coal mined from a depth of 50 or 100 feet.

There appears to be a persistent notion among many people that lignite mined from a great depth must naturally be of a higher quality. The writer has examined dozens of coal mines and so far is unable to see any relation between the depth and quality of the same bed after the crop line coal is passed.

The theory that lignite buried to great depths must be better is probably founded on the belief that the coals are older and have progressed further toward bituminous coal. On the eastern margin

of the coal area in North Dakota some of the oldest beds of coal—geologically speaking—are now exposed and being mined. These beds were once covered by hundreds of feet of material now removed by erosion. Likewise, in the extreme southwestern part of the state the oldest coal beds are again exposed. The writer has examined the analyses from all ages of lignite coal in North Dakota and is not convinced that these older coals are consistently a better grade than younger lignites, higher in the lignite formations. The depth to which a bed of lignite may be buried at present is purely a matter of the structure and erosion. The moderate depths—1000 feet or less—to which lignite in North Dakota has been buried, or is now buried, seems to have had little average effect in raising its grade.

NATURE OF THE OVERBURDEN

In general the Fort Union formation, which contains the most important lignite beds, is made up of clay shale, sandy shale, and loosely cemented sandstone. There is more sand than clay. Solid rock is rarely met. This overburden may be dug without blasting and has been easily handled by draglines, steam shovels, elevating graders, and simple plow and scraper. It is less difficult to dig than the shale and rock commonly overlying coal in the bituminous coal regions.

Where lignite is overlain with clay shale, the clay is nowhere strong enough to make a good roof but from 2 feet upward of lignite is left to support the overburden. The overburden is commonly dense enough to turn surface water. Clay beneath the coal seldom heaves or bulges, unless where kept continuously wet.

THICKNESS OF THE BED

Lignite beds vary from a few inches to 40 or more feet in thickness. A lignite coal bed one foot thick over an acre, contains from 1750 to 1800 short tons of coal. The staggering tonnage present per acre in a forty foot bed may be simply calculated. Thick coal beds, while containing a tremendous total tonnage, due to difficulties in underground mining, generally yield a very low percentage of recovery. In North Dakota the writer is familiar with one locality where the recovery on a forty foot bed is not over 15 per cent, or 85 per cent left in the ground and often spoiled for future recovery. The most favorable thickness for high recovery of lignite, by underground methods, seems to be from 8 to 14 feet.

In evaluating thick coal beds, the Department of the Interior recognizes this difficulty, as will be shown later. Generally speaking,

however, the thicker the bed the more favorable for open pit or strip mining.

WATER AND STRUCTURE

The presence or absence of water is often critical in determining the value of a coal property. Water and structure, or the attitude or position of the coal bed, belong together for it is a well known habit of water to flow down hill. It will likewise flow down dip underground just as surely.

It is common to assume in North Dakota that coal beds are nearly level. Careful levelling, however, has shown in recent years that few are really level, and dips in the coal beds must increasingly be taken into account. Just the past summer, the writer encountered two mines less than one-half mile apart, on the same coal bed, one very wet, the other dry. The coal at the wet mine was over ten feet lower than at the dry mine. The dry mine was near the axis of a low upfold or anticline, the wet mine toward a downfold or syncline.

Water in any quantity in a mine is very serious and may make an otherwise fine bed of coal unworkable. The lack of water for steam boilers may be equally serious but a source is usually sought other than in the coal.

Water in Coal. Attention should here be called to the nature of water in lignite. Horace C. Porter and O. C. Ralston of the United States Bureau of Mines, Technical Paper 113 say: "Coal, like many other substances of vegetable origin, contains water in the ordinary condition, which may give the coal a moist appearance, and also water that is frequently but erroneously called "water of combination," this water being concealed, as in hydrated salts, by the dry appearance of the material. The condition in which the so called "water of combination" in coal exists is problematical; in the true chemical sense the water is probably not "combined"; that is, united with another substance in definite proportions, as determined by its relative molecular weight and the number of molecules." "There is no sharp line of demarcation; the "free" water cannot be separated with exactness from the "combined" water by chemical analysis. Under all ordinary drying conditions there is a tendency for more than the "free" water to leave the coal. But the combined or better, the "inherent" water is distinctly different from the "free" water in its properties, as it has a subnormal vapor pressure and an energy change is involved in its combination with, or separation from, the coal substance. In other words, the inherent water is held more tenaciously

and cannot be entirely removed by drying the coal in ordinary air containing moisture."

North Dakota lignite as freshly mined and as found in the bed may be wet from "free" water or may be dry looking and yet contain from 30 to 40 per cent "inherent" moisture. The average of 84 mine samples as determined at the School of Mines, University of North Dakota, is 35.9 per cent and 52 samples collected by the U. S. Geological Survey and U. S. Bureau of Mines is 37.6 per cent. Lignite that is visibly wet may contain as much as 50 per cent moisture. Lignite after it is dried out develops more heat per pound just as drying wood increases its heating value. There is no safe way to guess at the water content by mere inspection.

GLACIATION

In North Dakota about 28,000 square miles are underlain with workable lignite. Of this nearly 15,000 square miles are covered more or less by glacial materials deposited during the epoch of continental glaciation. This glacial debris includes a wide range of materials from fine silt and boulder clay to large boulders. Over much of this area the Fort Union coal bearing rocks are concealed beneath this mantle of drift. This covering has imposed some additional problems in prospecting and development of coal beds that may be ignored in the non-glaciated portion of the state.

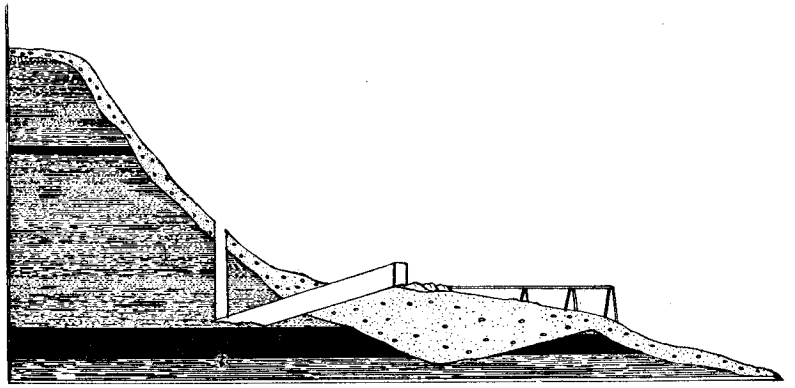


Fig. 3. The coal bed has been partially cut out by a valley which has been filled with glacial material.

In general, these problems are due to the fact that a land surface quite similar to the present surface was buried. Weathering,

burning and erosion altered and affected the coals much as at present in the unglaciated portion of the state. The problems introduced are largely a matter of the correct interpretation of this old buried surface. Ordinary clues as to the lands that probably contain coal are lacking since the new surface is often entirely unlike the old buried surface. A hollow or valley may be buried beneath what is now a hill.

In the glaciated portion of the state, drilling or boring assumes even greater importance, and a correct interpretation of the cuttings from the borings becomes essential.

The features to be carefully watched are:

1. How close to the coal is the old preglacial surface and what is the shape of this surface?
2. Is water in troublesome amounts present at this surface in any part of the area?

If the preglacial surface lies close to the coal, the following conditions may be present:

a. The coal may be "soft" or weathered in spots. In such places the cover is often glacial drift.
b. Old preglacial valleys may cut out the coal completely.
c. Old preglacial valleys may serve as underground basins to collect water.
d. Loose gravels or other glacial material may be so close to the top of the coal as to render the ground unsafe and dangerous cave-ins result.

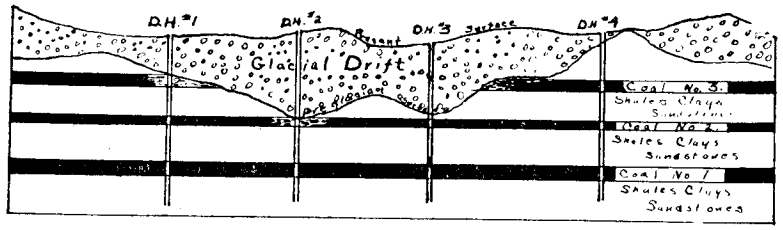


Fig. 3. Cross section showing an old preglacial surface covered by a mantle of boulder clay of varying thickness. Drill hole (D. H.) No. 1 penetrates first a thickness of till or boulder clay and finds coal No. 3 soft or weathered, coal Nos. 2 and 1 good, as they were covered and escaped weathering. D. H. No. 2 finds coal No. 3 lacking, a mass of clinker perhaps at horizon of coal No. 2; coal No. 1 of good quality. D. H. No. 3 finds coal No. 3 lacking, coal No. 2 weathered and soft, coal No. 1 good quality. D. H. No. 4 finds all three coals of good quality.

It is not to be inferred that in all portions included as glaciated are the bed rocks completely concealed over large areas, as incision by streams has often exposed coal beds, especially in border areas. It is common in prospecting from outcrops to work back from such peripheral or border areas where the drift is thin to areas where exposures are lacking. Such an area is well illustrated in the Altamont Moraine area of northern and central North Dakota. Structure traced back in such a manner and even checked with occasional well or boring records is often adequate to a fair assurance of the absence or presence of coal.

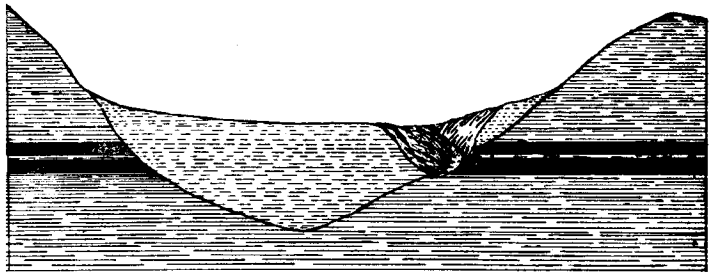


Fig. 4. A debris-filled valley in which a recent valley is being cut, re-exposing a bed of coal.

The contact between coal and drift may often direct water downward so that large amounts of water may have to be handled. In such cases the softening of the coals is a signal to stop mining and leave sufficient coal as a wall to shut off the water.

Careful drilling and equally careful interpretation will often show the position and trend of old preglacial surfaces with a consequent saving of time and money in development of the mine. For example, such areas are usually indicated on a map as "soft coal" or "coal lacking" while a suitable legend may likewise indicate where glacial drift lies immediately over the coal.

An example of a series of drill logs plotted graphically and a suggested interpretation is shown in Figure 3. While hpothetical this case is drawn from relations very commonly found.

It will be seen that conditions may easily be such that any considerable expenditure of money for opening a mine in advance of thorough testing may be the sheerest speculation.

Quality of Coals and Glaciation. Glaciation itself has probably had no direct effect on the quality of coals except the slight effect

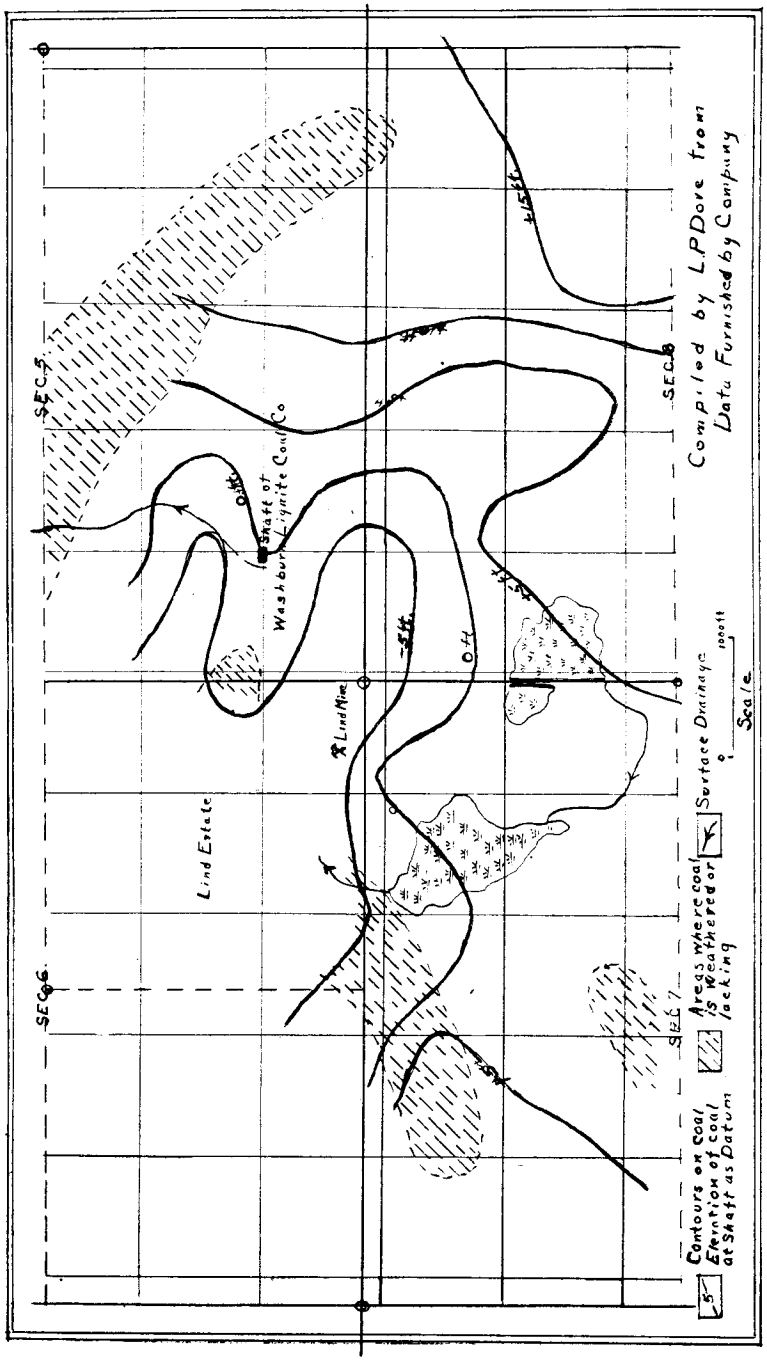


Fig 5. Structure Map of Washburn Lignite Coal Company Mine.

that pressure might exert, which in the aggregate would be small or negligible. It is in coals near outcrops, either preglacial or post-glacial, that the most immediate effects are noted. These are mostly due to weathering or a progressive oxidation that tends toward a reduction in the heat units, a higher ash, and friable or crumbly coal constituting a series at one end of the unweathered coal, at the other an ashy residue.

Fragments of coal are not uncommon in the till which indicates an erosive activity on the part of the glacier in exposed localities.

The preponderance of shales and clays and lack of strong jointing in the Fort Union coal bearing formation in North Dakota has probably operated to reduce the average abrasive activity of the ice as there was a tendency to override this smooth frozen mass, thus reducing the plucking activity of the ice, as compared to the active abrasion in more resistant rock that is subject to strong jointing. The transition from lignite to glacial drift in North Dakota is usually abrupt where erosion of the glacier was active or less commonly the lignite grades from unweathered coal through softer weathered coal to the drift itself. No evidence of any bodies of lignite of any size being moved has been noted. In rather interesting contrast is a case found by the writer in a strip pit at Carbon, Indiana, where the "block coals"—so-called because of two sets of vertical joints that divide the coal into more or less cubical blocks of from a few cubic feet up to two or more cubic yards in volume—were so close to the active bottom of the glacier that several blocks were moved bodily and till thrust into the widened cracks between. The blocks of coal uncovered by the shovel had been removed by the miners, leaving the network of till filling in the bottom of the pit much as the mortar

FIG. 5. STRUCTURE MAP OF WASHBURN LIGNITE COAL COMPANY MINE EXPLANATION OF FIG. 5.

This map or plat illustrates several features met with in mining on a large scale in glaciated areas. The Washburn Lignite Coal Company of Wilton is operating a large well-planned mine. From borings and other openings careful levels gave the elevation of the top of the coal bed and from these levels the above contours were drawn which show the undulations in the top and likewise the bottom of the coal. Since the dip is northwestward water will drain in that direction. It will be noted that starting south from the shaft a sag or low spot is first reached, then a steeper rise. It will be noted that elongated areas exist, one in the northeastern corner of the map and two in the southwestern. These areas appear to be old valleys or gullies in the coal that existed before the glaciers invaded the area and covered them with glacial drift. The present surface drainage shows little relation to these old channels.

between bricks might be left by the removal of the bricks. Apparently the nature of these "till veins" was not understood as the underground workings of an old mine were uncovered in the pit which showed several entries stopping at these veins on the assumption that the clay was intrusive while if a few inches of clay had been removed the coal would often have been found.

BURNING AND WEATHERING AT THE OUTCROP

Lignite beds have burned out extensively and over large areas in North Dakota. In the United States burning is largely restricted to lignite and sub-bituminous coal. Where such burning takes place the overlying materials are often baked or fused to a brick red color. It is rare that underlying beds are baked to any depth, consequently the lower limit of clinker may be assumed to be essentially in a plane with the unburned coal, allowing for any surface creep or slumping.

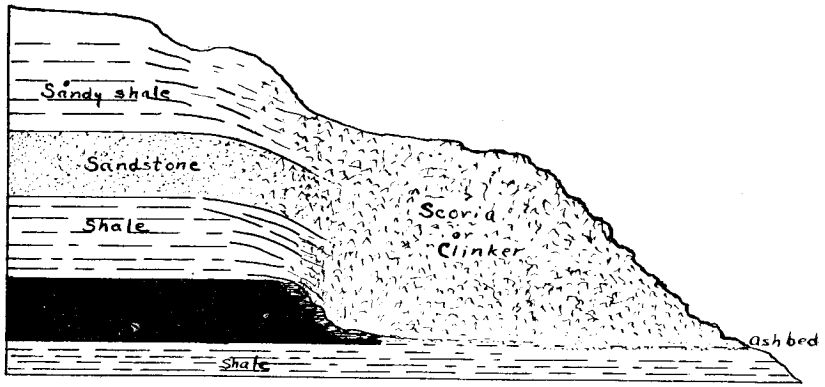


Fig. 6. Cross section to show the relation of clinker or "scoria" to a coal bed where no slumping or creep has taken place. The overburden is here shale, sandstone and sandy shale but the material may vary from fine clay shale to sand or sandstone. The level of the bottom of the clinker is almost the same as the bottom of the coal, as most of the baking or burning is limited to the material which was over the coal bed.

The size of the coal bed is roughly proportional to the amount of clinker. Except under very favorable conditions lignite beds less than 4 feet in thickness do not burn. A 10 or 12 foot coal bed will often give clinker beds 20 to 30 feet in thickness. Glacial till where it lies over the coal may be baked, as may be found along the tops of the bluffs bordering the Missouri river about three miles east of Hofflund, Williams county, North Dakota.

Such burning proceeds from the outcrop and as the coal burns the overburden slumps, opening cracks which admit air essential to combustion. Burning stops when one or both of the following conditions exist:

1. Seeps or creeks keep it too wet.
2. The overburden may be sand or sandy shale and slumps down over the coal, smothering any fire that starts.

If the overburden is very porous, weathering (slow burning) may proceed beneath 20 or 30 feet of cover, resulting in pits or depressions on the surface. Clinker from a lignite bed 10 feet thick may attain a thickness of 30 feet, from a 35 or 40 foot bed it may be 50 or even 60 feet thick, with considerable fused or slag-like material. Masses of such molten material of 10-20 tons weight are not uncommon.

The first stage of weathering is loss of moisture with crumbling or slaking, then a gradual reduction to a sooty powder which oxidizes slowly, with a consequent shrinkage in volume.

Coal beds of any thickness often weather so as to produce small slumps or sinks, bare patches several yards in area on slopes at the outcrop and if it is found that the particular coal bed has this habit, this becomes useful in tracing the bed. These peculiar slumps, however, may be caused by certain sand-clay combinations and taken alone do not indicate coal.

PROSPECTING LANDS

After the land is found to be underlain with coal there remains much to be done before a mine may be planned and the coal opened. No extensive mining should be undertaken without accurate and thorough knowledge of the following facts:

1. Thickness and nature of the overburden.
2. Character, thickness, and quality of the coal.
3. Accurate information of water both in overburden and in or beneath the coal.

For learning most about the nature of the overburden and coal, drilling or boring test holes is the cheapest method. If many holes are planned some sort of power driven machine is most economical. A machine that will bore or drill without water is preferable, especially in sampling the coal. Where the depth is not too great a simple soil augur, cutting a 2 inch or 3 inch hole, is quite satisfactory. Post hole augurs with gas pipe extensions are used in many places. Neither of

these, however, take a satisfactory sample of the coal. These may be used to bore to the coal, the hole cased and a bit that will cut a core or an augur that forces the sample into a tube for collecting a dry sample may be used.

For heavy duty testing where the coal bed is not over 100 feet deep, the writer has found the well boring machine, horse-power driven, boring a 12 inch to a 24 inch hole, the most satisfactory. An 18 inch augur removes about 140 pounds of lignite for each foot in depth and hence yields a generous sized sample that may be preserved for analyses or other tests.

The jetting well machine by which the cuttings or sludge is forced out by circulating water is one of the most rapid machines but in general does not preserve a good sample either of overburden or coal.

One of the simplest and least expensive is the pipe or bar with the ordinary spud bit, with a valve bottom bailer to remove the sludge. These are attached to ropes or cables operated by hand, with or without a spring pole. Similar in plan and operation but with a wider latitude of size of hole and depth is the power operated cable solid-tool rig. Both the above types bring up the cuttings as small fragments more or less contaminated with material from higher in the hole. Under such conditions accurate interpretation of the nature and kind of rock is difficult. The coal is often so contaminated that an analysis is impossible or unreliable, while conditions of roof and bottom are often impossible of interpretation.

Much superior to the churn type of drill is some form of the rotary drill that removes a core which in turn preserves a continuous record of all rocks penetrated. The ordinary well driller seldom has this equipment, however. These core drills are of three general types, as follows:

1. A calyx or shoe of steel with saw teeth which screws on to the end of the driving pipe, downward through which water is circulated and which removes the cuttings by the upward current of water in the space between the drive pipe and hole. Since the steel teeth do the cutting the material penetrated is limited to soft material such as poorly cemented sandstone, shale, clay, coal or soft limestone.

2. A second machine similar to the above by which the cutting is done by steel balls or other abrading material loosely placed between the soft steel hollow drill and the rock penetrated. Rather slower than the first but capable of drilling through harder material such as dense sandstone, dolomite, or even granite.

3. The diamond drill in which diamonds are the abrasive, being set in the soft iron shoe and capable of drilling the hardest material with considerable speed. Usually the simplest and most rapid but the initial cost is high.

Drilling may be done only for determining the presence or absence of coal, in which case single holes may be spaced on each quarter section, half section, or even section of land. Holes should be carried to the depth of commercial recovery and a careful log kept of the formations as well as samples of all rocks penetrated.

Subsequently intensive drilling is undertaken as a preliminary to the development of a property. The holes are spaced according to a plan of which a large scale map is usually made. A common system is to lay out the holes on a gridiron pattern with holes spaced 330, 500, 660, or 1000 feet apart. The following data are recorded for each hole:

1. Elevation of top; determined with instrument.
2. Depth to top of coal.
3. Thickness of coal; also nature of coal and impurities.
4. Character and position of certain critical formations such as water, sands, roof over coal, material underlying the coal, etc.

From 1, 2, and 3, a distribution and structural contour map may be made which will indicate the location of shaft or opening, direction and position of main entries and direction of drainage.

WHAT IS LIGNITE LAND WORTH?

The writer has noted little tendency among owners of coal land in North Dakota when selling to demand a materially higher price for coal land than non-coal land except lands near the larger producing mines where in the near future the land may be in demand for mining. Just now there are more sellers than buyers and hence coal lands are but little higher than non-coal lands. The range is from $10 per acre up, with $30 to $50 average. Should, however, there be a reasonable chance that the coal in a piece of land may be mined soon it naturally assumes a higher value. Royalties vary from 5 cents per ton to 75 cents per ton or even more, depending on the nature of the lease. 10 cents and 15 cents per ton is more common. The Department of the Interior sets a minimum rate of 5 cents per ton on public lands and reserves. Based on a royalty of 10 cents per

ton and a recovery of 60 per cent of the coal, a ten foot bed of coal may eventually return one thousand dollars an acre, though this by no means represents its present worth. In older coal regions the present value per acre is arrived at by assuming the present worth to be one-half the royalty value as calculated by the method above. It would appear that considering the price asked for land in North Dakota, royalty rates are too high since the one-half rule is used for thin beds in old coal regions where the surface is often worth from $100 per acre up. The Department of the Interior used the following rule for evaluating lignite lands before the present leasing system was adopted. "For purposes of valuation the price per ton of a non-coking, non- anthracite coal 6 to 10 feet thick shall be one-tenth of a cent for each 1,250 B. t. u." with additional provisions for a somewhat lower rate for thicker beds and special conditions. The above rule applies to air dried coal. At the above rate an acre of lignite land with a bed 10 feet thick and yielding 8000 B. t. u. on the air-dried basis would be evaluated at about $115.

While the above figures are suggestive, the price asked will be more or less controlled by the following factors: accessibility, quality and quantity of coal, competition, knowledge of coal content, cost of mining and marketing, demand, and artificial and legal restrictions.

ACCESSIBILITY

It is self-evident that with the immense calculated tonnage of lignite in the state and the present rather small rate of consumption it will be hundreds of years before many beds of lignite need be touched at all. Hence those deposits most easily reached or located favorably in respect to transportation and market will have the advantage. If your lands are distant from railroads, you must necessarily have other important advantages to balance this.

QUALITY

The quality of the lignite involves several things that may be determined with reasonable accuracy. It is important to know whether your coal will compare favorably with other coals that are sold and, after all, the cost of heat is the controlling factor that decides whether a consumer will burn lignite or some other fuel.

The directions for sampling in accordance with the regulations of the United States Geological Survey are briefly as follows:

"From a clean, fresh face a channel is cut perpendicularly from roof to floor, the partings that are thrown out in mining being discarded. The material thus obtained is broken to pass through a one-half inch screen and the sample is reduced by quartering to about 1 quart, which is placed in a galvanized-iron can, (or a fruit jar) sealed, and sent immediately to the laboratory."

MINING METHODS AND COST OF MINING

Cost of mining is a vital factor in the evaluation of coal land.

The size of operation, to a certain extent affects cost of mining. Out of a total of over 130 mines listed by the State Mine Inspector, less than 20 mines show a production of over 25,000 tons each per annum. In 1923 only three mines, one underground and two strip mines, approached or exceeded 100,000 tons each.

No adequate discussion of the cost of mining lignite in North Dakota may be undertaken here. The chief reason is that operators do not broadcast such information as it would essentially reveal profits and losses, since the mine price or selling price is more or less public information. The writer has found most operators willing to talk freely with him about their costs but so far as individual mines are concerned this information shall remain confidential. For the information of those interested in coal production outside of the state as well as those who may be interested within the state a general discussion seems in place. Since cost of mining to a considerable extent is dependent on management as well as the physical conditions of the coal bed and both show considerable variation, the cost range of mining lignite is large.

Both underground and stripping operations are represented in North Dakota as elsewhere. Underground mines are opened either by shafts varying from 35 feet to 200 feet in depth, by slopes or inclined tunnels or level drift or tunnel from a side hill. In the two former, hoisting is necessary. In the latter, the coal is pulled out usually by horse or mule or mine cars pushed to the dump by men. Essentially only one type of layout is used below ground. Whether single or double entry is used, the rectangular room and pillar plan is followed. From one foot to four feet or more of coal is left up for roof and both pillar and roof are robbed on retreat. Overlying material is invariably too weak for a roof and when roof coal is robbed, caving soon follows. Subsidence consists in straight vertical breaks of materials over rooms, and the surface is pitted and rendered essentially useless for farming.

Underground, the coal is either undercut or "shot from the solid."

In 1923 about one-third of the total lignite mined was undercut before blasting. This is in contrast to nearly two-thirds of the bituminous coal of the United States which is undercut before blasting or shooting. However, since in 1923 nearly a third of the production came from strip pits, it would appear that half of the coal mined underground was undercut. Since also the great bulk of underground production came from less than 15 mines, it follows that few mines are equipped with undercutters.

Shooting from the solid does not appear to injure a lignite mine, however, so much as a bituminous mine due to the toughness of the coal and the roof of lignite left.

Little timbering is done in North Dakota except in openings.

North Dakota has over one hundred small mines or pits. In many of these the mine is operated for only a few months to supply a local trade. Methods are often primitive and tonnage costs rather high, though in many cases an operator-owner is able to show costs that compare favorably with his larger brothers.

Prior to the war, the average mine price of lignite was 20 per cent to 50 per cent higher than the average mine price of bituminous coal in the United States. During that time it may be safely assumed that this represents rather closely the higher cost of mining lignite. During and since the war, cost of mining lignite has come closer to a parity with bituminous coal. It appears that a well planned, well equipped, and well managed underground lignite mine may expect costs that compare favorably with the average cost of mining bituminous coal.

During the past five years, open pit mining in North Dakota has increased rapidly, ranging from less than one-twentieth of the total tonnage in 1918 to nearly half in 1924.

Lignite has been removed from strip pits essentially since the state was settled. Horses and scrapers were employed in favorable locations where a coal bed could be easily reached from a valley or other natural exposure. No extended or consistent attempt was made to strip large areas. Increased thickness of overburden soon ends these small scale attempts. During the past five years, however, lignite has been attacked by modern, large, steam shovels or draglines comparable in size and scope to those used in the older bituminous fields, where this method has been employed for ten years or more.

North Dakota combines thick level coal beds and relatively flat areas adapted to this method of mining. For purposes of comparison

with older fields, in 1914 the average ratio of overburden removed to coal, in bituminous coal steam shovel pits in the United States was 6.04, ranging from 3.86 in Illinois to 10 in Oklahoma, or in other words in Oklahoma forty feet of overburden was stripped for four feet of coal. In North Dakota for present operations the average ratio is about 3.5 ranging from two to five. There are several hundred millions tons of lignite in North Dakota such that the ratio of overburden to coal does not exceed 3″. In addition, the covering above lignite is more easily dug on an average than in older coal fields of the east and south.

The cost of mining lignite in open pits is subject to as many, or more, variable factors as underground mining. The costs by this method, however, have become pretty thoroughly standardized by the perfection of modern machinery. Costs by this method in North Dakota are such as to insure permanence and extension of the method.

Another factor that has a distinct bearing on the value of coal land is the large amount of lignite that is held in mineral reserves. The Northern Pacific land grant placed a very large acreage and tonnage under the control of that railroad. The Federal Government coal reserves further limit the land to which title to the coal may be gotten with the land. Essentially in every township in the coal area, sections 16 and 36 are held as school lands, and other land grants both to the state and for special purposes cut still further the coal that may be owned by individuals. It is true both the Federal Government and Northern Pacific railroad will lease their coal under certain restrictions but usually for not less than five cents per ton royalty. At present there is no law under which state or school lands may be leased.

Artificial and legal restrictions might easily be too burdensome to allow mines to operate in which case the value of the land would depreciate accordingly. None have yet appeared in North Dakota.

After all, a sale of lignite land involves two parties—a buyer and a seller. The foregoing has been written for both and if it serves to furnish a basis for bringing the two together it has accomplished its purpose.

Description of the Lignite Deposits by Counties

ARTHUR G. LEONARD

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ADAMS AND GRANT COUNTIES

A. G. LEONARD

Two thick and important beds of coal are found in these counties, together with others of less importance. The Scranton coal bed is present in the western part of Adams county but is not known to extend more than a few miles east of Reeder. In the vicinity of that town the bed has a thickness of from 7 to 9 feet, but it grows much thicker farther west in Bowman county. The Haynes coal bed occurs in western Adams and in Grant county. In the Haynes district, where this bed is extensively mined, it is 11 to 13 feet thick.

The Scranton coal bed and the mines in that bed in Adams county are described under Bowman county, since it lies mostly within that area. The lignite deposits of eastern Adams county and the greater portion of Grant county were examined by E. R. Lloyd and other geologists of the United States Geological Survey during the summers of 1912 and 1913, and are fully discussed in a bulletin of that Survey.[1] In the preparation of the following description of these deposits this report has been freely drawn upon.

HAYNES COAL BED

The name Haynes coal bed is applied to the lowest important lignite bed in the area, except in the valley of the Cannonball river in T. 133 N., R. 90 W., where a still lower seam is present. It is believed, from all the evidence in hand, that this bed was once practically continuous over at least the greater portion of the field, and it is therefore probably present under all the area from which it has not been removed by erosion.

The Haynes coal bed reaches its greatest known thickness under the high ridge north of the town of Haynes. In this locality the bed is 11 to 13 feet thick. It is this thick seam of coal, located near the

[1]E. Russell Lloyd, The Cannonball River Lignite Field, North Dakota: U. S. Geol. Survey Bull. 541, pp. 243-291, 1914.

railroad, which makes this one of the most important mining districts in this part of the state. The Haynes bed is mined north of Haynes at the following mines: South Dakota State mine, NW. ¼ sec. 8, T. 129 N., R. 94 W., Haynes coal mine, secs. 8 and 9(see analysis No. 5514), Stevenson mine, sec. 15, and the Leroy Smith mine, NE. ¼ sec. 21. Spur tracks from the Chicago, Milwaukee and St. Paul railroad run to the South Dakota State and Haynes mines and most of the coal is shipped, only a small part being furnished the local trade.

North and east of the ridge in which the mines near Haynes are located, and between Duck and Cedar creeks, in T. 130 N., R. 94 W., the Haynes bed outcrops near the tops of a number of high buttes, where it has been burned extensively along the outcrop. There the thickness is from 10 to 12 feet. Between Cedar and Timber creeks the bed outcrops for the most part where the surface has a gentle slope, and therefore exposures of the same are practically confined to the places where it has been mined. The greatest known thickness, 10 feet, in this part of the area is at the Merry mine, across the line in Hettinger county, in sec. 34, T. 132 N., R. 93 W. From this locality southeastward the thickness gradually decreases to less than 2 feet in the southeastern part of T. 131 N., R. 92 W. In this township another lignite bed, about 50 feet higher than the Haynes, is exposed at a few places only. The very meager data in hand indicate that it is from 4 to 6 feet thick.

North of Timber creek, in the northern part of T. 131 N., and the southern part of T. 132 N., R. 91 W., there are two beds of lignite more than 2½ feet thick. The lower of these, which is correlated with the Haynes bed, is 5 to 7 feet thick. The upper bed, approximately 50 feet higher, is about 5 feet thick. In the northern part of T. 132 N., R. 91 W., and the southeastern part of T. 133 N., R. 90 W., is a group of small mines or strip pits in a bed which is 4 to 6 feet thick, and which is presumably the Haynes bed.

South of Coffin Butte, in T. 131 N., R. 90 W., very little information concerning the lignite could be obtained. There appear to be in this locality two beds from 3 to 6 feet thick, the lower being doubtfully correlated with the Haynes bed. It is probable that two beds which are exposed on the south face of Pretty Rock Butte, in T. 131 N., R. 89 W., are the same. The lower of these beds is 4 feet 2 inches and the upper 2 feet 5 inches. Farther north in the same

township the lower bed underlies a group of small hills, but is only from 2½ to 3 feet thick.

In the valley of Sheep creek, in T. 132 N., R. 90 W., and in portions of adjoning townships, three important beds are exposed. The lowest of these, which is doubtfully correlated with the Haynes bed, outcrops in the valley of Sheep creek, and has been mined at numerous places. The thickness in this vicinity ranges approximately from 2 to 6 feet. The second bed, which is about 50 feet higher, is worked in three large stripping mines in the southern part of T. 132 N., R. 90 W. The thickness of the bed in each of these mines is over 6 feet but its value is considerably impaired by thin partings of shale. The uppermost bed is exposed high up on the north side of Coffin Butte in the same township in an abandoned strip pit, where it is 4 feet 8 inches thick but contains a parting of shale over a foot in thickness. In the southwestern part of T. 133 N., R. 89 W., and the southeastern part of T. 133 N., R. 90 W., a group of high buttes is underlain by a bed of lignite, probably the same as that exposed in Coffin Butte. The bed has been burned extensively along the outcrop and the resulting red clinker forms a conspicuous topographic feature. A single measurement of the bed obtained in this vicinity (sec. 32, T. 133 N., R. 89 W.) shows a thickness of 7 feet 8 inches, with an 8-inch parting of sandstone 2 feet from the top.

In the valley of a branch of Cannonball river, in the eastern part of T. 133 N., R. 90 W., there are several exposures of a bed of lignite which is probably the Haynes bed. Its thickness ranges from 3½ to 5 feet. Another bed which is thought to be somewhat lower stratigraphically than the Haynes bed is exposed in the bluffs of the Cannonball river in the same township. Its thickness ranges from 1 foot 11 inches to over 6 feet in a distance of about a mile. The Patzer mine, in sec. 10, T. 133 N., R. 90 W., is in this coal bed, which here has a thickness of 6½ feet.

North of the Cannonball river, not far from the towns of Leith, Heil, and Kaiser, there are two lignite beds, the lower and more important of which is being mined near Leith. (See analysis No. 5515.) The thickness averages about 8 feet in the mines west of Leith but decreases both to the east and west. The upper bed averages 4 or 5 feet in thickness, and the vertical distance between the two beds is approximately 40 feet. In the Black Diamond mine, in the SE. ¼ of sec. 12, T. 133 N., R. 88 W., the lower coal bed is 8 to 8½ feet

thick, and is reached by a shaft. The lower seam is also mined in the Lehner mine, in sec. 10, of the same township, where it is 4 feet thick, and in the Rock mine, in sec. 2, where it is 4½ feet thick. These two mines are strip pits. The lower coal bed is believed to be the Haynes bed, and it lies about 100 feet above the base of the Fort Union.

In addition to the lignite beds mentioned above, a few other beds less than 2½ feet thick outcrop in various parts of the region. Since these are relatively unimportant they will not receive further mention. Those wishing a more detailed description of the coal beds of Grant and eastern Adams counties, with maps showing the areas underlain by the lignite seams, are referred to the bulletin of the United States Geological Survey mentioned on a previous page.[2]

In northern Grant county, north of the Mott branch of the Northern Pacific Railroad, a coal bed is exposed along Antelope creek, and has been mined in sec. 36, T. 135 N., R. 89 W. The section of the coal seam is as follows:

	Feet	Inches
Sandstone	10-18	
Coal		10-12
Clay	1-5	
Coal, bottom not exposed, at least	3	

Two coal beds occur along the Heart river valley in northwestern Grant county. They are exposed near the east line of T. 136 N., R. 90 W., where the upper bed with a thickness of 4 feet lies 150 feet above the river.

Ninety-five feet below is the lower seam which is 2½ feet thick.

BILLINGS AND GOLDEN VALLEY COUNTIES

A. G. Leonard

The Little Missouri river crosses Billings county from south to north, and this river and its many tributaries have cut deep valleys, gorges and ravines in the coal-bearing formation. It is the numerous streams of the region which have eroded the surface and carved it into the rough and picturesque badlands. In these badlands the many lignite beds or the clinker formed by their burning are well exposed in the bare, steep slopes of the bluffs and buttes, and these counties, therefore, like the others through which the Little Missouri flows,

[2]E. Russell Lloyd, The Cannonball Lignite Field, North Dakota. U. S. Geol. Survey Bull. 541, pp. 243-291, 1914.

afford exceptionally favorable conditions for the study of the lignite beds. The strata of the region have a northward dip which carries the lower coal beds successively below river level in going from south to north, while higher coal seams make their appearance in the bluffs, these in turn disappearing below the valley bottom when traced northward. Thus most of the coal beds which outcrop in the southern part of the district would if present lie far below river level in northern Billings and Golden Valley counties, and it is the higher beds that are there exposed.

The top of Sentinel Butte is 1163 feet above the bottom of the Little Missouri valley at Medora so that in going from the river to the top of that butte it is possible to determine the number of coal beds present in this vertical section of over 1100 feet of strata. The greater portion of the entire thickness of the Fort Union formation is here exposed to view and its lignite beds can be studied. No less than 13 coal beds over 4 feet thick are known to occur in Billings and Golden Valley counties, their aggregate thickness being 106 feet. The coal bed near the base of Sentinel Butte is 20 feet thick, and there are two others over 15 feet thick.

Some of these beds of coal formerly covered large areas, though they have now been largely removed by erosion or have burned out extensively. One coal bed (Bed R) with a thickness of 5 to 17 feet has been traced 27 miles north and south and 24 miles east and west, and while its known area as shown from outcrops is nearly 900 square miles it undoubtedly had an extent of 1000 to 1500 square miles.

Several of the coal beds of the Great Bend group (see Plate IV), occurring in Slope county, extend north into Billings and Golden Valley counties, and these will be traced down the valley from the mouth of Third Creek. At the sharp bend in the SW. ¼ of sec. 19, T. 137 N., R. 101 W., the upper member of the group, bed I, outcrops 50 feet above river level. It has a thickness here of 16 feet, is overlain by 20 feet of sandstone, and contains several thin clay seams one or two inches thick. Less than one-half mile northwest of this outcrop the same bed is exposed in a ravine tributary to the river, the thickness of the coal here being 13½ feet, with a 2-inch clay seam 2½ feet above the base. This bed can be traced in the bluffs bordering the west side of the Little Missouri valley, both by its occasional outcrops and by the thick layer of clinker formed where it has burned. At the oxbow bend in sec. 3, T. 137 N., R. 102 W., the coal measures 13 feet and 8 inches and lies 50 feet above the river,

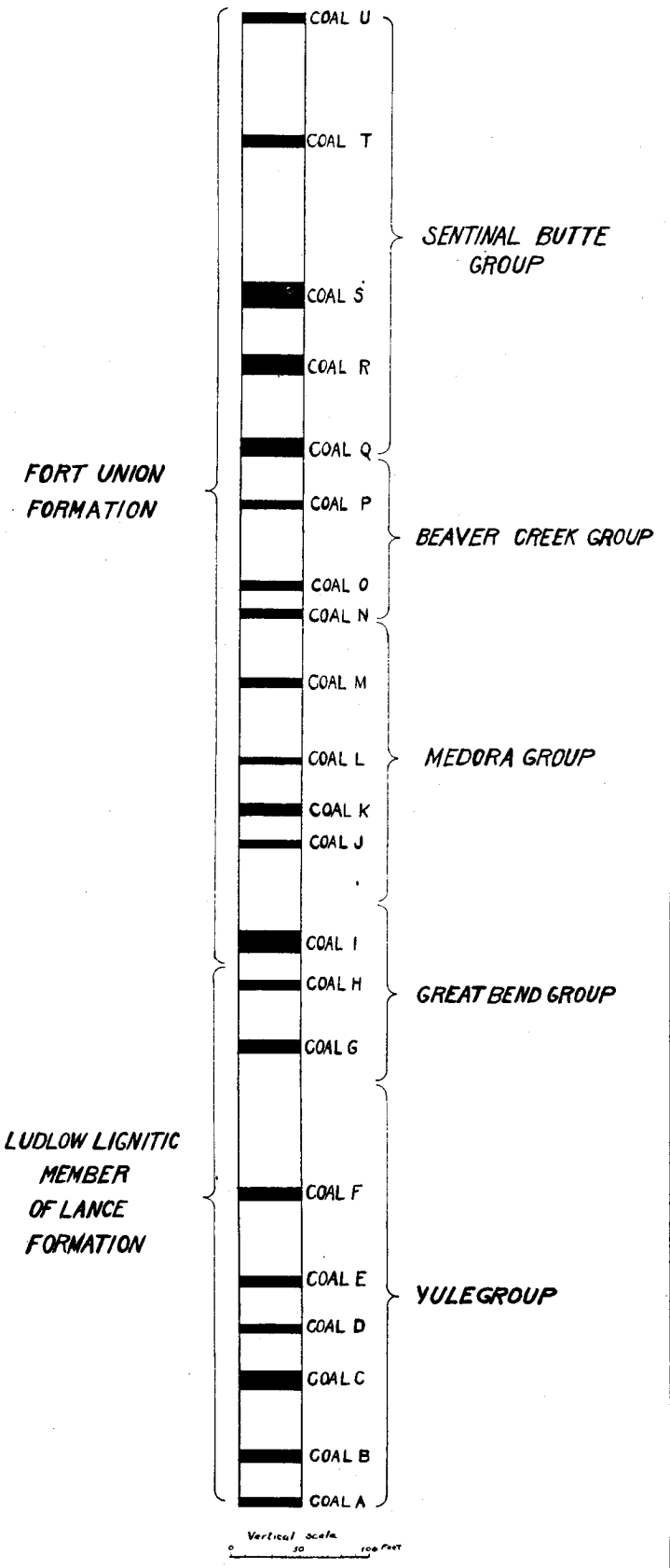
and its thickness at the mouth of Bullion creek is 10 feet. Between 4 and 5 miles below the mouth of Bullion creek in sec. 18, T. 138 N., R. 102 W., coal bed I is at water level and is 10 feet 4 inches thick. Two miles north of this point the northward dip of the strata carries this thick bed below river level and it does not appear again. Its last outcrop in going down the river is near the north line of sec 5, T. 138 N., R. 102 W., about three-quarter of a mile above the Harmon ranch. The section of bed I is here as follows:

	Feet	Inches
Shale, buff and gray	10-50	
Shale, carbonaceous, black and brown	5	6
Coal	11	8
Clay		7
Coal		8
Clay		4
Coal, bottom of bed several inches above low water	3	6

Since bed I is the highest of the Great Bend group, it follows that none of the members of that group is exposed north of the north line of T. 138 N., although they doubtless extend many miles in that direction below river level. Bed I outcrops at various points on Bullion creek for 5 or 6 miles above its mouth. In the SE. ¼ of sec. 1, T. 137 N., R. 103 W., about one mile above its mouth, the coal is 10 feet thick; near the east line of sec. 11 it is 9 feet thick; in sec. 13, T. 137 N., R. 104 W., it is 5 feet; and near the east line of sec. 10 of the same township and range it has a thickness of 5 feet and lies 25 feet above the creek. No outcrops of bed I were seen west of this point, unless the coal exposed in the NE. ¼ of sec. 9, and having a thickness of 26 to 30 inches, is this member, which grows thinner toward the west. In the NE.¼ of sec. 10 a lower coal bed, possibly H, has been mined on a small scale. The coal lies 2 feet above creek level and a thickness of 3 feet is exposed, but the base of the bed is not shown. It is overlain by 20 inches of brown, carbonaceous clay.

About one-half mile southeast of Alpha, near the center of sec. 33, T. 137 N., R. 104 W., a coal bed is well exposed on a short tributary of the Little Missouri river. The section is as follows:

	Feet	Inches
Clay wash	3-6	
Clay, blue	2	
Clay, brown, carbonaceous		8
Coal	6	6



Generalized vertical section showing position and grouping of coal beds

The entire thickness of the Fort Union and Lance formations is not known, only the coal-bearing portions being included in the section.

Considerable coal has been mined here by the farmers of the vicinity, who work it by stripping off the cover. This coal probably belongs to bed H, which appears in the river bluffs several miles to the southeast. The former presence of a higher coal bed (I) in this district is evident from the burnt clay seen at many points.

Coal is also exposed in several places in the vicinity of Burkey, where it outcrops on Bullion creek and its tributaries. In the SE. ¼ of sec. 5, T. 137 N., R. 105 W., 7 feet of coal outcrops just above creek level, and the bottom of the bed is not exposed. The cover is 10 feet thick, increasing in thickness back from the creek. The coal has been mined here for a distance of 60 feet along its outcrop. In the NE. ¼ of sec. 8, what is probably the same bed had been mined at intervals for a distance of 100 feet along the creek. The full thickness could not be determined here, as the bottom of the coal is below the creek bed, but a measurement near by gave a thickness of 7 feet 3 inches. Coal also outcrops two and a half miles east of Burkey, in the N. ½ of sec. 11, T. 137 N., R. 105 W., where the following section appears:

	Feet
Coal	5
Clay	10
Coal, exposed, but not the entire thickness	2½

It is evident from the foregoing detailed description of outcrops that the coal beds of the Great Bend group cover a large area. This is especially apparent in the case of the thick upper bed, whose outcrops are distributed over a more extensive area than those of the lower members of the group. This bed, I, as stated on a previous page, is known to cover at least 600 square miles, and it probably underlies a larger area.

THE MEDORA GROUP OF COAL BEDS

The members of this group outcrop along the valley of the Little Missouri river from the vicinity of Bullion Butte northward to the northern boundary of Billings county. The four beds which constitute the group have a vertical range of about 200 feet, the lower member lying some 90 feet above bed I. The two middle beds appear in the river bluffs at Medora, whence the name of the group, and the thicker one is mined at that point. The beds of this division have been designated in the vertical section by the letters J, K, L, and M. Not only do these outcrop on the Little Missouri river, but they occur in the northwestern part of the region, on Beaver and

Elk creeks, and on Andrews creek near Sentinel Butte station. (See Plate IV.)

For convenience in description we will begin near Medora and trace the beds first south, and then north to the county line.

The following is the section of the coal beds which are present in the bluffs at Medora:

		Feet	Inches
Shale			
Bed L:	Coal	4	6
Shale and sandstone		31	
Bed K:	Coal		2
	Clay		2
	Coal	8	
	Clay		3
	Coal		11
Shale and sandstone, to river		40	

The High Grade and Demores mines at Medora, and the Red Trail and Little Missouri mines located across the river from Medora are all in bed K. Spur tracks from the Northern Pacific railroad run to the High Grade (see analysis No. 5516) and Red Trail mines.

The lower coal, K, has been mined here for a number of years. From 6 to 6½ feet of coal are removed and the remainder is left to form the roof of the mine. This same bed was formerly mined extensively by the Northern Pacific Railway Company, their old workings being located on the west side of the river not far from the railroad bridge.

About two miles south of Medora, in the steep bluff at the mouth of Sully creek, the beds K and L are both well shown. The lower (K) is here 80 feet above the river and is 8½ feet thick, while 40 feet above is the upper bed (L) with a thickness of 5 feet.

The lower bed is exposed on Sully creek in the NW. ¼ of sec. 2, T. 139 N., R. 102 W., where its thickness is 9 feet, and it disappears below creek level near this point. Near the southern edge of sec. 1, T. 139 N., R. 102 W., the two higher beds of the Medora group appear in the side of the creek valley, the section being as follows:

		Feet	Inches
Shale and sandstone			
Bed M:	Coal	3	2
	Clay, brown and carbonaceous below	5	6
	Coal	4	4
Sandstone, massive, with some shale above		60	
Bed L:	Coal	5	
Clay, to creek bed		10	

The upper coal bed, M, is represented in many places by a single bed.

In the bluff of the Little Missouri river at the Custer Trail ranch, in sec. 10, T. 139 N., R. 102 W., the following exposure occurs:

	Feet	Inches
Bed M: Coal	2½	
Shale and sandstone	30	
Bed L: Coal	4	
Shale and sandstone	45	
Bed K: Coal	6½	
Unexposed, to river	95	

One and a half miles south of here, in the NE. ¼ of sec. 22, three coal beds are exposed in the river bluff, as follows:

		Feet	Inches
Bed K:	Coal	1	6
	Clay, brown		6-11
	Coal	6	6
	Clay, brown	1	
	Coal	6	
Shale and sandstone		32	
Bed J:	Coal	7	6
Shale and sandstone		21	
Coal		4	
Shale and sandstone, to river		45	

The lowest coal bed of the above section does not appear elsewhere and is probably found only locally.

Bed K also outcrops in the NE. ¼ of sec. 6, T. 138 N., R. 102 W., where it lies at an elevation of 125 feet above the river and is 7 feet thick. About 35 feet above K is a bed 3 to 4 feet thick which is probably L. No more outcrops of these beds were observed in going up the river until Bullion Butte was reached. Here, in a ravine on the north slope, in sec. 12, T. 137 N., R. 103 W., the following coal bed is exposed:

	Feet	Inches
Coal	4	4
Clay	4	
Coal	3	10

This coal lies about 180 feet above the river and probably is to be correlated with bed K of the Medora group. Five miles to the east, in the SW. ¼ of sec. 2, T. 137 N., R. 102 W., what is doubtless the same bed occurs in the river bluff. It has a thickness of 6 to 8 feet and is 200 feet above water level.

In the divide south of Bullion creek, between the latter and the Little Missouri, there is a coal bed 5 feet thick which belongs to

the same group. South of Bullion Butte and of the high divide just mentioned the members of the Medora group do not occur, since the surface of the plain is below their horizon.

North of Medora these beds outcrop at frequent intervals for many miles along the valley of the Little Missouri. They are well exposed where the river swings against the bluff near the center of sec. 15, about 2 miles north of the railroad. Here bed K is 6 to 8 feet in thickness and lies 50 feet above the river, while 30 feet higher is the coal bed L with thickness of 4 feet. The two beds approach each other toward the north and northeast, and in the bluff in the NE. ¼ of sec. 10 they are not over 12 feet apart. The lower outcrops on Knutson creek for about 2 miles above its mouth, measuring 7½ feet in thickness. Both are well exposed on the river in the northeast corner of sec. 11, where the following section is shown:

	Feet
Bed L: Coal	4½
Shale and sandstone	11
Bed K: Coal exposed above water of river but extends below	8

These two beds outcrop across the river, in a cut bank on Paddock creek, in the NW. ¼ of sec. 12, where only the upper foot or two of the lower coal is exposed, overlain by 12 feet of sandstone and clay and the 5-foot upper coal bed.

A short distance below the outcrop in sec. 11 the two beds of coal dip below river level, but reappear again about two miles to the north, in the NE. ¼ of sec. 32, T. 141 N., R. 101 W., and here in the cut bank on the west side of the river, the following section appears:

	Feet	Inches
Clay		
Coal		2-4
Clay	1½-2	
Bed L: Coal	4½-5	
Sandstone, finely laminated, passing below into clay	8-10	
Bed K: Coal, only the upper part of the bed is shown here, and the exposed thickness is	2	

For over 10 miles north of this exposure these two beds are below the river, and no workable coal is present in the bluffs of the Little Missouri, but the beds K and L are probably not far below the bottom of the valley, for they again appear farther down stream.

In the SW. ¼ of sec. 11, T. 142 N., R. 102 W., the following section is well exposed in the steep cut bank on the east side of the river:

	Feet	Inches
Clay, wash	4-6	
Clay, sandy	6-8	
Coal	1	
Clay	5	6
Coal	3	
Clay, sandy	6	
Bed K: Coal	6	
Bed K: Clay, sandy	3	6
Bed K: Coal	6	5
Clay exposed above river	1	

Three miles below, in the N. ½ of sec. 35, T. 143 N., R. 102 W., a coal bed 16 feet thick outcrops on the river. Less than one mile below, in the SE. ¼ of sec. 27, T. 143 N., R. 102 W., the following section is well shown:

	Feet	Inches
Sandstone, fine-grained, gray and buff	10	
Sandstone, argillaceous, fine-grained and finely laminated, contains many iron pyrites nodules	2	6
Bed L: Coal	2	10
Clay		10
Bed K: Coal	3	4
Bed K: Clay		10
Bed K: Coal	7	7
Sandstone, argillaceous, fine-grained and laminated, contains many iron pyrites nodules, and some carbonized roots running down from coal, exposed above river	4-5	

The three coal beds of the above section probably represent, as indicated, K and L, the clay separating the upper and lower coal having thinned to only 10 inches and the lower bed (K) being divided by a 10-inch clay band.

In the extreme northeast corner of sec. 21, T. 143 N., R. 102 W., less than 2 miles below the last-mentioned outcrop, the same beds are exposed in the river bluff, and a lower bed of coal appears, the sections being as follows:

	Feet	Inches
Sandstone		
Bed L: Coal		31
Clay		10
Bed K: Coal	3	2
Bed K: Clay		8
Bed K: Coal	6	8
Sandstone, argillaceous, fine-grained	40	
Bed J: Coal, partly under water	3-4	

The bed J is a lower coal which does not appear along the Little Missouri between Medora and this point, but which was traced from here to the mouth of Beaver creek.

Continuing down the river one mile another good exposure of the coal beds is found in the steep bluff on the east side of the river near the west line of sec. 15, T. 143 N., R. 102 W., the section being as follows: (See Plate V, Fig. 1.)

	Feet	Inches
Shale and sandstone		
Bed K and L: Coal, with three clay partings 1 to 3 inches thick in upper half of the bed	10	
Sandstone and shale	30	
Bed J: Coal		32-34
Clay, exposed to water level	2-6	

The coal beds K and L, which have been approaching each other through the thinning of the intervening clay, here unite to form one thick bed with, however, several clay partings, which farther north thicken in places and split the coal into several seams. This is well shown in the northeast corner of sec. 17, T. 143 N., R. 102 W., where the same coal beds are well exposed, as follows:

		Feet	Inches
Sandstone, argillaceous		12	
Clay		3	
Bed K and L:	Coal	2	
	Clay		4
	Coal		8
	Clay		1
	Coal	2	
	Clay		7
	Coal	5	6
Sandstone, massive, with some clay		30	
Bed J: Coal			32
Sandstone and shale, to river level		30	

The upper coal with three clay seams corresponds to the 10 foot bed of the preceding section formed by the union of K and L.

This same upper coal horizon outcrops in the river bluffs two miles to the north in the SW. ¼ of sec. 33, T. 144 N., R. 102 W., across the river from Roosevelt's old Elkhorn ranch, the section here being as follows:

		Feet	Inches
Clay			
Coal			8
Clay		1	
Bed L: Coal		4	
Sandstone		5	6
Bed K:	Coal		8
	Clay	3	6
	Coal	1	
	Clay	1	6
	Coal	4	
Unexposed to river, about		50	

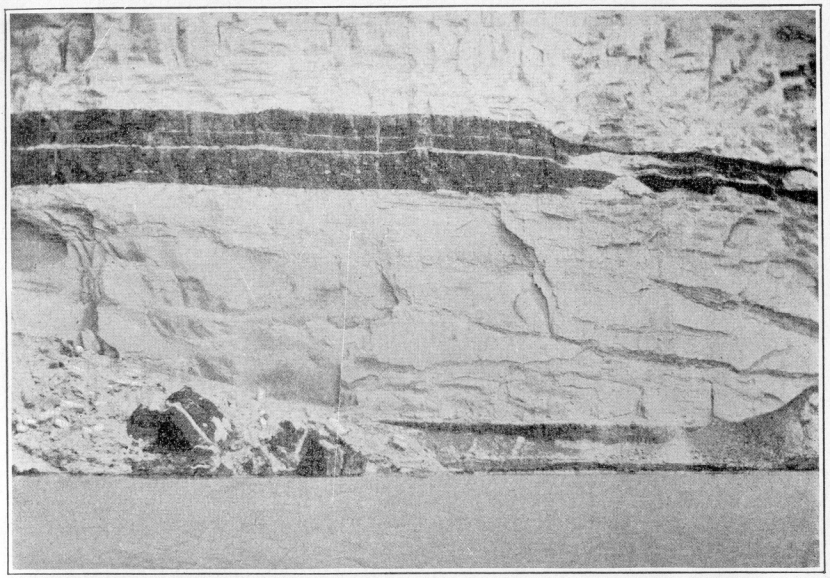


Fig. 1 Two coal beds exposed on Little Missouri river in northern Billings county. The upper bed is ten feet thick. The lower bed is just above river level.

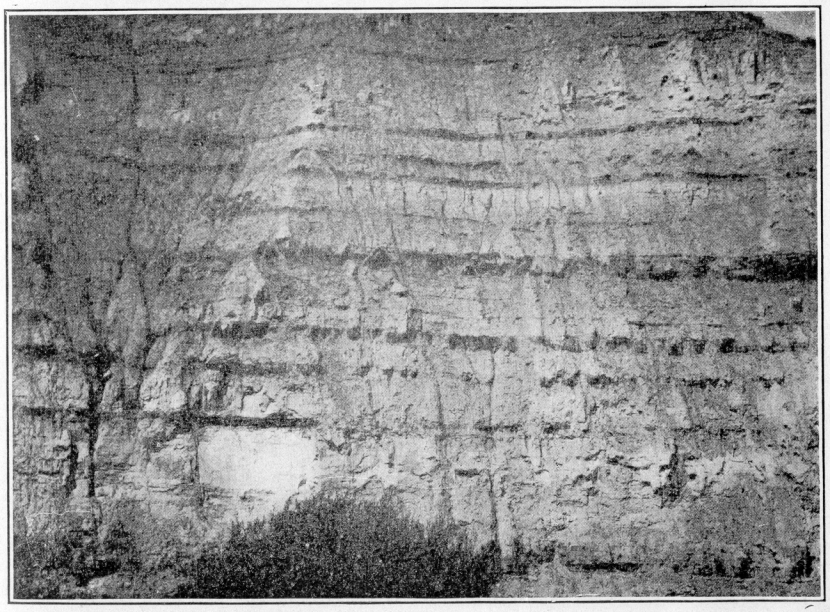


Fig. 2. Bluff on Beaver creek, in northern Billings county, showing ten coal beds. The thickest coal bed measures four feet, four inches.

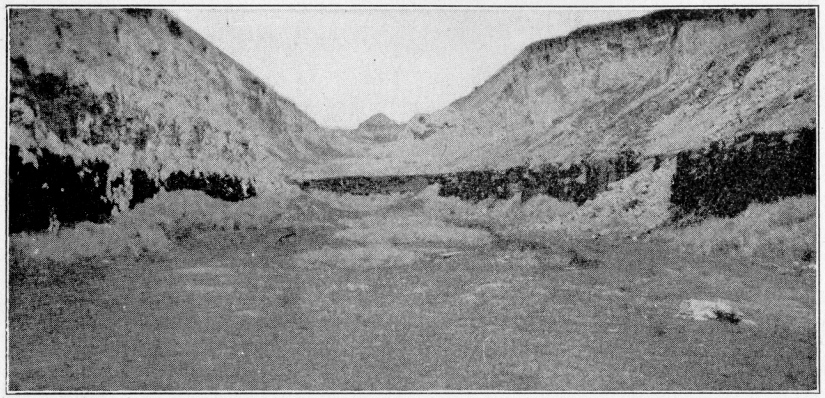


Fig. 1 Scranton coal bed exposed in open cut of Johnson Fuel Company. Only the upper twelve feet of the 20-foot coal bed is shown here.

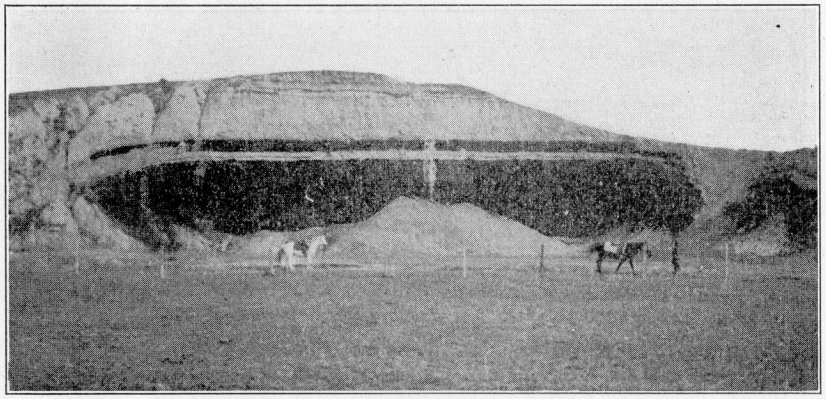


Fig. 2. Coal bed I exposed on Sand creek, five miles southwest of Amidon. Thickness of this lignite bed is 35 feet.

The lower bed is not exposed at this point.

The splitting up of the coal into many beds by clay seams is well illustrated in this section. There is no doubt that this is the same horizon which both to the north and south of here is represented by a single thick bed of coal.

Less than one and a half miles below the above outcrop, in the W. ½ of sec 27, T. 144 N., R. 102 W., the following section occurs:

		Feet	Inches
Sandstone, massive			
Bed K and L:	Coal	1	
	Clay		8
	Coal	3	
	Clay		15-40
	Coal		15
Sandstone and clay; sandstone massive, fine-grained and laminated		27	
Coal			6
Sandstone		3	
Bed J:	Coal		10
	Clay		8
	Coal, bottom of bed at river level	5	

The rapid variation in the thickness of the clay seams is well shown in this exposure, where within a distance of a few hundred feet the lower clay in the upper coal varies from 15 to 40 inches.

About three miles to the north, in the SE. ¼ of sec. 9, T. 144 N., R. 102 W., the same two beds of coal appear as in the following section:

		Feet	Inches
Shale and sandstone, to top of bluff			
Coal			26
Shale and sandstone with several thin coal seams, 1 to 3 inches thick		27	
Sandstone ledge		4-5	
Clay, sandy, with thin coal seam		2	
Bed K and L:	Coal	5	8
	Clay		6-10
	Coal	1	
Shale and sandstone		25	
Bed J: Coal		3	2
Clay, to water level			20

These coal beds outcrop again on the west side of the valley, about one quarter of a mile south of the mouth of Beaver creek, in sec. 6, T. 144 N., R. 102 W. Here in the bluff of the river the following section is exposed:

	Feet	Inches
Shale and sandstone to top of bluff with several thin coal seams, about	150	
Bed K and L: Coal	7	10
Bed K and L: Clay, passing above into coal	6	6
Bed K and L: Coal		13-15
Shale	15	
Coal		10-12
Clay, blue		20
Sandstone, fine-grained	10	
Bed J: Coal		38-40
Shale, to river bed	14	1

Coal on Beaver Creek. The two thick coal beds of the above section were traced up the valley of Beaver creek for a distance of 4 or 5 miles. They were exposed one mile above the mouth, in the SW. ¼ of sec. 34, T. 145 N., R. 102 W., McKenzie county, where the following section appears:

	Feet	Inches
Sandstone	10	
Bed K-L: Coal	6	7
Sandstone and shale	43	
Bed J: Coal		35
Shale	8	
Sandstone, to creek bed	21	

Three miles above the mouth of Beaver creek, in the SW. ¼ of sec. 2, T. 144 N., R. 103 W., there are several cut banks along the stream where the beds are well shown, as in the following section:

	Feet	Inches
Sandstone and shale to top of bluff	35	
Coal		20-24
Shale	18	6
Shale, brown, carbonaceous		3
Shale and sand	32	6
Bed L: Coal	4	8
Shale	4	8
Bed K: Coal	3	4
Shale, passing into sandstone above	5	2
Coal		15
Shale, blue	6	6
Shale, black, carbonaceous		10
Coal		8
Shale, sandy	8	
Coal		8
Sandstone	15	6
Bed J: Coal	3	5
Clay, to creek bed	1-2	

Beds K and L undoubtedly represent the single thick upper coal bed appearing on the creek two miles below and also at many points in the bluffs of the Little Missouri. The three thick coal beds of the above section also outcrop about one mile to the southwest, near

the south line of section 10, where the lower coal (J) has a thickness of 4 feet. The exposure of the beds in a bluff on the creek near the north line of sec. 22, T. 144 N., R. 103 W. ,is as follows:

	Feet	Inches
Sandstone, massive	65	
Bed L: Coal	2	3
Clay	1	6
Bed K: Coal	2	4
Clay, blue	3	2
Clay, black, carbonaceous		8-10
Coal		4
Sandstone, passing above into shale	7	2
Coal	1	6
Clay	8	
Coal		2
Clay	1	
Bed J: Coal	5	6
Clay		10
Coal		8
Clay, to creek level	1	

It will be noted that the lower coal bed (J) has thickened toward the south from 3 feet 5 inches in sec. 2 to 5½ feet two miles distant. It does not outcrop on Beaver creek above this point but passes below the bottom of the valley, the rise of the surface carrying it above the horizon of this bed. On the other hand, the beds K and L have become thinner toward the south and the thinning of the intervening clay has brought them closer together.

The section of the strata in the high bluff near the south line of sec. 22 shows a succession of beds quite different from anything seen below this point on Beaver creek. It is as follows:

	Feet	Inches
Coal	1	8
Sandstone	10	
Clay black and carbonaceous, below sandy above	5	
Coal		3
Clay, carbonaceous at bottom	2	
Coal		8
Sandstone, stained with iron, with some shale	20	4
Coal	2	
Shale	7	
Coal	1	3
Clay	2	6
Coal, impure, clayey	1	8
Shale, sandy	18	8
Bed M: Coal	4	
Clay	4	3
Coal, impure		2

	Feet	Inches
Shale, sandy, carbonaceous layer 4 inches thick near middle	8	
Coal	2	10
Clay	4	6
Coal	2	4
Sandstone and shale	9	6
Coal	1	6
Sandstone and shale	17	4
Bed K-L: Coal	4	4
Clay		6
Coal		6
Clay, sandy	2	3
Coal		10
Clay and sandstone	6	
Coal		8
Clay and sandstone, to creek level	16	

It will be noted in the above section that there are 15 coal beds outcropping in this bluff and 10 of them appear in the accompanying picture. (Plate V., Fig. 2.) There are only two, however, beds K-L and M, which are of workable thickness. Of these two, the lower is believed to represent the beds K and L, it having been found that in places these approach each other and even unite to form a single bed. The upper of the two thick beds corresponds in position to the uppermost of the Medora group and is probably to be correlated with coal bed M. The two thick beds shown in the above section and the three thinner ones between them outcrop above here at frequent intervals for a distance of about 6 miles in the bluffs bordering Beaver creek.

They are well shown in the SE. ¼ of sec. 32, T. 144 N., R. 103 W., where the following beds occur:

	Feet	Inches
Sandstone	4	3
Coal	1	3
Shale and sandstone	14	
Coal		4
Sandstone, argillaceous	6	
Clay, black, carbonaceous		4
Clay	5	6
Coal		8
Clay, sandy	5	
Bed M: Coal	5	2
Sandstone and shale	16	
Coal	1	4
Sandstone and a little shale	21	
Coal	2	
Sandstone	5	10
Coal	2	
Shale	6	
Coal		2
Shale	9	
Bed K-L: Coal, base at creek level	5	8

The lower coal bed (K-L) outcrops on the creek in the northwest corner of sec. 6, T. 143 N., R. 103 W., where the base of the coal is below the bed of the creek, but it is not exposed above this point, since the coal passes below the bottom of the valley. But the uppermost member of the Medora group (M) is seen in the bluffs bordering the valley of Beaver creek as far as the McQuillon ranch, in sec. 20, T. 143 N., R. 104 W. It will be mentioned again in connection with sections showing the coal beds of the Beaver Creek group.

In the valley of Elk creek, a tributary of Beaver which enters it from the south in the SW. ¼ of sec. 11, T. 143 N., R. 104 W., only one workable coal bed is exposed. This is probably the one that appears 50 feet above creek level at the junction of Beaver and Elk creeks, and in that case is the upper member of the Medora group, or bed M. It outcrops in the NW. ¼ of sec. 1. T. 142 N., R. 104 W., where the following section occurs:

	Feet	Inches
Sandstone, massive, to top of bluff	20	
Coal		8
Clay, blue		8
Bed M: Coal	4	6
Clay		6
Coal		4
Sandstone and shale, above creek bed	25	

Where the coal bed M outcrops in the NW. ¼ of sec. 14, T. 142 N., R. 104 W., it is 6 feet thick and one mile west it measures 5 feet 10 inches. It is this bed which is mined in the NW. ¼ of sec. 21, T. 142 N., R. 104 W. The base of the coal does not show here, but it is at least 5 feet thick. The mine is in the bottom of the valley of Elk creek and the coal is obtained by stripping off the cover, which is here only a few feet thick.

On Wannigan creek, in sec. 34, T. 142, R. 103 W., a bed of coal 3 feet 9 inches thick is exposed. This is probably bed M.

The upper coal bed of the Medora group, M, also outcrops on Andrews creek at several points between two and three miles east of Sentinel Butte. In the SW. ¼ of sec. 21, T. 140 N., R. 104 W., the section is as follows:

	Feet	Inches
Sandstone, soft, yellowish	20	
Coal	5	2
Clay	5	6
Coal	1	
Clay	5	6
Coal	1	6

The coal is mined here on a small scale during the winter for local use. A little over one mile below here, in the SE. ¼ of sec. 22 T. 140 N., R. 104 W., there is another exposure of the same bed as follows:

	Feet	Inches
Clay	6	
Coal	1	6
Clay, bituminous		4
Coal	5	

Summarizing the data of the foregoing sections it is seen that the two middle beds of the Medora group, K and L, are 45 feet apart near the Custer Trail ranch, and the lower of the two is about 100 feet above the Little Missouri. They dip to the north and are carried below river bed level a few miles beyond the old Burgess ranch. They also approach each other in the same direction, being 35 feet apart at Medora and only 8 feet apart opposite the mouth of Jewell creek. Then for nearly 10 miles these coal beds are below the river and do not reappear until near the mouth of Ash creek. The three beds exposed here are believed to represent K and L, and the thick upper coal bed occurring in the river bluffs between Ash creek and the northern boundary of Billings county, sometimes split into several by clay seams and sometimes forming a single bed with no partings, is undoubtedly the same horizon. Near the mouth of Roosevelt creek a lower coal bed, J, appears and continues above river level to the mouth of Beaver creek and beyond.

It will thus be seen that from near the Custer Trail ranch to the northern limits of the area two workable coal beds of the Medora group are present in the bluffs bordering the Little Missouri, the only place where they are below water level being the 10 miles between Jewell and Ash creeks.

All four members of the Medora group occur on Beaver creek, but they disappear successively below the bottom of the valley, bed K and L near the south line of T. 144 N., R. 103 W., and bed M continuing to within 6 miles of the Montana line. The latter coal bed also appears on Elk creek as far up as the old Wilson ranch.

BEAVER CREEK GROUP OF COAL BEDS

The coal beds of this group are exposed in the northwestern corner of Billings county, along the valley of Beaver creek and its tributaries. They lie above the beds of the Medora group and the uppermost

member is about 100 feet below the Sentinel Butte group. No workable beds of coal at this horizon were found elsewhere in the area under discussion. (See Plate IV.)

In following up the valley of Beaver creek the lowest member of the group, N, first appears in the NE. ¼ of sec. 2, T. 143 N., R. 104 W., where the following succession of strata is exposed:

	Feet	Inches
Bed N: Coal	5	
Shale and sandstone	42	
Bed M: Coal	2	9
Shale	8	
Coal		13
Shale	10	
Sandstone, to creek bed	31	

The bed M is without question the upper of the two workable beds exposed on the creek for many miles below, since it was traced almost continuously by its outcrop or the burned clay bed formed by its burning. The 5-foot bed of the above section therefore lies over 40 feet above the uppermost coal of the Medora group.

The beds M and N of the above section are seen at many points in the bluffs bordering the valley between this section and the mouth of Elk creek. At the junction of Elk and Beaver creeks the following section is well shown, in sec. 11, T. 143 N., R. 104 W.:

	Feet	Inches
Shale and sandstone, to top of bluff		
Bed N: Coal	3	
Bed N: Clay	2	
Bed N: Coal	1	6
Shale and sandstone, not well exposed	42	
Bed M: Coal	3	6
Bed M: Clay	3	
Bed M: Coal	2	
Shale and sandstone	30	
Coal	3	10
Shale, to creek bed	16	

Bed N has burned out extensively and the clinker layer formed by it shows in many places along the valley. The bed 16 feet above the base of the section appears to be one which is not exposed elsewhere, unless it be the same coal which outcrops about 5 miles above.

On Beaver creek about 3 miles above the mouth of Elk creek, the following section is exposed in the northwest corner of sec. 21, T. 143 N., R. 104 W.:

	Feet	Inches
Bed O: Coal	6	6
Shale and sandstone	14	
Bed N: Coal	2	4
Shale	7	
Coal	2	2
Unexposed	46	
Bed M: Coal	4	
Unexposed, to creek	50	

It will be noticed in the above section that a workable bed, O, is here present above coal N, and for 8 or 10 miles below the old McQuillon ranch this has a uniform thickness of 6½ feet and is the thickest bed appearing in the bluffs of Beaver Creek valley. It is the middle bed, O, of the Beaver Creek group.

A little over a mile west of the above section the following beds appear in a steep bluff rising from the creek, in the NE. ¼ of sec. 19, T. 143 N., R. 104 W.:

	Feet	Inches
Sandstone to top of bluff	12	
Bed O: Coal, with 3-inch clay seam 18 inches above base	6	6
Shale and sandstone	15	6
Coal	2	
Shale	10	6
Bed N: Coal		20
Bed N: Clay	3	10
Bed N: Coal	2	2
Shale and sandstone	37	
Bed M: Coal	3	8
Shale and sandstone	21	
Coal	2	10
Unexposed, to creek bed	14	

The lowest bed in the above section is probably the same as the lower one exposed at the mouth of Elk creek.

About 4 miles above the last section, in the NE. ¼ of sec. 26, T. 143 N., R. 105 W., the coal bed O is again exposed, the outcrop here being as follows:

	Feet	Inches
Bed O: Coal	6	6
Shale and sandstone	37	
Coal	3	
Shale	8	
Coal		26
Shale	4	
Coal, with 2-inch clay seam near top		29
Unexposed, to creek	44	

The most westerly outcrop visited on Beaver creek was in the NW. ¼ of sec. 34, T. 143 N., R. 105 W., three miles from the Montana line. In a steep bluff the following section is exposed here:

	Feet	Inches
Sandstone and shale to top of bluff	20	
Bed O: Coal	6	6
Sandstone and shale	22	
Coal	3	
Sandstone	10	
Coal	2	6
Shale and sandstone	36	
Coal	4	
Sandstone, exposed above creek	40	

Four beds of coal are exposed in the sides of the valley of the tributary of Beaver creek which flows through T. 142 N., R. 105 W. The thickest of these is the 6½-foot coal bed O, and 65 feet above is the upper bed of the Beaver Creek group, bed P., which has a thickness of 4 feet.

It will be seen from the foregoing sections that the Beaver Creek group includes three coal beds. The lower, N, is exposed along the creek in T. 143 N., R. 104 W., and has a maximum thickness of 5 feet in section 2. Above here it is separated by a clay seam into two coal beds. The middle bed, O, has a uniform thickness of 6½ feet and lies about 15 feet above N, outcropping along the creek from the old McQuillon ranch in sec. 20, T. 143 N., R. 104 W., almost if not quite to the Montana line. The upper bed, P, has a thickness of 4 feet and was only seen at one point several miles south of Beaver creek.

The three coal beds occurring below bed O, above the old McQuillon ranch, are so variable and unlike those farther down the creek that they cannot be correlated with any certainty with those found elsewhere.

The beds of this group undoubtedly extend back from Beaver creek for some miles to the north and south and should be struck in boring wells or in prospect holes.

Two beds of workable thickness are present on Little Beaver creek, in T. 141 N., R. 105 W. One of these disappears below the level of the creek about one-half mile east of the Montana line, where it is 6 feet thick.

The coal bed mined in the NW ¼ of sec. 8, T. 141 N., R. 105 W., shows the following section:

	Feet	Inches
Coal	6	6
Shale, sandy	8	
Coal	3	

The same bed is mined in the NW. ¼ of sec. 16, T. 141 N., R. 105 W., where the following section appears:

	Feet	Inches
Coal	2	2
Clay		6
Coal		5
Clay		6
Coal	5	6

SENTINEL BUTTE GROUP OF COAL BEDS

The coal beds of this group are the highest in the region and are thus named from the fact that at least three of the members are present in Sentinel Butte. Five coal beds are included in this division and they have a vertical range of about 300 feet. The upper four beds are in the dark strata forming the upper portion of the Fort Union, while the lowest member lies forty to fifty feet below the base of the dark strata. The coal beds of the Sentinel Butte group extend from Bullion Butte and the divide between Third and Bear creeks on the south to the divide north of Ash creek on the north, a distance of 35 miles; they extend from Sentinel Butte on the west to the divide near Fryburg on the east, a distance of 25 miles, and how much farther east they occur was not determined. These coal beds have been extensively eroded over wide areas and they have also burned out on a very large scale. The bed R can be readily traced by its red clinker horizon in the bluffs and ridges of the Little Missouri badlands as far as the eye can see. (See Plate IV.)

The outcrops of the Sentinel Butte group south of the Northern Pacific railroad will first be discussed and later those north of the track will be considered.

Three of the coal beds of this group occur in Bullion Butte, that portion of the section containing them being as follows:

	Feet	Inches
Bed S: Coal	3	3
Shale, sandy, dark gray, contains near base many ferruginous nodules	50	
Bed R: Coal, at contact of upper and lower divisions of Fort Union	15	
Shale and sandstone	40	
Bed Q: Coal, at elevation of about 360 feet above river	5	

Coal bed R outcrops in the SE. ¼ of sec. 12, T. 137 N., R. 103 W., near the north end of the butte, and it is also exposed near the south end in secs. 29 and 30 of T. 137 N., R. 102 W. In this latter

locality the coal measures 6½ feet thick and contains a 3-inch clay seam 2 feet above the bottom. This thick coal bed undoubtedly underlies the entire butte.

About 4 miles southeast of Bullion Butte two very conspicuous elevations rise above the nearly vertical bluff of the Little Missouri and in these Teepee Buttes, as they are called, 3 high coal beds of the Sentinel Butte group occur. They are shown in the following section:

	Feet	Inches
Sandstone and shale to top of Teepee Buttes	52	
Bed T: Coal	4	6
Shale and sandstone	95	
Bed S: Coal	6	3
Shale and sandstone	25	
Bed R: Coal, with 2-inch clay seam two feet above bottom. Bed 400 feet above river	5	2

The lowest coal bed, Q, of this group occurs in the high divide west of Bullion Butte, between Bullion creek and the river, which here has an easterly course. This coal is about 50 feet below the coal bed R. It lies at an elevation of about 320 feet above the river and has a thickness of 10 feet. It is exposed in the SE. ¼ of sec. 28, T. 137 N., R. 103 W., and at other points in the divide. No measurement was secured on this divide of the coal bed R, as it has burned out over a large area and its outcrop is marked by a thick layer of clinker.

The beds of the Sentinel Butte group are known to extend at least 8 miles east of the Little Missouri and probably continue conciderably farther in that direction. The beds Q and R occur in the higher ridges and divides between Third and Bear creeks, in T. 137 N., R. 101 W. The coal R near the center of this township is 9 feet thick and the lower bed, Q, is here only 15 feet below and is 5½ feet thick. The former bed, R, was traced by its clinker horizon several miles east of the above township, or as far as the divide between the drainage of the Little Missouri and Missouri rivers.

The lower bed, Q, is exposed on Bear creek in the SE. ¼ of sec. 36, T. 138 N., R. 102 W., where it measures 4 feet 4 inches in thickness and lies just above creek level. The bed R outcrops for some distance along the creek 3 miles above here, near the southwest corner of sec. 34, T. 138 N., R. 101 W. The section of the coal bed is as follows:

	Feet	Inches
Coal	6	2
Clay		14
Coal		20

This is one of the few places where this bed of coal contains a clay seam, and it is generally free from clay partings. Mr. Schuyler Lebo, who has a detailed and accurate knowledge of township 138, ranges 101 and 102, states that coal bed R outcrops in the following sections: 12, 14, 26 of T. 138 N., R. 102 W., and in 8, 10, 21 of T. 138 N., R. 101 W. This thick bed of coal underlies practically all of the latter township, except where it has been cut out by the streams. A measurement of this same bed was secured in the SE. ¼ of sec. 23, T. 139 N., R. 102 W., where the coal is exposed near the top of the bluff at an elevation of 280 feet above the river. It here has a thickness of 17 feet and is overlain by 15 to 20 feet of clay.

Along the valley of Sully creek the bed R has burned out extensively and along either side of the valley its horizon is marked by a thick layer of clinker which forms a very conspicuous scenic feature of this region. This bed of coal disappears below the bottom of the valley about one-half mile east of Sully Springs. The burnt clay so abundant along the Northern Pacific railroad in the vicinity of Scoria was largely formed by the burning of this coal, although there is a higher bed which has formed some clinker. The so-called "burning mine," about one-half mile south of Sully Springs, is in this same coal bed, which has been burning for many years. The only place on Sully creek where an outcrop of the coal R was found was in the west half of sec. 14, about one mile from the above station; the upper part of the coal is here burned and has also been eroded, so that the full thickness could not be obtained, but 7 feet of coal remain. Layers of clinker indicate that there are in this vicinity two coal beds above this one. One is 150 feet and the other 240 feet above the bed R, and it is quite likely that they are to be correlated with the two higher coal beds occurring in Sentinel Butte, at the same relative distances above the coal R. No outcrops were found on Sully creek where the thickness of these upper coal beds could be measured.

West of the Little Missouri river two members of the Sentinel Butte group are present in the base of Square Butte. The lower of the two, R, is 5 feet thick, and 25 feet above, separated by sandy

shale, is the upper bed, S, with a thickness of 15 feet. This latter bed is exposed in the NE. ¼ of sec. 9, T. 139 N., R. 103 W. East of the river this upper thick bed does not occur on Sully creek or to the south of that stream.

Between Flat Top and Sentinel buttes there is a conspicuous clinker layer formed by the burning of coal bed S. About midway between the two buttes the lower bed, R, outcrops, with a thickness of 5 feet, and lies 50 feet below the clinker layer.

In Sentinel Butte the three upper members of this group are present. The lower of them outcrops at several points toward the bottom where it has been mined in the northeastern base, in SE. ¼ of sec. 5, T. 139 N., R. 104 W., and the section of the bed S is as follows:

	Feet	Inches
Clay, sandy		
Coal	14	
Clay		3
Coal	6	11

The following mines south of Sentinel Butte are in bed S: Sentinel Butte mine in sec. 5, and the Grimm mine in sec. 8, both in T. 139 N., R. 104 W. Coal has also been mined on the south side of the butte, in secs. 22 and 25 of the same township.

This same bed has been mined in the NW. ¼ of sec. 7, where it is 20 feet 11 inches thick. It has also been mined in the SW. ¼ of sec. 5, and on the west side of the butte. Ninety feet above this thick one is a 6-foot bed of coal. The highest member is known to occur by its clinker and no exposure was seen.

A few small areas underlain by beds R and S occur in the southeastern corner of T. 139 N., R. 105 W., where they have escaped the erosion which has removed them from much of the region. Near the center of sec. 25 coal has been mined by stripping, the section here being as follows:

	Feet	Inches
Clay, white		
Coal	8	
Clay		10
Coal, base not exposed	7	

This bed also occurs in the base of Rocky Butte, in sec. 34, but it is concealed by clinker so that its thickness could not be determined.

The bed S is present in the base of Camels Hump Butte, in secs. 9 and 10, T. 140 N., R. 104 W., but the coal has burned out along

its outcrop and is concealed by clinker, so that no exposure could be found.

In the divide north of Andrews creek, the two beds R and S of the Sentinel Butte group occur. Near the western edge of T. 140 N., R. 103 W., they are separated by 55 feet of the dark gray strata of the upper division and each measures 5½ feet in thickness. Both the beds are extensively burned.

In sec. 35 of T. 141 N., R. 102 W., bed R outcrops at an elevation of 250 feet above the Little Missouri river, but only the upper 6½ feet of coal is exposed to view.

The same coal bed, R, underlies the irregular plateau in secs. 8, 9, 10, 16, and 17, T. 140 N., R. 102 W., at an elevation of about 275 feet above the Little Missouri river. Its outcrop is nearly everywhere concealed by clinker so that its thickness could not be determined.

In the divide between Government and Franks creeks, in T. 141 N., R. 101 W., the bed R occurs at the contact of the dark-colored strata with the buff and light gray beds below. It lies from 250 to 300 feet above the Little Missouri river and is found in the buttes which rise above the general level of the divide. In the SW. ¼ of sec. 5 the coal is 11 feet 6 inches thick, with a 3-inch clay parting 6 inches from the bottom. In the SE. ¼ of sec. 12 that portion of the bed which is exposed measures 16 feet and the entire thickness is probably not much more than this. The bed R is also found in the divide between Franks and Ash creeks, though it is not well exposed in that area, but north of Ash creek the coal grows thin and partings develop in the bed. Thus in the NE. ¼ of sec. 4, T. 142 N., R. 101 W., the section of this bed is as follows:

	Feet	Inches
Coal	1	3
Clay	7	
Coal	3	

Three workable coal beds are exposed in the valley of Ash creek, in the eastern part of T. 142 N., R. 101 W. The lowest is bed R and is at the contact of the light and dark colored divisions of the Fort Union. The following section of this bed appears in the N. ½ of sec. 14, T. 142 N., R. 101 W.:

	Feet	Inches
Shale		
Bed R: Coal	6	8
Bed R: Clay, gray		14
Bed R: Coal	1	4
Shale, exposed above creek	3	

A short distance below this outcrop, and in the same section, all three of the coal beds occur in the steep bluff bordering the valley of Ash creek, the section here being as follows:

	Feet
Coal	5
Sandstone	40
Bed S: Coal	4-5
Shale and sandstone	35
Bed R: Coal	6
Shale and sandstone, to creek bed	20

The upper coal bed does not correspond in position to any bed found elsewhere and is probably of limited extent. The upper two beds also appear in the NE. ¼ of sec. 13, T. 142 N., R. 101 W., where S is 6 feet thick and has been mined on a small scale at the outcrop. The upper bed here measures 5 feet.

Bed S is well exposed just above creek level in the NE. ¼ of sec. 20, T. 142 N., R. 100 W., the section being as follows:

	Feet	Inches
Clay wash	2-20	
Bed S: Coal		6
Bed S: Clay		3
Bed S: Coal	6	
Clay, blue, exposed to creek bed	3	

Considerable coal has been mined here from the outcrop by the farmers of the vicinity, although the locality is not very accessible, being in the bottom of the valley of Ash creek and about 275 feet below the level of the upland.

Coal bed R, of the Sentinel Butte group, is known from its outcrops in the bluffs of the Little Missouri river and in the badlands on either side of the valley to cover a large area and to be one of the most extensive coal beds in the state. It ranges in thickness from 5 to 17 feet, and is known to extend from the bluffs of the Little Missouri river near the mouth of Deep creek, in northern Slope county, north several miles beyond Ash creek, a distance of 37 miles. It extends from the head of Sully creek on the east to Sentinel Butte on the west, or a distance of 24 miles. This coal bed thus covered an area of at least 900 square miles as shown by its outcrops, and its areal extent was probably considerably more than this.

Very few coal outcrops occur on Green river, in northeastern Billings county. In the southern part of T. 142 N., R. 99 W., there is considerable clinker formed by the burning of a coal bed which is perhaps the same as that mined on a small scale near the base of Saddle

Butte. No measurement could be secured of this bed since it is everywhere concealed. A workable coal bed is exposed on Green river in the NE. ¼ of sec. 16, T. 141 N., R. 98 W., where it has a thickness of 4 feet 4 inches, and a few loads of coal have been taken from the outcrop here.

Two coal beds appear along the upper course of the Knife river in the northeastern corner of Billings county. Their presence is indicated chiefly by clinker along their outcrop in the sides of the valley, but they are exposed in Hungry Man's Butte, in the SE. ¼ of sec. 35, T. 144 N., R. 98 W. The lower bed is 3 feet thick and lies 120 feet above the river; the upper bed is 40 feet above and has a thickness of 2½ feet. Both beds are in the upper, dark colored division of the Fort Union.

COAL IN THE VICINITY OF RAINY BUTTES

In East Rainy Butte a bed with a thickness of at least 6 feet occurs 100 feet above the base. This does not represent the entire thickness of the coal, which is partially concealed, and the measurement given above is only for the portion exposed. It is very probable that the same coal bed is also present in West Rainy Butte. It is doubtless to be correlated with one of the lower members of the Sentinel Butte group.

Six or seven miles north of the Rainy Buttes, on the Cannonball river, and at a considerably lower elevation, two workable beds of coal occur. They are exposed not far from the east line of Billings county, where the following section appears:

	Feet
Alluvium	4
Sandstone	5
Clay	2
Coal	4
Clay	4
Coal	5
Clay, to water level	5

BOWMAN AND SLOPE COUNTIES

A. G. LEONARD

These two counties are considered together since several of the coal beds of the region underlie portions of both and extend from one county into the other. In the Little Missouri badlands of western Slope county the conditions are particularly favorable for the study of the lignite beds, since they outcrop in many places in the bluffs of

the river and its tributaries. Ten coal beds over 4 feet thick are known to be present in western Slope county. In addition to these two thick coal beds occur in eastern Bowman and Slope counties. Two of these twelve beds of coal are the thickest in the state, one having a maximum thickness of 38 feet, and the other of 35 feet. A third bed is 28 feet thick, and another 20 feet. These counties in the southwestern corner of North Dakota probably contain the most extensive coal deposits of the entire state, so far as the number of thick beds and their aggregate thickness is concerned. The area underlain by several of the beds is crossed by the Chicago, Milwaukee and St. Paul railroad, while many of them lie some distance north of the railroad in Slope county.

The coal deposits of Bowman county will be described first.

SCRANTON COAL BED

One of the important beds of coal in Bowman county is the one mined at Scranton, and it will therefore be called the Scranton coal bed. The most easterly point where this bed has been mined is in sec. 19, T. 130 N., R. 97 W., about 5 miles southeast of Reeder, in Adams county. It is exposed in places almost as far west and north as Buffalo Springs, and it is probably this same bed which is struck in wells several miles west of Bowman, though it lies at considerable depth below the surface in that region. The coal of this bed has been mined at a number of places in the vicinity of Reeder and Scranton and it doubtless underlies several townships in northeastern Bowman and western Adams counties.

The Hjort mine is located in the SW. ¼, sec. 10, T. 130 N., R. 98 W., about one mile southeast of Reeder. (See analysis No. 5517.) A slope leads down to the coal bed, which is 40 feet below the railroad at Reeder, or 2766 feet above sea level. The seam is 7 to 9 feet thick, with an average of 8 feet. This mine supplies a large portion of the lignite used in Reeder, and a little coal is shipped. Another mine has been opened not far from the center of sec. 15 of this same township, about one mile southeast of the Hjort mine. The coal bed is here 7 to 8 feet thick, with a 6-inch clay parting 2 to 3 feet above the bottom.

The Powell mine, which has been worked many years, is located near the center of sec. 13, T. 130 N., R. 98 W. The mine is on the side of a shallow valley and is worked by stripping off the overlying shale and soft sandstone. The bed is 8 feet thick.

The Ladson mine is the most easterly mine in the Scranton coal bed. It is in the southwest corner of sec. 19, T. 130 N., R. 97 W., and the coal is mined by stripping off the overburden. How much farther east this bed extends could not be determined in the absence of outcrops or clinker, but it is not unlikely that it continues in this direction for some miles. It is not believed to extend far south of sec. 19, since the surface is low and the bed has doubtless been eroded by Buffalo creek and its tributaries.

The Leff mine is located near the east line of sec. 10, T. 130 N., R. 98 W., and a large area has been stripped during the many years that coal has been mined here. The coal bed is 6 to 8 feet thick and is overlain by 6 to 12 feet of shale and soft sandstone. Sections 11 and 12 of this township are doubtless underlain by this coal bed. In sec. 11 the railroad passes through a depression and in this the coal should not lie over 30 to 40 feet below the railroad. This coal also underlies large portions of sections 13, 14, and 15, north of the low area formed by the tributaries of Buffalo creek. North of the railroad it is very likely that the Scranton coal bed is present in the northern tier of sections of T. 130 N., R. 98 W., and it probably extends considerably farther in this direction but under a thick cover.

The Minnehaha or Jepson mine is on the line between sections 5 and 6, T. 130 N., R. 98 W., about two miles northwest of Reeder. A considerable area has been stripped here, the cover ranging from 6 to 8 feet. The coal bed has a thickness of 7½ to 9 feet, and lies 20 to 40 feet below the railroad at Reeder. A small opening has also been made on this bed of coal about 1¾ miles west of the Jepson mine, in the NW. ¼ of sec. 1, T. 130 N., R. 99 W. Six feet of coal show in the mine but this does not appear to be the full thickness.

Several wells south of Reeder, in sec. 9, are reported to pass through two coal beds, separated by a clay parting. The upper bed, which has a thickness of 8 feet, lies 20 to 40 feet below the surface, and the lower bed is 12 feet thick. It is the upper of these two beds which is mined in the vicinity of Reeder. As will be shown later, two beds of coal are also found at Scranton, and they are doubtless the same as those occurring about Reeder.

The Scranton coal bed has been mined in small strip pits in the NW. ¼ of sec. 34, T. 131 N., R. 99 W., and in the southern part of sec. 27 of the same township. The lower coal bed is also reported as being present here. Clinker formed by the burning of the Scranton coal bed is found in the vicinity of Gascoyne, and in railroad cuts

between that town and Scranton. The coal of this bed is mined beside the road in the SW. corner of sec. 20, T. 131 N., R. 99 W., and also one-half mile south in sec. 29. In these sections the bed has a thickness of 12 feet and over.

Two drill holes put down on the south side of the valley at Scranton, in secs. 25 and 36, T. 131 N., R. 100 W., show that there are two coal beds here as at Reeder. The records of these holes are as follows:

Record of drill hole in the SW. ¼ of sec. 25, T. 131 N., R. 100 W.:

	Feet
Shale	18
Coal	20
Clay	5
Coal—did not get through this on account of broken augur, but at least	8

Record of drill hole in NE. ¼ of sec. 36, T. 131 N., R. 100 W.:

	Feet
Shale	16
Coal	21
Shale	4
Coal	15

The largest mine in this region is that of the Johnson Fuel Company at Scranton which has mined the upper or Sranton coal bed both by stripping and by slope. (See Plate VI, Fig. 1.) In the open pit one steam shovel was used to strip off the overburden, and another to load the coal into the cars. Two test holes at the mine showed that the upper coal seam is 20 feet thick and the lower 12 feet. The distance between the two varies from 5 to 11 feet. The depth to the coal under the hill north of the plant, as shown by four test holes, varies from 56 to 67 feet, but in places the cover is only 5 to 20 feet. In the valley of Buffalo creek at the Chicago, Milwaukee and St. Paul station at Scranton the top of the coal lies at a depth of only 5 to 10 feet.

A thick bed of clinker in the southwest corner of sec. 35, T. 131 N., R. 100 W., two miles south of Scranton, is perhaps formed by the burning of the upper or Scranton coal bed, though it is higher here than farther north. How far north of town this coal seam extends could not be determined, since it lies at a depth of 50 to 100 feet and more below the surface, but it doubtless extends many miles in this direction.

Going northwest from Scranton the next outcrop of this thick coal bed is found in the NW. ¼ of sec. 16, T. 131 N., R. 100 W., on the side of a valley of a short tributary of Buffalo creek. The coal has here been mined by stripping. Near Buffalo Springs the water of a number of springs doubtless comes from this same coal seam, which probably does not lie far below the surface. The clinker from this coal bed is found in the NW. ¼ of sec. 33, T. 131 N., R. 100 W., and is also seen in a railroad cut one mile west of Scranton.

No outcrops of the Scranton coal bed are found west of the mine in the NW. ¼ of sec. 16, T. 131 N., R. 100 W. This bed seems to have been eroded in the broad flat-bottomed valley of Buffalo creek, since several wells failed to pass through coal in this part of the valley. Farther to the north and west, however, a coal bed at about the horizon of the Scranton bed has been struck in several wells, and is mined in the SW. ¼ of sec. 14, T. 132 N., R. 101 W. In the SW. ¼ of sec. 23, of the same township, a bed of coal was reached at a depth of 50 feet, but the well did not go into the coal, and another well near the south line of sec. 28 also struck coal at the same depth, but the thickness of the bed was not determined in either of these wells, since they did not go through the coal. A well several miles northwest of Bowman is also reported to have reached a coal bed at about the same horizon, so that the Scranton bed probably extends at least a few miles west of Bowman. How much farther it may continue in that direction is not known. The Scranton coal bed lies 200 feet below the thick upper bed mined several miles north of Bowman, and known as the Bowman coal bed, which is described below. (See Fig. 7.)

BOWMAN COAL BED

Since one of the few places where this coal bed is mined is 5 miles north of Bowman, it has been named the Bowman coal bed. It lies so near the surface that it has either burned out over much of the area formerly covered by it, or has been removed by erosion, so that only a comparatively small portion of the coal bed is left. Its probable former extent can, however, be determined by the clinker, or "scoria" as it is commonly called, formed by the burning of the coal bed, and in part by outcrops of the coal itself, or from well records. It reached from the eastern edge of T. 132 N., R. 101 W., about 7 miles northeast of Bowman, west at least as far as Rhame, or a distance of 20 miles, and its north and south extent was 30 miles or over. The Bowman bed thus originally covered an area of approximately 500 square miles. It varies in thickness from 8 to 38 feet, and probably averages 20 feet. West of Bowman it has a marked dip toward the north and east.

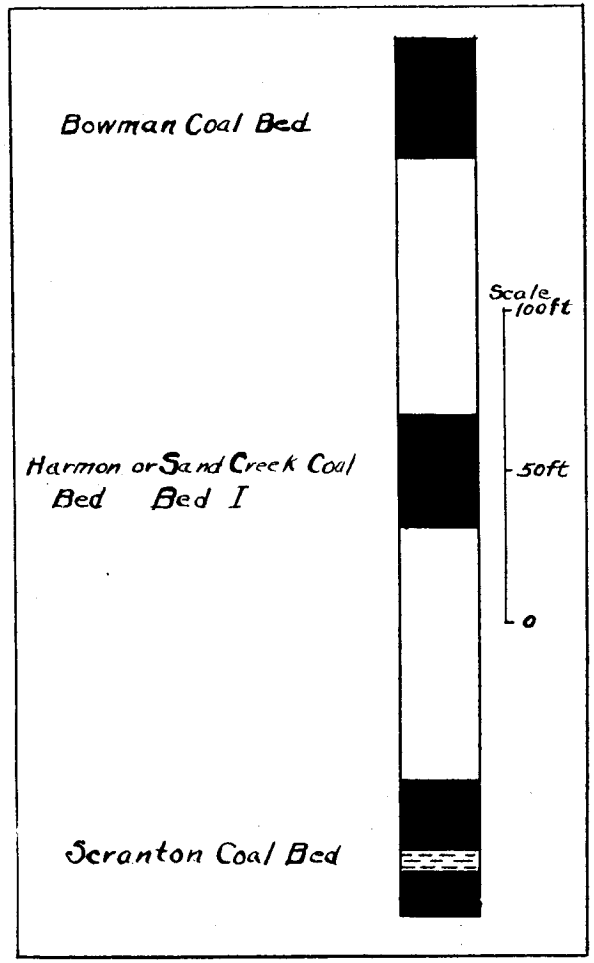


Fig. 7. Vertical section showing the relation of the three thick coal beds in Bowman and Slope counties. The Bowman and Harmon coal beds each have thickness of 35 feet. The Scranton coal bed is 20 feet thick, with a 12-foot coal bed 5 to 11 feet below it.

The Bowman coal bed is mined 5 miles north of Bowman, in the SW. ¼ of sec. 14, T. 132 N., R. 102 W., and at the Halleck mine in the S. ½ of sec. 15 of the same township. (See analysis No. 5518.) The coal is here 30 to 38 feet thick, and the bed contains no clay seams, the lignite being of good quality from top to bottom. The cover above the coal varies from 12 feet and less to over 25 feet. This Bowman bed probably underlies much of secs. 1, 2, 11, 12, 13, 14, and 15, T. 132 N., R. 102 W., and a number of sections in T. 132 N., R. 101 W. It is believed to be this same coal bed which is mined 2 miles south of Amidon, in which case the Bowman coal bed doubtless underlies a number of townships in southeastern Slope county, though it would lie at a considerable depth below the surface in many places.

By means of the thick layer of clinker from the burning coal the Bowman bed was traced southeast from the Halleck mine into sec. 33, T. 132 N., R. 101 W., and there are evidences of it as far east as sec. 26, of the same township. Beyond this point it appears to have been removed by erosion, since the surface is below the horizon of the coal bed.

The clinker from the burning of the Bowman bed appears near the base of the Twin Buttes, just north of Bowman, and the coal doubtless underlies these buttes, since it is not likely that the clinker extends back far from the outcrop. The coal bed should be found in the NE. ¼ of sec. 2, T. 131 N., R. 102 W., and the SE. ½ of sec. 35, T. 132 N., R. 102 W., extending also into the two sections lying just east of these. As near as could be determined it lies about 50 feet above the railroad at Bowman. It is doubtless the clinker from this same coal bed which appears in several places in Talbut Butte, in secs. 18 and 19, T. 131 N., R. 101 W., at an elevation of about 70 feet above the railroad. Except in Twin and Talbut buttes the Bowman coal bed has been removed by erosion in the immediate vicinity of Bowman, and west of town it has either been burned out or eroded.

The thick layer of clinker which caps the buttes between Bowman and Griffin, and between the latter station and Rhame is evidence that the Bowman coal bed formerly extended west at least to within 8 or 10 miles of the Little Missouri river. Post Office Butte, one mile northwest of Rhame, and the other buttes near the town, are all capped by this thick clinker layer. The heat of the burning coal was so great that in many places the overlying clays were thoroughly

fused, and large masses of slag-like or lava-like material are found in great abundance.

This clinker is found in the high ridges four miles south of Griffin, in sec. 16, T. 131 N., R. 103 W., and a badly weathered coal bed is exposed in one place at the same elevation, so that it is quite likely that the Bowman coal bed underlies this high ridge.

In T. 132 N., R. 103 W., and in six or seven townships in Slope county which lie within the drainage basin of Deep creek there are many hundreds of buttes capped with the thick clinker layer produced by the burning of the Bowman coal bed. Perhaps in no other area of the same size in the entire state is there such a vast amount of clinker. The clinker from this particular coal bed is found as far north as the center of T. 135 N., R. 103 W., and T. 135 N., R. 102 W., extending south to the Chicago, Milwaukee and St. Paul railroad and from Black (H. T.) Butte west to the divide between Deep creek and the Little Missouri drainage. At only a few places within this area has the Bowman coal bed escaped burning and erosion. It is formed, however, in the above mentioned divide between Deep creek and the short westward-flowing tributaries of the Little Missouri. It is probably this coal bed which was struck in a well in the NW. ¼ of sec. 30, T. 134 N., R. 103 W., at a depth of 40 feet. The coal bed is reported to have a thickness of 30 feet, the well reaching the bottom of the coal at 70 feet below the surface. Near the north line of sec. 18, T. 134 N., R. 103 W., what is perhaps the same bed is mined, though the coal has here slumped down a little.

The Bowman coal bed is mined two miles south of Amidon, in secs. 1 and 2, T. 134 N., R. 101 W. The section of the beds exposed here is as follows:

	Feet	Inches
Clay	10-15	
Coal	2	8
Clay	2	
Coal, bottom not exposed, but thickness is at least	7	

The coal outcrops along the sides of the valleys formed by the tributaries of Sand creek, and it doubtless underlies the upland to the east and northeast, in T. 135 N., R. 100 W., where it should lie not far below the bottom of the shallow valleys of the branches of the Cannonball river.

Between the main valleys of Deep and Sand creeks the Bowman coal bed is known to have extended as far north as secs. 16 and 21,

T. 135 N., R. 102 W., since the clinker from the burning of this coal bed is found on the top of the high ridge in these sections. North of here the surface is below the level of this coal bed, the latter having been removed by erosion. It probably did not extend much farther north for no thick bed of coal occurs at this horizon in the bluffs of the Little Missouri, 8 to 10 miles north of this high ridge. The Bowman coal bed doubtless thins out and disappears not many miles north of the H. T. ranch and Amidon.

The 35-foot coal bed mined on Sand creek, in the NE. ¼ of sec. 31, T. 135 N., R. 101 W., lies 80 feet below the Bowman coal bed. (See Fig. 7.)

While the Bowman coal bed is the most important in Bowman county it is by no means the only one which is found in that area. Coal outcrops at various points along the North Fork of the Grand river in the southeastern part of the county. A bed is well exposed in the cut bank of the river two miles west of Haley, in sec. 27, T. 129 N., R. 100 W., the section here being as follows:

	Feet
Sandstone and sandy clay	25
Coal	6½
Sandstone, soft, exposed above river	4 to 6

A bed reported to have a thickness of 5 to 6 feet is also mined 4 miles above, in sec. 19 of the same township. Coal occurs on Spring creek, one of the chief tributaries of the North Fork of the Grand, and is exposed in sec. 3, T. 129 N., R. 101 W. A coal bed outcrops on Lightning creek between 4 and 5 miles north of Haley and has been mined in sec. 5, T. 129 N., R. 99 W. Coal is also found between Lightning and Buffalo creeks.

Four miles west of Rhame a thick bed of coal is exposed on Coyote creek, in sec. 30, T. 132 N., R. 104 W. Its thickness is over 12 feet, but since the bottom is not exposed the full thickness could not be determined. What is probably the same bed of coal outcrops 7 miles north on Bacon creek, at the old T. Cross ranch, in sec. 20, T. 133 N., R. 104 W. The coal here has a thickness of 28 feet above the creek bed and the total thickness is said to be 30 feet. This thick coal bed has been traced from T. 134 N., R. 105 W., to the west side of T. 129 N., R. 101 W.,[1] or a distance of about 40 miles. It lies 150 to 200 feet below the Bowman coal bed. No workable

[1]E. R. Lloyd and C. J. Hares, "The Cannonball Marine Member of the Lance Formation of North and South Dakota and its bearing on the Lance-Laramie Problem." Jour. Geol., Vol. XXIII, p. 540.

coal beds occur along the valley of the Little Missouri in western Bowman county, since the formations which are present in that area carry only thin seams of coal or none at all.

In sec. 4 and the NE. ¼ of sec. 8, T. 132 N., R. 102 W., and elsewhere in the vicinity a coal bed over 4 feet thick is mined. It lies some 35 feet or more below the Bowman coal bed, and at no place was the bottom exposed, so that the full thickness could not be determined.

WESTERN SLOPE COUNTY

For convenience of description the coal beds of western Slope county, together with those of Billings and Golden Valley counties, may be divided into groups, and these will be considered in the order of their occurrence from the lowest to the highest. There are five such groups, namely: (1) Williams Creek (Yule) group, (2) Great Bend group, (3) Medora group, (4) Beaver Creek group, and (5) Sentinel Butte group. (See Plate IV.) The older beds occur in northwestern Slope county, and for that reason our description will begin with that district.

WILLIAMS CREEK (YULE) GROUP OF COAL BEDS

The coal beds belonging to this group are found in the vicinity of old Yule Post Office, at the mouth of Williams creek, and are also exposed farther south on Bacon and Coyote creeks. All the beds included in this group occur in the Ludlow lignitic member of the Lance formation.

In following down the Little Missouri river from the southern boundary of the area no coal is found until two or three miles below the mouth of Cash creek. Here, in the SW. ¼ of sec. 34, T. 135 N., R. 105 W., a coal bed (A) 5 feet thick outcrops in the steep bluff of the river, 65 feet above water level. So far as known this is the lowest workable bed outcropping anywhere in the region. About two miles west of here the following section is exposed in some high buttes and ridges in the west half of sec. 32, T. 135 N., R. 105 W.:

	Feet	Inches
Clinker layer		
Shale and sandstone, mostly light gray and buff	85	
Coal, with 6-inch clay seam one foot below top	5	6
Shale and sandstone	25	
Coal	4	8
Shale and sandstone, to river	130	

The upper of the three coal beds represented in the above section has been largely burned out in this vicinity and no measurement of it could be secured. The lower bed may be the same that outcrops two miles east of here, but this was not definitely determined.

Three miles below the mouth of Cannonball creek, in sec. 16, T. 135 N., R. 105 W., no less than 7 workable coal beds are exposed on the west side of the Little Missouri river. The section here is as follows:

	Feet	Inches
Coal	4	8
Shale, with 8-inch coal seam	6	8
Coal	4	3
Shale and sandstone	75	
Bed F: Coal	8 to 9	
Shale and sandstone	40	
Bed E: Coal	3	
Shale and sandstone	20 to 30	
Bed D: Coal	2 to 4	
Shale and sandstone	12	
Bed C: Coal	8 to 10	
Shale and sandstone	10 to 20	
Bed B: Coal	6	
Shale and sandstone, to river level	50	

Coal bed B of the above section does not appear in the river bluffs below this point and probably dips below water level near here. The upper two coal beds were not seen elsewhere and are too high to appear in the bluffs bordering the valley of the Little Missouri. The four remaining coal beds exposed in the foregoing section, namely, beds C, D, E, and F, appear at a number of points along the river between sec. 16 and the mouth of Williams creek. Thus bed C, which in most places has a thickness of 10 feet, outcrops near water level in the SE. ¼ of sec. 15, the SW. ¼ of sec. 11, and the NE. ¼ of sec. 12, all these outcrops being on the east (or south) side of the river in T. 135 N., R. 105 W. Where exposed in sec. 12 the bottom of the coal is below water level and the dip of the beds carries this coal under the river, so that bed C is not exposed below this point. On the west side of the river, in the NE. ¼ of sec. 10, T. 135 N., R. 105 W., the same 10-foot coal bed (C) occurs at an elevation of 50 feet above the river and outcrops at various points for over a mile along the valley of Deer creek, which enters the river at this point. The coal in bed C is a good quality and contains no clay seams.

Beds D and E appear in the river bluffs almost continuously as far as the mouth of Bull Run creek, in sec. 36, T. 136 N., R. 105 W. Coal bed F. appears at several points where the bluffs are high enough

to reach that horizon, but south of Yule, at the mouth of Williams creek, it has been largely removed by erosion over extensive areas. At the sharp bend one mile south of Yule, in the SE. ¼ of sec. 36, T. 136 W., R. 105 W., this bed is well shown toward the top of the river bluffs. In some places the coal is overlain by one to 10 feet of clay, on which rest 25 to 35 feet of sand and gravel. In other places the gravel, locally hardened into a conglomerate, lies directly on the coal.

At Yule, in the bluffs of Williams creek, in sec. 25, T. 136 N., R. 105 W., and sec. 30, T. 136 N., R. 104 W., the coal bed F occurs at an elevation of 110 feet above the river and is 6 feet thick. It extends up Williams creek 4 or 5 miles and is exposed in sec. 16, T. 136 N., R. 105 W., where it has the same thickness.

The beds in the vicinity of Yule have a marked dip to the northeast and this carries them down toward river level, where the bed F appears in the steep bluff on the east side of the river. In sec. 29, T. 136 N., R. 104 W., it is 8 feet thick and only 40 feet above the river. The same bed is well exposed one mile northeast, in the SW. ¼ of sec. 21, where the following section is found:

	Feet	Inches
Clay		7
Coal		15
Clay, brown, carbonaceous	9	
Coal, with one-inch clay seam 5 feet 6 inches above bottom	9	8
Sand and clay, to river	43	

This bed again outcrops one and a half miles below here, in sec. 17. In the southern part of the section 7 feet of coal are exposed above water level, but half a mile below this coal bed F disappears below the bed of the river and is not again seen.

The Lance beds are well exposed on Bacon creek, near the southern border of Slope county, and the thick bed of coal outcropping on the latter creek occurs in these strata. The coal is exposed at the old T Cross ranch, in the southern part of sec. 20. T. 133 N., R. 104 W., where it has a thickness of 28 feet above the creek bed and the total thickness is said to be 30 feet.

About 7 miles south of here on Coyote creek in Bowman county, in sec. 30, T. 132 N., R. 104 W., what is probably the same bed is found. Only 12 feet of coal are exposed at this point, the lower portion being covered by talus and deposit from the creek. Three miles west of the above outcrop a bed 5 feet 6 inches thick appears along

the creek. The coal bed exposed on Bacon and Coyote creeks is perhaps to be correlated with bed F, but this could not be determined with any degree of certainty.

THE GREAT BEND GROUP OF COAL BEDS

The coal beds of this group occur along the Little Missouri river from the vicinity of Yule to the north line of township 138, one mile above the mouth of Garner creek, although all the beds of the group do not extend the entire distance of nearly 30 miles. They are also found on Deep, Sand, Bullion and other creeks emptying into the river along this portion of its course. This group of beds lies mostly in the lower part of the Fort Union formation, though they may in part occur in the Ludlow lignitic member of the Lance formation. (See Plate IV.)

Two miles east of Yule, on the east side of the river in secs. 21 and 28, T. 136 N., R. 104 W., two thick beds of coal occur in the upper strata exposed here, the section being as follows:

	Feet
Bed I: Coal at 200 feet above river	8 to 10
Shale and sandstone	35 to 40
Bed H: Coal	5½ to 7
Shale and sandstone, to river	160

The lower of these two beds, H, outcrops below here in the NE. ¼ of sec. 17, and the NE. ¼ of sec. 9, of the same township. Several miles farther down the river, on the north side, in the NE. ¼ of sec. 1, T. 136 N., R. 104 W., the following beds are exposed:

		Feet	Inches
Bed I:	Coal		8
	Clay	1	4
	Coal	2	4
	Clay	3	
	Coal	1	
Shale and sandstone		35	
Bed H: Coal		5	6
Shale and sandstone		70	
Bed G: Coal, overlain by brown clay		4	6

The two upper beds, H and I, appear again in sec. 5, T. 136 N., R. 103 W., where the upper is 5 feet thick and the lower 6½ feet. All three beds of this group are exposed in the bluff on the north side of the river in sec. 3, T. 136 N., R. 103 W., across from the J. H. Follis ranch. The section here is as follows:

	Feet	Inches
Bed I: Coal	8	8
Shale and sandstone	10	
Bed H: Coal	5	2
Shale and sandstone	55	
Bed G: Coal	5	6
Shale and sandstone	80	

These beds are again exposed three miles below, in the east half of sec. 1, T. 136 N., R. 103 W., where, across from the Tyler ranch, the following section is well shown:

	Feet	Inches
Shale and sandstone	25	
Coal	1	6
Shale	2	
Bed I: Coal	11	6
Shale	4	6
Bed H: Coal	5	4
Sandstone	7	8
Coal	1	2
Shale	7	6
Bed G: Coal	6	10
Unexposed, to river, about	70	

One-half mile north of this section and on the opposite side of the river only two coal beds occur, beds H and I having apparently become one by the thinning out of the intervening clay. The section here, near the north line of sec. 1, T, 136 N., R. 103 W., is as follows:

	Feet	Inches
Coal	2	
Shale and sandstone	20	
Beds H and I: Coal	17	6
Clay	1	
Coal	1	3
Clay	3	5
Coal		2
Clay	4	9
Coal		3
Clay		20
Coal		8
Clay, brown, carbonaceous		27
Bed G: Coal	5	6
Shale and sandstone, to river	35	

One mile southeast, in the SW. ¼ of sec. 6, T. 136 N., R. 102 W., the three coal beds are present, though the upper one, I, has been burned out in the face of the bluff. The section here is:

	Feet	Inches
Clinker formed by burning of coal bed I		
Shale, buff	30	
Bed H: Coal	5	6
Shale	10	
Bed G: Coal	7	8
Shale and sandstone, to river	75	

One mile east, in the lower part of the Teepee Butte section, in the SW. ¼ of sec. 5, T. 136 N., R. 102 W., the three coal beds each contain clay seams as shown in the following section:

		Feet	Inches
Bed I:	Coal	1	4
	Clay		3
	Coal		6
	Clay		6
	Coal	9	4
Shale and sandstone		31	
Bed H:	Coal	2	2
	Clay		2
	Coal	2	8
Sandstone and shale		22	
Bed G:	Coal		10
	Clay		6
	Coal	1	6
	Clay		2
	Coal	3	2
	Clay		1
	Coal	1	8
Shale and sandstone, to river		85	

About one mile south of the foregoing section, the same coal beds are well exposed on the south side of the river, in the NW. ¼ of sec. 17, T. 136 N., R. 102 W., where the following section appears:

	Feet	Inches
Shale, to top of bluff	10	
Bed I: Coal which forms the thick clinker bed on Sand and Deep creeks	16	
Shale	2	
Bed H: Coal	5	6
Shale	12	6
Bed G: Coal, with several clay partings	13	
Sandstone, in massive ledges, and shale to river level	127	

It will be noted that in the above section beds H and I are here separated by only 2 feet of shale, and it is possible that farther south these two beds may form only one through the thinning out of the clay parting. Coal bed I, however, is the thickest and most persistent bed of the entire region, and is the coal which has formed the conspicuous clinker horizon along Deep and Sand creek valleys and the intervening area. In places on this divide the coal bed is unburned, as in the NE. ¼ of sec. 19, T. 136 N., R. 102 W., where the thickness of the bed is 18 feet.

About one mile east of the above section, on the opposite side of the river and across from the mouth of Sand creek, only the two upper coal beds appear. The lower bed, G, is doubtless present but does not outcrop, since the strata forming the lower part of the bluff

are largely unexposed. The section here in the SW. ¼ of sec. 9, T. 136 N., R. 102 W., is as follows:

	Feet	Inches
Bed I: Coal, with 9-inch clay seam 5 feet above base	21	6
Shale	22	
Bed H: Coal, with 3-inch clay parting 13 inches below top	6	10
Shale and sand, mostly unexposed, to river	105	

It will be seen from the foregoing sections that there are three workable coal beds outcropping in the bluffs of the Little Missouri river for 10 miles above the mouth of Sand creek, the upper, I, being the thickest and varying from 9 to 21 feet.

Bed H is exposed two and one-half miles below the mouth of Sand creek, in the northwest corner of sec. 11, T. 136 N., R. 102 W. The upper bed, I, is here represented by a layer of clinker formed by its burning, and 14 feet below is bed H, which shows the following section:

	Feet	Inches
Coal with 2-inch clay parting 2 feet below top	7	4
Clay	2	4
Coal		9
Clay	3	3
Coal	3	2
Clay		2
Coal	1	9

In sec. 2, about one-half mile below, in the bluff of the Little Missouri, the upper coal bed, I, lies 135 feet above the river and measures 11 feet 4 inches in thickness, while 40 feet below is bed H, which is 5 feet 4 inches thick. These same beds appear in the following section, which is found on the west side of the valley in the NE. ¼ of sec. 36, T. 137 N., R. 102 W.:

		Feet	Inches
Sandstone, fine-grained, argillaceous, to top of bluff		20	
Coal		3	4
Sandstone, fine-grained, argillaceous		7	7
Clay		1	
Coal			1
Clay, gray			18
Coal			3
Clay		3	1
Bed I:	Coal		14
	Clay		3-4
	Coal	10	6
	Clay		2
	Coal	5	1
Shale		33	
Bed H: Coal		3	8
Unexposed to river		24	

Coal bed H does not appear in the bluffs of the Little Missouri below this point, since the dip of the strata carries it below river level, and only one thick bed of coal, I, is present. But the beds of this group occur on Third, Second and Sand creeks, where there are many outcrops.

All three beds of the Great Bend group appear on Third creek. The presence of the upper bed, I, is made known largely by the layer of clinker formed by its burning along the outcrop, this clinker horizon being traceable for many miles up the creek. The middle bed, H, outcrops in secs. 33 and 35, T. 137 N., R. 101 W. In the former locality the section of the bed is as follows:

	Feet	Inches
Coal	6	
Clay	6	6
Coal	7	

In sec. 35 the following section is exposed:

	Feet	Inches
Coal	8	3
Clay	2	
Coal	2	

The lower of the three coal beds, G, is well exposed in the cut bank on Third creek, in sec. 4, T. 136 N., R. 101 W., where the following section appears:

	Feet	Inches
Shale	15 - 50	
Coal	7½-8½	
Shale	8 - 10	
Coal	10	
Shale	3	
Coal	3	6
Unexposed to creek	7	

The three coal beds in the above section are considered as belonging to a single horizon, G, and they lie from 30 to 40 feet below the middle coal bed of the group.

Second creek empties into the Little Missouri river two miles below the mouth of Sand creek and thick beds of coal are well exposed in the valley. In a ravine tributary to the main valley, in the NW. ¼ of sec. 12, T. 136 N., R. 102 W., the following section appears:

	Feet	Inches
Bed I: Coal	12	3
Shale	20-24	

One-half mile south of here in the SW. ¼ of sec. 12, T. 136 N., R. 102 W., the lower bed, H, is well shown and is here represented by three coal beds, as follows:

		Feet	Inches
Shale		10	
Bed H:	Coal, with 2-inch clay parting 5 feet below top	21	8
	Clay	18	
	Coal	3	8
	Clay	11	6
	Coal, exposed above creek	7	

It will be noted that the total thickness of the coal exposed in the above section is 32 feet 4 inches. The 21-foot coal bed outcrops along Second creek for over a mile above this point.

One-half mile east, in the SE. ¼ of sec. 12, the upper coal bed, I, which is 24 feet above that just given, is well shown as follows:

		Feet	Inches
Shale, sandy		10	
Bed I:	Coal	7	6
	Clay		3
	Coal	12	
	Clay		6
	Coal		5½
	Clay		5
	Coal	2	10

On the Dry Fork of Sand creek, in the W. ½ of sec. 24, T. 136 N., R. 102 W., the following section is shown along the creek:

	Feet	Inches
Shale	12	
Coal	7	6
Clay	2	
Coal, with 1-inch clay parting 5 feet below top; base of coal is at creek level	12	

Between one and two miles south of here, in the SE. ¼ of sec. 26, T. 136 N., R. 102 W., the following section is exposed:

	Feet	Inches
Shale	10-15	
Coal	8	3
Clay	2	4
Coal	10	4
Sandstone	3	
Coal, with 2-inch clay parting	5	4
Shale, exposed to creek bed	6	

These are doubtless the same coal beds as those outcropping in sec. 24, except that at the latter place the lower coal does not show above the bed of the creek. At both localities the horizon represented is probably that of bed H.

About one mile above the mouth of Dry Fork, in the NE. ¼ of sec. 22, T.136 N., R. 102 W., bed I is exposed in the bluff bordering the valley. It is here 20 feet 3 inches thick and a section of the coal is as follows:

	Feet	Inches
Coal	7	3
Clay		10
Coal	9	10
Clay		4
Coal	2	

This coal is burned out extensively in the vicinity and is represented by a thick layer of clinker. In the NW. ¼ of sec. 22, T. 136 N., R. 102 W., at the junction of Dry Fork and Sand creek valleys, the following section occurs:

	Feet	Inches
Clinker layer, formed by burning of coal bed I	10	
Shale, gray, sandy	24	
Shale, brown		16
Bed H: Coal	2	4
Bed H: Clay		6
Bed H: Coal	2	8
Unexposed, to creek	90	

Both the upper and lower coal beds, H and I, appear on the west side of the valley of Sand creek, about three miles above its mouth, in the SE. ¼ of sec. 28, T. 136 N., R. 102 W. The section is as follows:

	Feet	Inches
Bed I: Coal	20	
Shale	15	
Bed H: Coal	7	8
Unexposed, to creek	85	

Following up the valley of Sand creek there are few outcrops of these coal beds until the old Russell ranch is reached, in the NE. ¼ of sec. 31, T. 135 N., R. 101 W. Here is exposed the thickest coal bed which appears at the surface anywhere in North Dakota, the section being as follows:

	Feet
Shale and sandstone	15-20
Coal	3-4
Clay	2½
Coal (Bed I), to creek level	35

The coal is mined from the outcrop here in sec. 31, and a thickness of 28 feet is exposed in the face of the mine (See Plate VI, Fig 2),

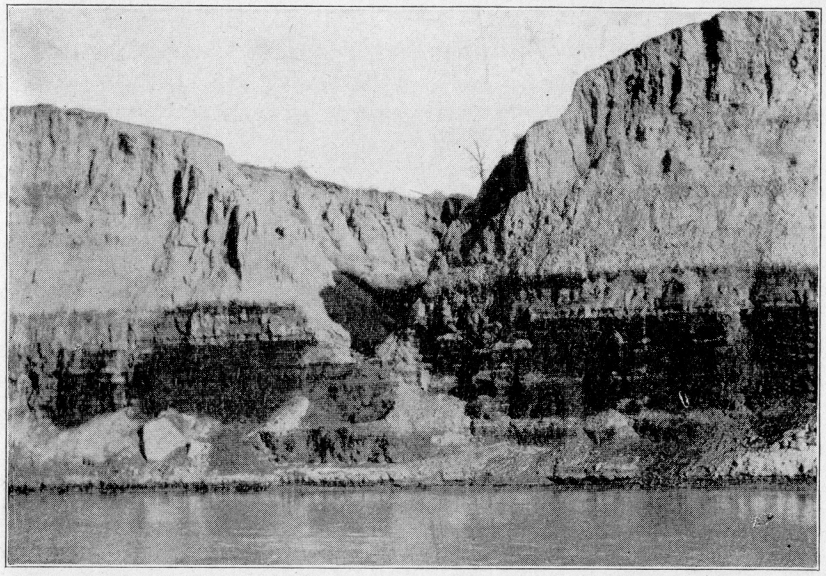


Fig. 1. Coal bed I of the Great Bend group exposed on Little Missouri near Harmon ranch. Total thickness of coal is 16 feet.

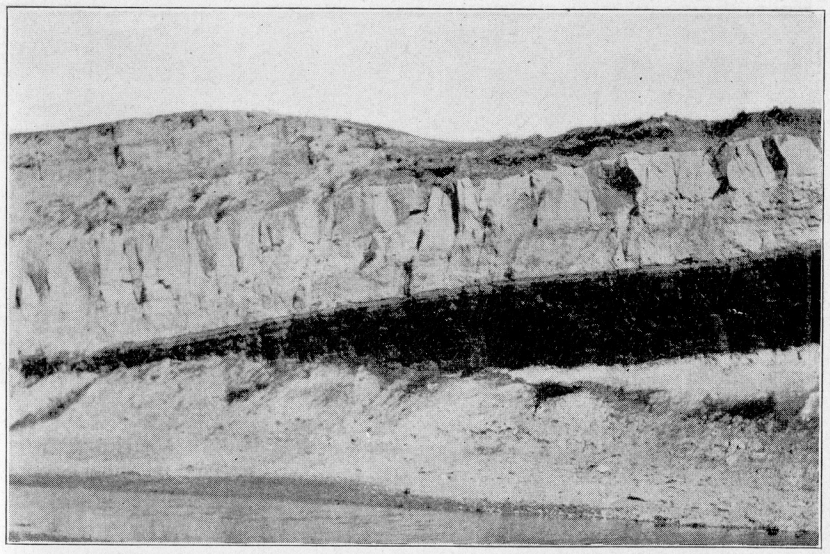
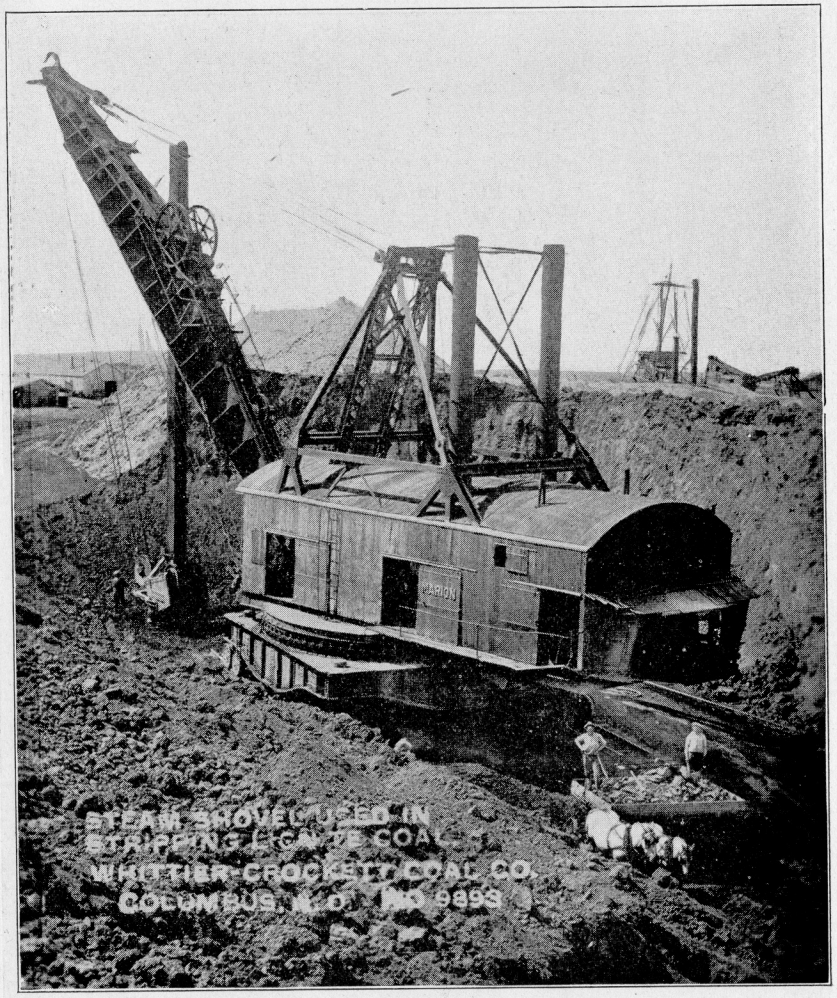


Fig. 2. Coal bed exposed on Yellowstone river, showing well pronounced dip. Thickness of this lignite bed is 13 feet.



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Large steam shovel used in uncovering coal near Columbus, N. Dak.

but the bottom of the bed appears near by, not far above creek level, and shows that the total thickness is 35 feet. The mine is about 5 miles southwest of Amidon. This coal bed underlies a large part of secs. 30 and 31, at a depth of 10 to 30 feet, and extends under adjoining sections where not removed by erosion.

This 35-foot coal bed is doubtless the same as that outcropping on Sand creek between 7 and 8 miles below, in sec. 28, T. 136 N., R. 102 W., where its thickness is 20 feet. It is therefore coal bed I, possibly here combined with bed H through the thinning out and disappearance of the intervening clay. This thick coal bed, I, has been traced along the Little Missouri valley a distance of over 40 miles or from old Yule Post Office at the mouth of Williams creek almost to the Harmon ranch, 8 miles south of Medora. At its southernmost outcrop it lies 200 feet above the river, and its northward dip carries it below the level of the Little Missouri about three-quarters of a mile above the Harmon ranch. This coal bed, I, or the Sand Creek coal bed as it may be called, is known by outcrops to extend north and south a distance of 24 miles, and east and west 25 miles, so that it has an area of at least 600 square miles, and probably much more than this. It varies in thickness from 10 to 35 feet and doubtless averages 20 feet. (See Plate VII, Fig. 1.)

The relation of the Sand Creek coal bed, bed I, to the Bowman coal bed, the two thickest coal beds in North Dakota, is well shown in the vicinity of the H. T. ranch, in sec. 19, T. 135 N., R. 102 W. Here the clinker from coal bed I appears along the valley of Deep creek while the clinker from the Bowman coal bed is found on top of the high ridge in secs. 16 and 21, T. 135 N., R. 102 W. The Bowman coal bed here lies 80 feet above the Sand Creek coal bed, and they are about the same distance apart near Amidon, where the lower bed is mined 5 miles southwest of town, and the upper 2 miles south.

A coal bed 5½ feet thick outcrops on Sand creek near the east line of sec. 34, T. 134 N., R. 101 W. The following coal beds occur in Black Butte where they are exposed near the east end, in a ravine in sec. 19, T. 134 N., R. 101 W.:

	Feet	Inches
Coal	5	1
Clay	4	5
Coal	3	6
Clay		14
Coal	3	4

DIVIDE AND BURKE COUNTIES

A. G. Leonard and H. N. Eaton

Since the important coal bed of the region underlies parts of both these counties, they are considered together. The Noonan-Columbus district, in which most of the mines are located, includes ranges 93, 94, and 95 of township 162, in eastern Divide and western Burke counties. One of the best lignite beds in the state as regards quality is found in this area. It outcrops near Noonan along the sides and near the bottom of a coulee, the bed lying about 30 feet below the general level of the surface of the plain. What is doubtless the same coal seam is mined four miles south of Columbus, where it may be traced for a distance of two and a half miles east and west. The coal here lies between 10 and 27 feet below the surface. In thickness this bed ranges from 7 to 10 feet, and the lignite is exceptionally good quality. (See Plate VIII, also Plate XI, Fig. 2.)

In the vicinity of Noonan this coal bed is reported to thin out toward the north, so that it does not occur north of the railroad and it does not seem to continue very far west. It is not known how far south it extends, but it is not unlikely that the coal may underlie a large area in this direction, as well as toward the east. This Noonan coal bed, as it may be called, extends at least eleven miles east of Noonan, and probably farther. In sec. 20, T. 162 N., R. 93 W., the coal seam has a thickness of 10 feet and over, and lies about 27 feet below the surface.

The mines on this lignite bed in the vicinity of Noonan are in secs. 3, 9, and 10, T. 162 N., R. 95 W. The Hought mine is located one mile southeast of Noonan, in sec. 3 (see analysis No. 5519), and the Lorbeski mine (see analysis No. 5520) is just north of it, in the same section. The coal bed is here 7 feet thick. The Tamberg and Logelin mines (see analysis No. 5521) are in sec. 10, and the Kimball mine in sec 9 (see analysis No. 5522).

In the vicinity of Larson there are three coal beds, one of which is doubtless the Noonan coal bed. It is the upper and middle of these seams that are mined, the mines being located in secs. 14, 15, 17, 18, and 7, T. 162 N., R. 94 W. (See analysis No. 5523.)

Since the Noonan coal bed, where it occurs 4 miles south of Columbus, lies only 10 to 27 feet below the surface, mining operations are here carried on mostly by stripping off the overburden. At the mine of the Whittier and Crockett Coal Company, the largest in

the district, a steam shovel is used in stripping. The mine, which is in the SW. ¼ of sec. 19, T. 162 N., R. 93 W., is on a spur track of the Great Northern railroad. The Sunlight mine is located in the SE. ¼ of sec. 20, T. 162 N., R. 93 W., the Larson mine in the NW. ¼ of sec. 24, T. 162 N., R. 94 W., and the Kielhock and Wixon mine is in the SW. ¼ of sec. 20, T. 162 N., R. 93 W. Sample No. 5524 is from the Noonan coal bed in sec. 24, T. 162, R. 93 W.

A coal bed 6 feet thick is mined 6 miles north of Columbus, just south of the Canadian line, in sec. 31, T. 164 N., R. 93 W.

In eastern Burke county, in what may be called the Lignite-Bowbells district, there are several coal beds. One seam 6 to 8 feet thick has been mined in sec. 30, T. 162 N., R. 92 W., but the quality of the coal varies and in some places is poor

A strip pit in the SE. ¼ of sec. 31, T. 162 N., R. 92 W., shows the following section of the coal bed:

	Feet	Inches
Coal, weathered and slacked	2	
Clay	2-3	
Coal	2	6
Clay		6
Coal	3	9

A coal bed which varies in thickness from 2 to 9 feet and averages about 5 feet has been mined in the SW. ¼ of sec. 35, T. 162 N., R. 92 W. The quality of this lignite varies from good to poor grade. A well 120 feet deep, put down in the SE. ¼ of the above section, is reported to have passed through four coal beds, one said to be 10 feet thick, and to have gone 6 feet into a fifth bed without going through it. A seam formerly mined in sec. 6, T. 161 N., R. 91 W., is said to be 6 to 8 feet thick. A well drilled in the SW. ¼ of sec. 12, T. 161 N., R. 91 W., reached a coal bed 9 feet 9 inches thick at a depth of 97 feet.

The following log of a well drilled in the NW. ¼ of sec. 1, T. 161 N., R. 91 W., is given by Mr. John Stenson:

	Feet
Drift clay and 2 feet of gravel	40
Coal	8
Clay	83
Coal	6

A coal bed 5 feet thick lying at a depth of 40 feet below the surface has been mined near Bowbells, in the SE. ¼ of sec. 5, T. 161 N., R. 89 W.

COAL IN WESTERN DIVIDE COUNTY

The coal bed mined about 7 miles south of Alkabo while of importance only locally so far as production is concerned, is of considerable interest on account of the steep inclination or dip of the bed. Coal has been mined here on a small scale for many years, the bed being exposed or occurring near the surface in secs. 13 and 14, T. 161 N., R. 102 W. Dips as high as 23° and 33° to the north or northwest were measured, and a dip of 45° is reported. In mining the coal slopes are driven in along the bed, and the following section is exposed in one of these, near the east line of sec. 13:

	Feet
Sandy yellow clay with thin lignite seams	
Gray clays	6
Coal	4
Sandy clay	

The coal bed here has a dip of 33° to the north. The lignite bed continues but a short distance in the direction of the dip and is reported to end suddenly against a nearby vertical wall of clay, so that none of the mines are deep, or the workings extensive. When the mines were visited they were filled with gas, so that it was unsafe to to explore any distance underground.

The inclination or dip of this bed may have been produced in several ways. It may be the result of folding, the tilted strata being a portion of the northward dipping limb of an anticline, which has perhaps been faulted parallel to the axis of the anticline. Another possibility is that a large block or section of the strata slumped down from a formerly southward facing escarpment and turned up from the inertia of the heavier rear portion of the block. The country to the south is about 100 feet below the highest portion of the hill. It should be stated, however, that there is little evidence of slumping on such a large scale.

DUNN COUNTY

A. G. LEONARD

Coal beds are found in all parts of the county and are exposed in many places along the Little Missouri and Knife rivers, Spring and Crooked creeks and their many tributaries. While there are few large shipping mines, many small mines are found scattered throughout the county and these supply the local demand of the surrounding country.

The lowest coal bed of the area is the Reservation coal bed which outcrops at many points along the Little Missouri and Missouri rivers for a distance of 50 miles. Several miles below the mouth of Jim creek this bed has an elevation of 1825 feet above sea level. The highest coal seam is doubtless the one which has formed the conspicuous clinker layer 5 or 6 miles south of Crooked creek, on either side of the Dickinson-Killdeer road, in the southern part of T. 142 N., R. 95 W., and T. 142 N., R. 96 W. This coal has an elevation of about 2438 feet above see level. The coal beds of Dunn county thus have a vertical range of at least 600 feet, but other seams undoubtedly lie below the Reservation coal bed.

The coal beds of the Little Missouri district, in northern Dunn county, are described in connection with the other coal seams along that river in McKenzie county, and the discussion of them will be found under the heading of the latter county. The coal deposits of the Fort Berthold Indian Reservation west and south of the Missouri river, including parts of McKenzie, Dunn and Mercer counties, are fully described in a recent bulletin of the United States Geological Survey,[1] and only those lignite beds which outcrop along the valley of the Little Missouri river are considered in this report. The rest of the coal beds will be considered under the following districts: Spring creek, Knife river above Emerson, Lower Knife river and Crooked creek.

SPRING CREEK DISTRICT

In this district are included those coal beds which occur along the valley of Spring creek between Dunn Center and the eastern boundary of the county, or are found within 6 or 7 miles north and south of the latter creek.

Near the eastern edge of Dunn county, in T. 144 N., R. 91 W., there are two clinker horizons. The lower is exposed in sec. 24 of the above township, and lies 10 to 20 feet above creek level, while the upper appears in sec. 36, about 100 feet above the creek, and not far below the surface of the upland. No outcrops were found of the coal beds whose burning produced these clinker layers, and so the thickness of the coal is not known.

In sec. 9, T. 144 N., R. 91 W., about one-half mile west of Dodge, a coal bed with a thickness of 7 feet was formerly mined by

[1] Lignite in the Western Part of the Fort Berthold Indian Reservation South of Missouri River, North Dakota; C. M. Bauer and F. A. Herald. U. S. Geol. Survey Bull. 726, pp. 109-172, 1921.

stripping along the side of a draw or ravine tributary to Spring creek but it is now worked by drifting in along the seam. The seam lies about 50 feet above creek level here at the Sloan mine, and the Dodge mine is in this same bed. What is probably a higher coal bed has been mined in the SE. ¼ of sec. 11, T. 144 N., R. 92 W., and in the east half of sec. 18, T. 144 N., R. 91 W.

Another coal bed 4 feet 2 inches thick outcrops in a cut bank on the east side of Spring creek, not far from Halliday. Near the top is a clay parting 3 to 4 inches thick, and the coal seam lies 20 feet above the creek. This bed is exposed at several points in secs. 19 and 30, T. 145 N., R. 91 W., and also two miles west of Halliday, in sec. 22, T. 145 N., R. 92 W.

In the northwest corner of this same section a higher bed has been mined, but the coal was not exposed and its thickness could not be determined. This coal seam lies about 60 feet above Spring creek. It is perhaps this same upper bed which has formed the clinker appearing in sec. 26 of the same township. In the vicinity of Halliday there is thus a lower coal bed not far above Spring creek, and some 40 to 50 feet above the lower is a higher seam of coal.

The following section is well exposed in the cut bank of the creek in sec. 28, T. 145 N., R. 92 W., about two miles east of Werner:

		Feet	Inches
5	Shale, to top of bluff	42	
4.	Coal		4-5
3.	Shale, gray	7	
2.	Coal	5	2
	Shale	1	8
	Coal	5	1
1.	Sandstone, massive, exposed above creek	52	

No. 2 of the above section, which is the upper of the two coal beds present in T. 145 N., R. 92 W., is the same bed as that mined in the northwest corner of sec. 22. The Pulver and Logan mine, in sec. 29, is working No. 2, but the coal is here not in place, and is broken and crushed. It has also burned out in the vicinity of the above outcrop, and caps several low buttes and hills.

Between 6 and 7 miles south of Werner, in the SE. ¼ of sec. 27, T. 144 N., R. 93 W., a coal bed at least 7 feet thick is mined at the Lewis mine. The shale cover, which has a thickness of only 6 to 8 feet, is removed with scrapers and the coal mined by the strip pit method. The bottom of the seam was not exposed. Seven miles north of Werner, in sec. 21, T. 146 N., R. 92 W., a coal bed with a thickness of over 7 feet has been mined on a small scale.

DUNN CENTER COAL BED

One of the thickest coal beds in the county underlies a large area in the vicinity of Dunn Center, and on account of its location near that town it may be called the Dunn Center coal bed. It is known to underlie parts of four townships, and probably extends into those adjoining. It varies in thickness from 14 to 20 feet and lies not far from creek level. Not only does it appear in a number of places along Spring creek, but it has been struck in many of the wells of the region.

The Paulson mine, in the SE. ¼ of sec. 28, T. 145 N., R. 93 W., 4 miles east of Dunn Center, is in this coal bed, which is here 16 feet thick, and lies just above the level of Spring creek. The coal is mined by a drift which runs in along the bed. The upper part of this coal seam is exposed above creek level near the bridge on the line between secs. 22 and 23 of the same township. About one mile north of this bridge, in the northeast corner of sec. 22, a well reaches this coal bed at a depth of 70 feet, where an abundant supply of good water is obtained.

The Hy Grade coal mine, which is also working the Dunn Center bed, is located two and one-half miles east of Dunn Center, in the NW. ¼ of sec. 29, T. 145 N., R. 93 W. The shaft reaches the coal at a depth of 15 feet and the bed there has a thickness of 20 feet, only the upper 5 feet being above creek level. The High Carbon mine is in the W½ of sec. 27 and SE. ¼ of sec. 28, of the same township (see analysis No. 5525). At the Bang mine, one-half mile south of Dunn Center, in the SW. ¼ of sec. 26, T. 145 N., R. 94 W., the same coal bed is mined by stripping off the overburden. The coal at this point is 14 feet thick. The same bed is also mined at the Three Star mine, in sec. 1, T. 144 N., R. 95 W., and it is also reached by a well in the SW. ¼ of sec. 4, T. 144 N., R. 94 W. In this well the coal bed is struck at a depth of 20 feet, and has a thickness of 14 feet.

While the Dunn Center coal bed is the lower bed which outcrops in the vicinity of Dunn Center, a middle and upper seam is present. The middle coal bed has been mined in the SW. ¼ of sec. 34, T. 145 N., R. 94 W., at the head of a short tributary of Spring creek. The coal is here not well exposed, but there is a seam 2 to 3 feet thick, separated by a clay parting from a thicker bed just below, the latter being mostly concealed so that its thickness could not be determined.

This middle coal bed lies 30 to 40 feet above the lower. Clinker formed by its burning occurs in the SW. ¼ of sec. 20, T. 145 N., R. 94 W., in some low hills. The lower and middle coal beds probably underlie much of the upland in the northern part of T. 145 N., R. 94 W., and the adjacent township on the east. They doubtless are also present in T. 144 N., R. 94 W.

The clinker formed by the burning of the upper coal bed appears in many places in T. 144 N., R. 94 and 95 W., where it caps a number of the lower buttes and hills.

UPPER KNIFE RIVER DISTRICT

This district includes the Knife River valley above the mouth of Crooked creek.

A coal bed 5 feet thick has been mined near Fayette, in sec. 36, T. 144 N., R. 97 W. It lies 30 feet above the Knife river. A lower seam occurs at the level of the river, and a higher coal bed is present in the northern part of T. 143 N., R. 97 W., where it has formed a layer of clinker on the south side of the Knife River valley.

Two coal beds are found in the northern portion of T. 143 N., R. 97 W. The lower, which has a thickness of at least 6½ feet, is mined in sec. 4 of this township, and lies not over 50 to 60 feet above the Knife river. The coal bed which has been mined in secs. 17 and 18 of the same township is a higher seam, being about 250 feet above the river. It has a thickness of 4 to 6 feet.

Two coal beds over 5 feet thick are found in the vicinity of Manning, the lower being 30 to 40 feet above the Knife river, and the upper 70 feet above the river. The lower seam is mined in the NE. ¼ of sec. 5, one and a half miles east of town, the coal being 5 feet thick, and this is probably the bed mined four miles west of Manning, in sec. 4, T. 143 N., R. 96 W. The Blecha coal mine, located in the SW. ¼ of sec. 12, T. 143 N., R. 96 W., is also doubtless mining this same lower bed, which here has a thickness of 5½ to 6 feet.

The upper coal bed where it has been mined in the NW. ¼ of sec. 29, T. 144 N., R. 95 W., has a thickness of 7 feet, and lies 20 to 40 feet above the lower seam. This upper bed is probably the one mined at the Heiser mine, one and a half miles southeast of Manning, in sec. 17. From 6 to 8 feet of overburden is stripped from the coal, which is here 5 to 6 feet thick. These two coal beds no doubt underlie a considerable area in the vicinity of Manning although they do not outcrop along the Knife River valley either above or below town. The only coal bed appearing in the cut banks of the Knife, between Manning and Emerson, is a seam 2 feet thick, while the higher and thicker beds are not exposed though probably present and extending some miles east of Manning.

In the region about Emerson, which is located 2 miles west of the confluence of the Knife river and Crooked creek, there are three coal beds, lying at elevations of 25, 120 and 220 feet, respectively above the river. The coal of the middle and upper seams has burned out extensively, forming the thick and conspicuous clinker layers which appear north of Emerson. The clinker of the upper coal bed occurs in the northeast corner of sec. 27, T. 144 N., R. 94 W., while in sec. 29 the clinker of both the middle and upper coal beds is well exposed.

The Bailey mine, located one mile northeast of Emerson, in the SE. ¼ of sec. 17, T. 143 N., R. 94 W., is in the lower coal bed, which is here 3½ to 4 feet thick, and is mined by stripping off the cover. At the Chase mine, in the NE. ¼ of sec. 32, T. 144 N., R. 94 W., the middle seam, 120 feet above the Knife river, is mined. The coal bed is 4 feet thick, and 6 to 8 feet above it is a 3-foot seam of coal just below the surface. The clinker produced by the burning of this middle coal bed forms a thick layer in sec. 9, T. 143 N., R. 94 W., and this is seen to extend 3 or 4 miles both to the east and west, capping many low hills and knolls. Both the upper and middle coal beds have been largely removed by erosion in T. 142 N., R. 95 W., much of the surface here being lower than either of the seams, though they perhaps underlie the high divide in the northeastern corner of the township. In the hilly and rough upland area forming the northeastern portion of T. 142 N., R. 94 W., the upper and middle coal beds are known by their clinker to underlie much of the surface, and a still higher bed of coal has been almost wholly removed by erosion. A lower coal seam, perhaps the same as that mined near Emerson, has been mined on Deep creek, in secs. 19 and 20, T. 142 N., R. 94 W. This bed has a thickness of at least 5 feet.

CROOKED CREEK DISTRICT

This district comprises the drainage basin of Crooked creek in T. 142 N., Rs. 96 and 97 W., and the southern sections of T. 143 N., Rs. 96 and 97 W. Three coal beds are present in this area. The lowest and thickest is exposed at several points along Crooked creek, its most easterly outcrop being in the extreme southeastern corner of

sec. 29, T. 143 N., R. 96 W. The bed here lies 25 feet above creek level and is 12 feet thick.

Two miles west, in the SE. ¼ of sec. 36, T. 143 N., R. 97 W., the bottom of the coal is only 4 feet above the creek, and its thickness is 10½ feet. Three and a half miles farther west, in sec. 4, T. 142 N., R. 97 W., this coal bed is represented by a thick clinker layer, the base of which is below creek level, showing that the coal where unburned here lies in part below Crooked creek. This lower coal bed doubtless extends west to the Billings county line and beyond.

The middle coal bed lies about 50 feet above the lower. It has been mined in the NW. ¼ of sec. 10, T. 142 N., R. 97 W., where the coal is at least 6 feet thick, but the bottom is not exposed. It has also been mined in the NW. ¼ of sec. 12 and in sec. 13 of the same township. It is perhaps this middle bed which is mined in the SW. ¼ of sec. 3 and NW. ¼ of sec. 10, T. 142 N., R. 96 W. The bed is here 9 feet thick.

The upper coal bed lies 60 feet above the middle seam, and is the one which has been mined in the SW. ¼ of sec. 15, T. 142 N., R. 96 W. The bottom of the coal was not exposed, but its thickness is over 5 feet.

A thick bed of clinker is conspicuous along the Dickinson-Killdeer road in secs. 30 nad 31, T. 142 N., R. 95 W., and in secs. 25 and 36, T. 142 N., R. 96 W. It is formed by the burning of a thick coal bed lying about 100 feet below the general elevation of the upland, or 230 feet above Crooked creek at the bridge 4 or 5 miles north. The only place found where this bed was unburned along its outcrop was in the NE. ¼ of sec. 25, T. 142 N., R. 96 W., where 5 feet of coal is exposed, but the total thickness of the bed could not be determined here. This is probably the upper of the three coal beds mentioned above, and which has been mined in sec. 15, T. 142 N., R. 96 W., though it is possibly a still higher, fourth bed. This coal bed has been largely removed by erosion, or burned out, in T. 142 N., Rs. 95 and 96 W., but it doubtless underlies a considerable area of the upland to the south of these townships.

LOWER KNIFE RIVER DISTRICT

This district includes the drainage area of the Knife river in the southeastern corner of Dunn county.

No coal beds are exposed along the valley of the Knife between the mouths of Crooked and Deep creeks. About one mile below the mouth of the latter stream, in a cut bank on the Knife river, in the

NW. ¼ of sec. 10, T. 142 N., R. 93 W., a coal bed 6½ feet thick is exposed at an elevation of 20 feet above the river. A seam 2 feet thick occurs 12 feet above the thicker bed. In this vicinity a higher coal bed is shown to be present by its clinker. It lies 70 feet above the river, and may be the same bed that is mined at the Bailey mine, in sec. 17, T. 143 N., R. 94 W. This upper coal bed, which has formed the clinker, occurs north of the Knife river, in the southern part of T. 143 N., R. 93 W. It is also present not far below the upland surface west of the confluence of the Knife river and Deep creek, and is found on either side of the valley of Deep creek for several miles above its mouth.

Four miles east of the outcrop in sec. 10, near the bridge, a coal bed 4 feet thick is exposed 25 feet above the river, in the SW. ¼ of sec. 8, T. 142 N., R. 92 W. The coal is overlain by 6 to 10 feet of sandstone, and is doubtless the same bed as that exposed near the bridge, in sec. 10. Only one-half mile north, in the NW. ¼ of sec. 8, the same coal bed is exposed in a cut bank, but it here has a thickness of 7 feet 4 inches, and is only 4 feet above river level. One and a half miles west, in the NE. ¼ of sec. 12, T. 142 N., R. 93 W., the same coal bed appears. It is 4 feet 7 inches thick and is 50 feet above the river.

In the SW. ¼ of sec. 1, T. 142 N., R. 92 W., the following section is found in a bluff along the Knife river:

		Feet	Inches
9.	Shale, to top of bluff	3-8	
8.	Coal	2	2
	Clay parting		2
	Coal	1	7
	Clay parting		4
	Coal	3	3
7.	Shale and sandstone	15	
6.	Coal	1	6
5.	Shale, gray	16	
4.	Coal	2	3
3.	Shale, gray	4	10
2.	Coal		3
	Clay parting		3
	Coal	3	6
1.	Shale, exposed above Knife river	6	

The upper coal bed of the above section (No. 8), which is here 50 feet above the river, is probably the seam which is exposed 4 miles to the west in sec. 8 of the same township. It does not appear to extend very far east, since about one mile below it is split up into several thin beds with thick clay partings between them.

HETTINGER COUNTY

A. G. Leonard

Hettinger county is well supplied with lignite deposits. In the eastern part of the county there is little or no coal along the valley of the Cannonball river. The beds of lignite occur at an elevation considerably above the river and underlie the higher land some miles back from the stream. The mines in this part of the county are, therefore, not very near the railroad.

On the extreme eastern edge of the county a coal bed 8 to 9 feet thick underlies the upland over many sections in T. 134 N., R. 91 W., and T. 134 N., R. 90 W. This bed lies about 90 feet above the Cannonball river and 30 to 40 feet or more below the general level of the upland surface. It is mined at the Kallis mine, in the SE. ¼ of sec. 24, T. 134 N., R. 91 W. The overburden, which is 5 to 8 feet of sandy shale, is stripped off and the mine worked as an open pit. The coal seam is here 9 feet thick with a 5-inch clay parting 3 feet above the bottom. A short drift has been opened in this same bed in the SW. ¼ of sec. 13, T. 134 N., R. 91 W. The Kallis mine is 3 miles north of the Mandan-Mott branch of the Northern Pacific railroad. (See Plate IX, Fig. 1.)

The Square Deal mine, located in the SE. ¼ of sec. 35, T. 133 N., R 91 W., is in a coal bed 5½ to 6 feet thick. The overburden is 10 to 15 feet of shale, which has been stripped off and a considerable area of the bed has thus been uncovered and removed. Some of the coal has been hauled to Bentley, about three miles distant, and shipped to Mott and other towns on the railroad. This coal bed doubtless underlies the upland south of the mine, but the cover grows thicker in that direction so that the coal could probably not be mined to advantage by stripping but could be worked by a slope or shaft.

Two beds of coal occur in the hills several miles south of Mott, but the mines opened in these are so far from the railroad that they supply only a country trade. The upper of these coal seams which is 11 to 12 feet thick, is probably the Haynes coal bed, described in connection with the Adams county deposits, and the lower has a thickness of 5 to 7 feet.

The Loe mine is located between 4 and 5 miles southeast of Mott, in the NW. ¼ of sec. 20, T. 133 N., R. 92 W. It is on a short tributary of the Cannonball river which has a broad, shallow valley, the mine being located on the side of this valley. The coal

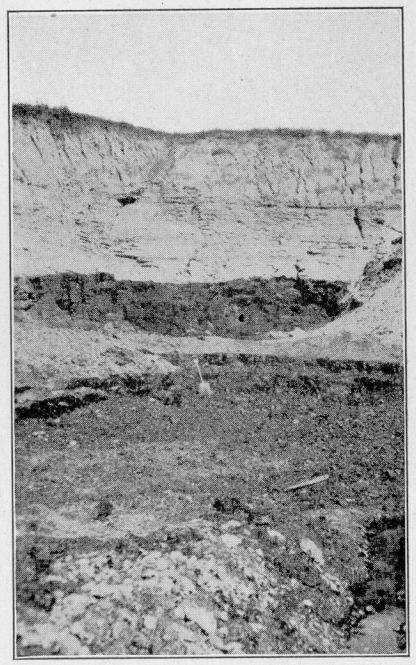

Fig. 1. The Kallis mine showing coal bed 9 feet thick.

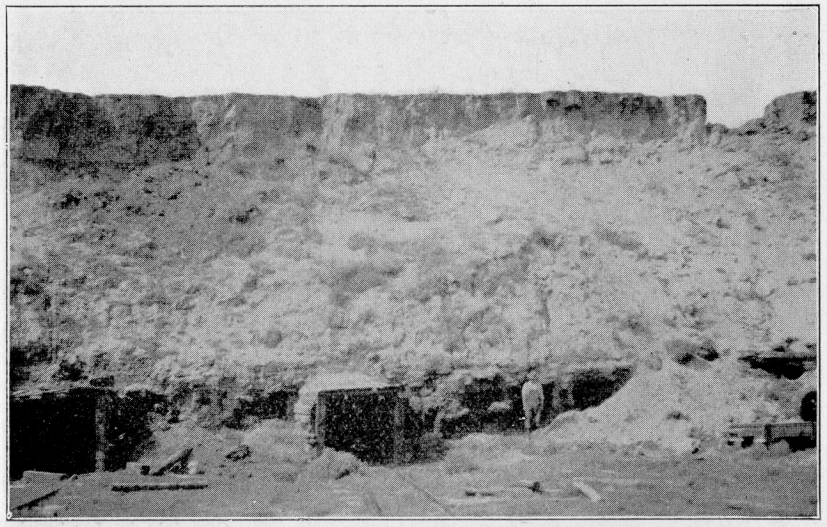

Fig. 2. Lehigh coal bed at the Lehigh mine. Thickness 8 to 12 feet.

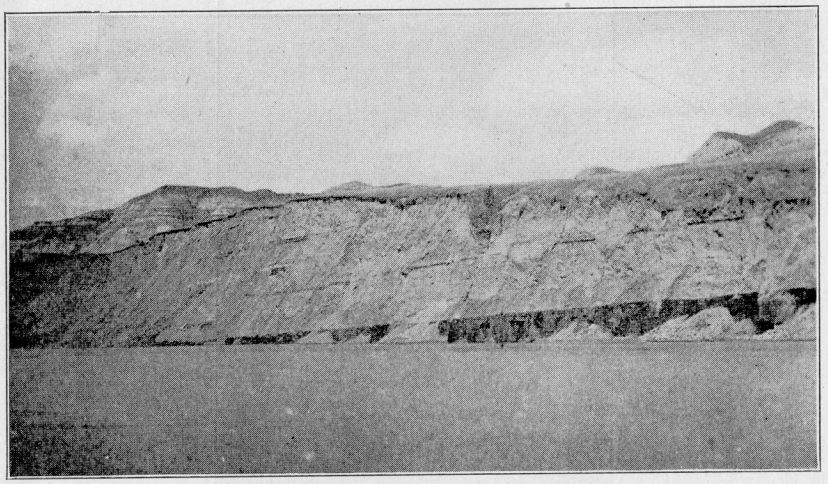

Fig. 1. Coal bed 12 feet thick exposed on Little Missouri near mouth of Jim's creek, Dunn county. The coal bed here has a dip which carries it below river levels within a short distance.

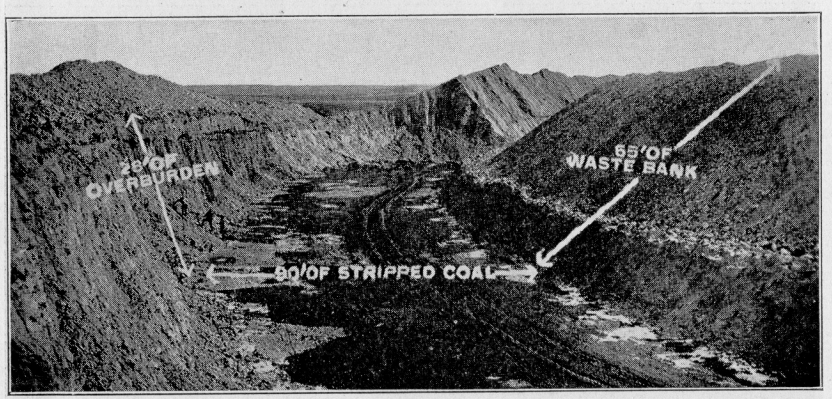

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Fig. 2. Showing dimensions of strip pit as left by the large steam shovel shown in Plate VIII, at the Whittier-Crockett Coal Company mine near Columbus.

bed is here 6 feet 9 inches thick. The mine is not much over one mile from the Chicago, Milwaukee & Puget Sound railroad and a spur track could readily be built to it up the broad valley. Between one and two miles south of the Loe mine, the same coal bed, which is doubtless the lower of the two occurring south and southeast of Mott, is mined at the Rumph mine, located in sec. 30, T. 133 N., R. 92 W.

It is probably the upper of the two coal beds which is mined in several places in T. 132 N., R. 93 W. At the Watson mine, in the NW. ¼ of sec. 28, the coal bed is 11 to 12 feet thick, with an overburden of shale which varies in thickness from 4 to 6 feet, and is readily stripped off. The Merry mine is less than 2 miles from the Watson mine, in sec. 34, the coal bed here being 10 feet thick, and it has this same thickness in the Schmidt mine, in the SE. ¼ of sec. 18, of the same township.

The two coal beds are struck in many wells south of Mott. Thus in the SE. ¼ of sec. 7, T. 132 N., R. 92 W., the log of the well shows the following section:

	Feet
Shale and sandstone	25
Coal	8
Shale	1
Coal	1
Shale and sandstone	26
Coal	7

Another well in sec. 6 of the same township, gave the following log:

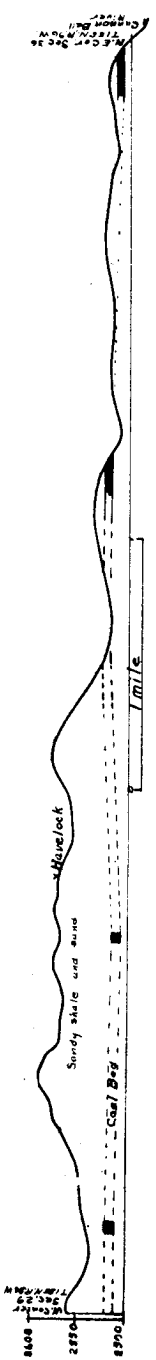
	Feet
Shale and sandstone	98
Coal	9
Shale and sandstone	14
Coal	8
Brown shale	3
Coal	3
Sandy clay	40
Sandstone, soft	18

A well put down in sec. 15, T. 132 N., R. 92 W., passed through a coal bed 10 feet thick at a depth of 36 feet.

These two coal beds which are mined south of Mott, and are encountered in many wells, thus underlie large portions of several townships south of the Cannonball valley.

REGENT-HAVELOCK DISTRICT

One of the most extensive and important coal beds in Hettinger county is found in the region between Regent and Havelock . Since it



An approximately east-west cross section through Havelock, showing the undulations in the Coalbank creek lignite bed. Low spots such as the one immediately west of Havelock tend to collect water and mines in such localities are usually wet.

EXPLANATION OF PLATE X.

The topography of this area was mapped because of the local interest in mining the Coalbank creek lignite bed by stripping. Rather extensive flat areas exist near the railroad in this region, hence a map showing the elevation of the top of the coal bed and the elevation of the surface makes the amount of overburden that must be removed easy to determine.

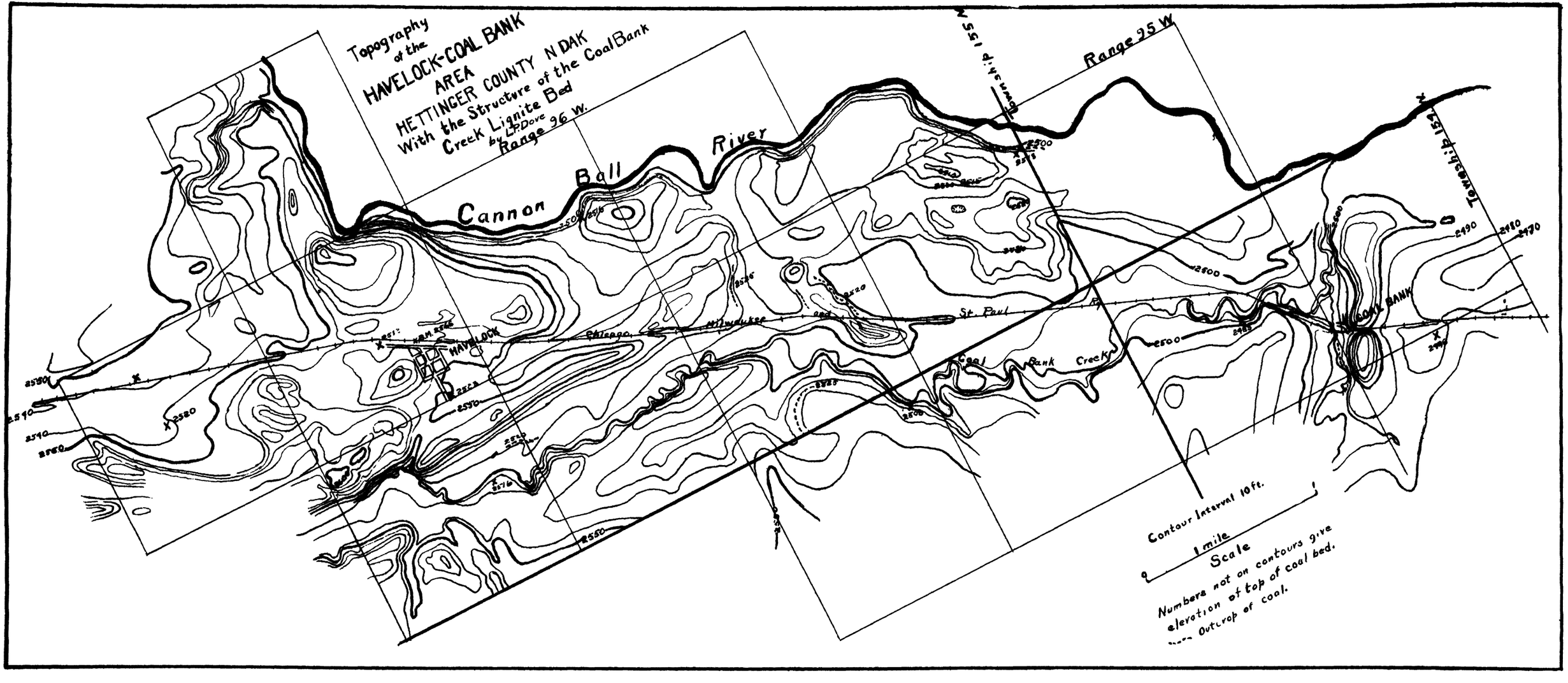
The elevation of the base of the rail in front of the Havelock depot is taken as datum to which all elevations are referred. This is given by the Chicago and Milwaukee Railway Company as 2566 feet above sea level. The mapping was done by a plane table and telescopic alidade. Elevations are probably accurate to 2 feet.

The coal bed mapped is not level. A general easterly dip carries this bed from an elevation of 2520 feet in the western part of the area to an elevation of 2436 feet in the eastern part about seven miles distant. The dip is not regular but is more pronounced eastward from the township line between ranges 95 and 96. In general this coal bed dips eastward at but slightly less than the gradient of the Cannonball river and Coalbank creek, hence the bed is exposed along the banks of both streams for a considerable distance.

The Coalbank creek coal bed maintains a remarkable uniformity of thickness over the whole area studied, ranging from 10 feet to 12 feet thick. It is free from partings or other impurities and is of uniformly good quality. Overlying the bed is a sandy clay-shale which in places changes to nearly pure sand or poorly cemented sandstone. This change is critical in determining the quality of the coal under thin cover. Where the overburden is sand and is naturally porous and occurs high enough to be thoroughly drained, the coal appears to be badly weathered and of inferior quality. The sand is likewise blown about by the wind, some of the hills giving evidence of being in part or wholly dune like. In view of this condition, careful drilling and testing should precede mining, particularly where these conditions are found.

Two mines have recently been opened at Havelock, the Quality Coal Company, one quarter mile south of town and the Havelock Coal Company in the northwestern part of town.

Due to the porous nature of the material overlying the coal water percolates down to the coal and tends to accumulate there since a clay is present under the coal. This condition is particularly noticeable in mines located in valleys or low places. Water increases with increase of rainfall. Advantage should be taken of slight dips in planning any extensive underground mine and strip pits will likewise face the necessity of disposing of at least the precipitation that normally soaks into the ground. Underground entries driven down dip will tend to collect water.


Topography
of the
HAVELOCK-COAL BANK
AREA
HETTINGER COUNTY N DAK
With the Structure of the Coal Bank
Creek Lignite Bed
by L.P. Dove
Range 96 W.
Range 95 W
Township 155 N
Township 154 N
Cannon Ball River
HAVELOCK
Chicago, Milwaukee and St. Paul Ry
Coal Bank Creek
COAL BANK
Contour Interval 10 ft.
1 mile
0
Scale
Numbers not on contours give
elevation of top of coal bed.
Outcrop of coal.

is well exposed along Coalbank creek it may be called the Coalbank coal bed. The outcrop of this coal bed was mapped for a distance of 10 miles along the valley of the Cannonball river and 15 miles along Coalbank Creek valley. It extends east and west a distance of at least 16 miles, or from near Regent almost to the western edge of

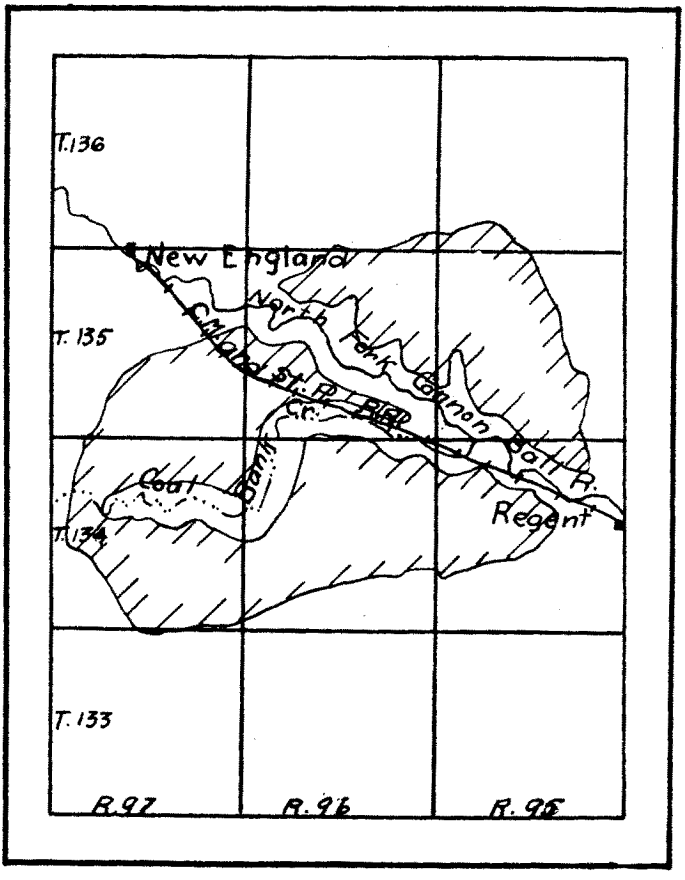


Fig. 8. Sketch map showing approximately the area underlain by the Coalbank coal bed.

Hettinger county, and its north and south extent is probably 8 to 10 miles and over. This coal underlies portions of five or six townships. The Cannonball river and Coalbank creek have eroded their valleys below the level of this coal bed, so that it outcrops along the sides of the valleys and thus can be traced many miles. (See Fig. 8.)

A second lower coal bed is reported to underlie a large area in this district. It lies at a depth of about 180 feet and has a thickness of 22 feet. A well put down at Regent, by the Equity Cooperative Elevator company, to a depth of 215 feet struck this 22-foot bed of coal at 180 feet; it was reached by a well 3½ miles southwest of Regent at the same depth and had the same thickness. Another well close to Black Butte is said to have passed through this same thick bed of coal, and it is reported to have been struck in many wells over a wide area, even as far south as Cedar creek or the South Fork of Cannonball river.

THE COALBANK COAL BED

In most places the Coalbank coal bed lies about 20 feet above the Cannonball river, though it is somewhat undulating and at one point rises 37 feet above the river. Since the latter has an average fall in this district of 7 feet per mile, the coal bed dips toward the southeast by about the same amount per mile.

A large number of measurements at widely scattered exposures of the Coalbank coal bed show that it varies in thickness from 8 to 12 feet.

Since we know approximately the area and thickness of this bed we can make an estimate of the amount of coal contained in it. A seam 10 feet thick contains about 17,000 tons per acre, or 10,880,000 per square mile. The Coalbank coal bed undoubtedly covers at least 100 square miles, and therefore contains 1,088,000,000 tons.

The coal bed mined on Indian creek, at the Davis mine in the NE. ¼ of sec. 23, T. 134 N., R. 95 W., one and a half miles southwest of Regent, is perhaps the Coalbank coal bed, or it may possibly be a higher seam. The bed is 6 feet thick and lies near creek level. A coal bed 4 feet thick has been mined by stripping at the Nelson mine, in the SW. ¼ of sec. 35, T. 134 N., R. 95 W.

The Coalbank coal bed grows thin toward the east, and in one of its most easterly outcrops along the Cannonball River valley, in the SW. ¼ of sec. 11, T. 134 N., R. 95 W., it is only 4 feet thick and lies 21 feet above the river. About one mile west of this outcrop, in the SW. ¼ of sec. 10, the coal is well exposed in the Rogers mine, the section here being as follows:

Section at the Rogers Mine

	Feet
Sandy shale and sandstone	15-20
Coal, with 2-3 inch clay parting 1 foot 8 inches below the top	8
Unexposed, to river level	20

The coal bed continues to thicken toward the west, and where it is well exposed in the river bluff for a distance of 20 rods at the Gibbs mine, in the SW. ¼ of sec. 4, T. 134 N., R. 95 W., it has a thickness of 9 feet 6 inches. Less than one mile north the coal is mined in the extreme southwest corner of sec. 33, T. 135 N., R. 95 W., at the Kouba mine. The bottom of the bed is here not exposed, but it is at least 8 feet thick, and lies 20 feet above the river.

The Cannonball Coal Company mine is located on the Chicago, Milwaukee and Puget Sound railroad, in the SW. ¼ of sec. 5, T. 134 N., R. 95 W. (see analysis No. 5527). The coal bed, which is here 11 to 12 feet thick, is reached by a slope. The coal is 38 feet below the level of the railroad. The Arnold mine is in the NW. ¼ of the same section as the Cannonball mine (see analysis No. 5528).

The Jackson mine is also on the railroad, one-half mile west of the Cannonball mine, in the SE. ¼ of sec. 6, T. 134 N., R. 95 W. The coal here is 11 to 12 feet thick and lies 22 feet below the railroad. It is reached by a drift driven in from the outcrop along Coalbank creek (see analysis No. 5529).

The Weinandy mine is about 1½ miles west of the Jackson mine and is also on Coalbank creek, in the NE. ¼ of sec. 2, T. 134 N., R. 96 W. (see analyses Nos. 5530 and 5531). The coal bed is here 10 to 11 feet thick, with a cover of sandstone 15 to 18 feet thick. It is mined by drifting in along the bed.

Returning to the Cannonball river valley and going west from the mouth of Coalbank creek, the coal bed is seen outcropping in the NW. ¼ of sec. 32, T. 135 N., R. 95 W., its thickness here being 7 feet 8 inches. It is probably the Coalbank coal bed which is worked about 1½ miles north of the latter outcrop, at the Griswold mine, in the SW. ¼ of sec. 19, T. 135 N., R. 95 W. The coal seam is here 5 to 6 feet thick and is overlain by 4 to 6 feet of shale. The latter is stripped off and the coal mined by open pit methods.

The Coalbank coal bed is exposed on the south side of the Cannonball valley, in the southwest corner of sec. 32, T. 135 N., R. 95 W. Its thickness is 8 feet, and it lies 27 feet above the river. The bed

has the same thickness and elevation above the river where it is well exposed one mile farther west, in the SW. ¼ of sec. 25, T. 135 N., R. 96 W. It is this bed which is mined one mile north, on the south line of sec. 24, and has formed the clinker in the NE. ¼ of sec. 25

The most westerly outcrop of the Coalbank coal bed along the Cannonball valley is in the NE. ¼ of sec. 27, T. 135 N., R. 96 W., about one mile northeast of Havelock. A steep cut bank here rises 40 feet above the river, and where not burned out the coal appears in the bluff. Here the bed is mined by means of a drift running in along the seam. The coal at this point has a thickness of 10½ feet and lies 21 feet above the Cannonball river.

A number of wells in Havelock strike the same bed of coal, with a thickness of 12 to 14 feet, at a depth of 60 feet. Prospect holes put down in sec. 28, in which Havelock is located, and in sec. 29, are reported to have reached this coal seam, so that it doubtless underlies these sections.

The Coalbank coal bed outcrops for many miles along Coalbank creek. At the Weinandy mine, in the NE. corner of sec. 2, T. 134 N., R. 96 W., which has already been described on a previous page, the coal seam is 5 to 6 feet above creek level, while about three-quarters of a mile northwest, in sec. 35, T. 135 N., R. 96 W., a thick clinker bed formed by the burning of the same coal seam has an elevation of 27 feet above the creek. The clinker of this bed is found again 3 miles west in the southwest corner of sec. 32 of the same township. The coal bed doubtless underlies most of the S. ½ of sec. 32 and a small area in the NE. ¼, but in the rest of the section it has been eroded. The coal of this seam is mined on a small scale in the SW. ¼ of sec. 5, T. 134 N., R. 96 W., and also in the SE. ¼ of sec. 7 of the same township, where a considerable area had been stripped and the coal uncovered preparatory to mining. The coal bed is here 4½ feet thick, and the shale cover has a thickness of 6 to 8 feet. The clinker from this coal bed is present in the northeast corner of sec. 13, and sec. 14, T. 134 N., R. 97 W.

The Culver mine, located in the SW. ¼ of sec. 14, T. 134 N., R. 97 W., 6 miles southwest of Havelock, is mining the Coalbank coal bed. A large area has been stripped and much coal has been mined. The section here is as follows:

Section at the Culver Coal Mine

	Feet	Inches
Shale	10-18	
Coal	4	
Clay parting		4 to 8
Coal	6	

This coal bed was traced as far west as the center of sec. 17, T. 134 N., R. 97 W., where it has been mined on a small scale on a tributary of Coalbank creek. The coal is here about at creek level and the bed probably passes below the bottom of the valley only a short distance farther west. On account of the absence of outcrops it is not possible to say how much farther the Coalbank coal bed extends in this direction. It doubtless underlies much of this township, as well as those to the north and east.

A higher coal seam is mined 6 miles north of Havelock, at the Albrecht mine, in the NE. ¼ of sec. 33, T. 136 N., R. 96 W. The coal bed is 6 feet thick and lies 115 feet above the Coalbank coal bed at the Havelock mine. A large area has been stripped along one of the branches of Dead Horse creek, and much coal has been taken out. The overburden is a sandy shale varying in thickness from 8 to 12 feet.

It is probably this same higher coal seam which is being worked at the Aaby Light and Power Company mine, located 2 miles north of New England, in the SE. ¼ of sec. 21, T. 136 N., R. 97 W. The coal bed ranges in thickness from 8 to 10 feet and lies about 60 feet above the railroad at New England. It was formerly mined by stripping, but a drift is now being run in along the seam and underground mining will be carried on in the future. An electric undercutting machine is used in mining the coal. The electric light and power plant which supplies New England is located at the mine.

McKENZIE COUNTY

A. G. LEONARD

The entire county is underlain by workable beds of coal. These vary in thickness from a fraction of an inch to 14½ feet. There are at least six beds which have a thickness of 10 feet or more. The thickest coal bed which was found in the region was the one occurring in Hay Draw, in the southwestern part of the county, the thickness of this bed being 14½ feet. Beds of coal from 4 to 6 feet thick are common. The individual beds often show considerable variation in

thickness, thickening in some places and growing thinner in others. Thus one coal bed which was traced many miles along the Little Missouri river was found to range in thickness from 13 feet 10 inches to 5 feet 6 inches. Again, not infrequently the coal beds contain one or more clay seams or partings from 1 to 6 inches or more in thickness.

Many of the coal beds of the county have great extent and cover large areas. A number have been traced by their outcrops a distance of 10 or 12 miles, and one thick bed was followed for 50 miles along the Little Missouri and Missouri rivers. It probably covers between 1000 and 2000 square miles. The great majority of the thicker coal beds undoubtedly underlie many townships where they have not burned out or been removed by erosion.

An interesting illustration of the burning of a coal bed is seen on Redwing creek, where at one point the upper portion of a seam 12 feet 8 inches thick has burned out, leaving only 4 feet 2 inches of coal which is overlain by burned clay or clinker, with a thin layer of ash at its base resting on the unburned coal. See Plate III, Fig 1. The fire was smothered before the entire thickness of the coal was consumed.

The lowest coal bed appearing at the surface in McKenzie county is the one which outcrops at river level on the Yellowstone near the mouth of Horse creek. This coal bed lies about 650 feet above the base of the Fort Union formation, or approximately 1880 feet above sea level. The highest coal seam is that which formed the thick clinker bed capping Sheep Butte, near the head of Horse creek. This coal bed, which has burned out and been largely removed by erosion, had an elevation of about 2650 feet above sea level, or not far from 770 feet above the lower seam at the mouth of the creek. The coal beds of the county thus have a vertical range of nearly 800 feet, and are scattered through this thickness of the Fort Union formation. They are not confined to any one portion or horizon, but are distributed throughout the formation from top to bottom.

It was found impossible to correlate the coal beds in some parts of the county with those occurring in other portions of the region, and for this reason the number of beds present in McKenzie county could not be definitely determined. It is known, however, that the number of workable coal seams, or those with a thickness of 4 feet or over, is between 15 and 20, the total number being probably near

the latter figure. The aggregate thickness of these coal beds is approximately 146 feet.

The undulating character of many of the coal beds is well illustrated by one which outcrops at intervals on the Little Missouri river for a distance of over 25 miles. For a distance of 6 miles above the mouth of Jim creek, in northern Dunn county, it has an average dip toward the southeast of 16 feet per mile. It disappears below river level, but rises above the Little Missouri in a low anticline 2 miles below the mouth of Jim creek (see Plate XI, Fig. 1) to dip again below water level. Four miles below the point where it disappears the bed has an elevation of 21 feet above the river, and continues to rise toward the east at the rate of 16 feet per mile for a distance of at least 6 miles. This coal bed thus forms a broad, gentle syncline, with a low anticline rising near the bottom of the shallow depression.

For convenience of description the coal deposits of McKenzie county are discussed under the following districts: Lower Yellowstone district, Little Missouri district, Tobacco Garden Creek district, and Northern McKenzie County or Missouri River district.

LOWER YELLOWSTONE DISTRICT

The lowest coal beds in the county are those exposed along the Yellowstone river and its tributaries.

A bed of lignite reported to have a thickness of 5 feet appears at river level along the Yellowstone at the mouth of Horse creek. Since it is at water level it is only exposed at low stage of the river. It has been mined here for the use of steamboats. At the base of the bluff bordering the Yellowstone valley between Chaney and Horse creeks there is a thick bed of clinker, probably formed by the burning of this 5 foot coal seam. In this same bluff, at an elevation of 65 feet above the Yellowstone, a lignite bed 4½ to 5 feet thick occurs. It has burned out along the outcrop in many places and is represented by clinker. For some miles below the mouth of Horse creek, the slopes of the Yellowstone valley are gentle and grassed over, so that this upper coal bed does not outcrop, though it perhaps extends for some distance to the north. In the bluffs back about two miles from the river, in the eastern part of T. 150 N., R. 104 W., a coal seam 5 feet thick is present at an elevation of about 310 feet above the river. See Plate VII, Fig 2.

In the higher bluffs bordering Horse creek valley on either side, and back a mile or more from the stream, there is a well marked

clinker bed, formed perhaps by the burning of this same higher coal seam exposed along the Yellowstone. The coal forming this clinker is 5 to 6 feet thick, and underlies large areas of the divide and upland in T. 149 N., R. 103 W., and T. 149 N., R. 104 W. It is undoubtedly this same bed which is present near the head of Chaney creek, in the northwest corner of T. 148 N., R. 104 W., where it is 7 feet thick, and occurs in the divide between Chaney and Bennie Pierre and also in that between Chaney and Horse creeks. This coal has been mined at various points on upper Horse creek and elsewhere.

Two workable coal beds occur along West Charbonneau and Charbonneau creeks. The upper is 6 feet thick, and outcrops for a considerable distance at an elevation of 6 to 8 feet above water level, in the southwest corner of T. 150 N., R. 102 W. The lower coal bed outcrops 4 or 5 miles lower down the creek and has a thickness of 4 feet and over. These two beds doubtless underlie large areas on either side of the creek valley.

Below the mouth of Charbonneau creek the Yellowstone river follows the base of the bluffs on the east side of its valley for several miles, so that the Fort Union beds are well exposed, but no thick seams of lignite are exposed. One coal bed 3 feet 4 inches thick appears near the top of the bluff, at an elevation of 257 feet above the river, while another seam 2 feet 2 inches thick lies 40 feet above the river.

LITTLE MISSOURI DISTRICT

BETWEEN BEAVER AND REDWING CREEKS

Along the Little Missouri river in southwestern McKenzie county, in T. 145 N., Rs. 101 and 102 W., two workable coal beds are present. These outcrop in many places in the bluffs bordering the river. The lower varies in elevation above river level from 38 feet one mile above the mouth of Magpie creek, to only 6 feet at the mouth of the latter stream, while the upper bed lies 300 feet above the Little Missouri. The lower coal seam has a thickness of 4 feet to 6 feet 7 inches, and the upper is 5 feet thick.

The lower bed has been traced along the Little Missouri a distance of 45 miles, or from a point 9 miles south of Medora to the place it disappears below river level 8 miles north of the Billings county line. This coal seam is Bed L of the Billings county lignite beds, which is exposed in many places along the river, and also on lower Beaver creek. See Plate IV.

At the sharp bend of the Little Missouri opposite the mouth of Magpie creek the following section is exposed:

	Feet	Inches
Coal	1	
Shale	5	4
Coal (Bed L)	5	
Shale	6	
Coal		8
Shale, exposed above river	3	

The 5-foot coal bed (Bed L) of the above section disappears below river level about 6 miles below the mouth of Magpie creek.

In the northwestern part of T. 145 N., R. 101 W., and the southeast corner of T. 146 N., R. 102 W., the upper coal bed, 300 feet above the river, is present in places, though it has been extensively burned out along its outcrop. It is 5 feet thick and lies only a little below the level of the extensive flat bordering the east side of the Little Missouri valley.

In the badlands of Boland creek, in the area between that creek and Bennie Pierre, and in the vicinity of Sheep Butte, no less than five coal beds are present, ranging in thickness from 3½ to 14 feet. The lowest of these is near the water level of the Little Missouri river, the highest is 600 feet above the river, occurring in the higher buttes of the region. A sixth coal seam 650 feet above the river has formed the thick clinker which caps Sheep Butte. At least 4 of these coal beds underlie large areas between the Little Missouri and the tributaries of the Yellowstone, in T. 147 N., R. 102 W., T. 147 N., R. 103 W., T. 148 N., R. 102 W., and T. 148 N., R. 103 W.

Sheep Butte has an elevation of 2706 feet above sea level,[1] and the elevation of the Little Missouri river at the mouth of Boland creek is 2014 feet, so that the butte rises nearly 700 feet above the river. This gives a vertical section of 700 feet of Fort Union strata from river level to the top of Sheep Butte, and outcrops are abundant almost from top to bottom, so that a good opportunity is afforded for determining the relations of the various coals beds of the district.

The following is a general section of the coal beds of the Boland Creek-Sheep Butte area:

[1] U. S. Coast and Geodetic Survey, Special Publication No. 19, p. 14.

General Section of the Coal Beds of Boland Creek-Sheep Butte Area

	Feet	Inches
Clinker bed (Bed No. 6) forming top of Sheep Butte. This red clinker has in it a number of thin streaks of coal ash, and at its base is a layer of white ash 11 inches thick. The clinker is formed by the burning of a thick coal bed, and probably several thinner seams, the interbedded clays also having been changed to clinker. Thickness of entire clinker layer	50	
Shale and sandstone	50	
Coal. Bed No. 5. Is present in Sheep Butte, and its clinker caps the high buttes and ridges	3	6
Shale and sandstone	150-200	
Coal. Bed No. 4	9	
Shale and sandstone	125	
Coal. Bed No. 3	6-14	
Shale and sandstone	82-130	
Coal. Bed No. 2	8½-10	
Shale and sandstone	100-135	
Coal. Bed No. 1b	5	
Shale	3	4
Coal. Bed No. 1a	3	5
Shale, to river level	4	

The lower coal bed of the above section (Bed No. 1a) lies about 11 feet above Bed L, mentioned on a previous page, which disappears below river level 6 or 7 miles south of Boland creek. Both 1a and 1b are well exposed in the cut banks along Bicycle creek for a distance of 1 to 2 miles along its lower course, and in the bluffs of the Little Missouri river near the mouth of the same creek. Both coal beds dip below river level not far below the mouth of Boland creek. Bed 1b is exposed on the latter creek about 2 miles above its junction with the river. It is here near creek level and passes below the bottom of the valley not far north of the outcrop. The two coal beds thus appear above water level for a distance of about 6 miles.

Coal bed No. 2, which lies 115 to 150 feet above the Little Missouri, is the seam forming the lower of the thick, conspicuous clinker horizons which appear in the river bluffs near the mouth of Boland creek and for many miles below. This coal bed is also well exposed in the badlands bordering the same creek.

Bed No. 3 is shown by its outcrops to have a wide distribution, and is today probably the most important coal seam in the region. It is known to extend from the south line of T. 146 N., R. 103 W., at least 24 miles north, since the coal or its clinker horizon appears on either side of Horse Creek valley, in T. 149 N., R. 103 W. The bed doubtless reaches at least as far south as the Billings county line. It extends from lower Boland creek, in T. 147 N., R. 101 W., on the east almost if not quite to the Montana line or beyond on the west, or a distance of some 20 miles. In the northwest corner of T. 148 N., R. 104 W., it has a thickness of 7 feet. It is the clinker from the burning of this coal seam which forms the well marked burned clay horizon in the higher bluffs bordering the valley of Horse creek, in T. 149 N., R. 103 W., and in the township to the west. The conspicuous and thick clinker bed appearing in the bluffs bordering Hay Draw, near the southern margin of T. 147 N., R. 102 W., and also found along the valley of Bennie Pierre creek and its tributaries, was formed by the burning of this same coal bed. Where measured in the southeastern corner of T. 147 N., R. 103 W., the coal has a thickness of 14 feet, and another measurement several miles farther east showed 13 feet of coal. In the vicinity of Sheep Butte, not far from the center of T. 148 N., R. 103 W., this coal bed is 7 feet 9 inches thick, with a clay parting 4 inches thick near the base. Farther east, on Boland creek, the thickness ranges from 5½ to 6½ feet.

This thick coal bed, which underlies more or less of the area of 12 townships, has been eroded by the streams of the region, which have cut their valleys through the coal, exposing it in places in the valley sides. Much of the lignite has also burned out along the outcrop, but still this coal bed doubtless underlies large areas in the townships between the Little Missouri river and the Montana line. It must have covered an area of at least 500 square miles. It lies from 210 to 280 feet above the Little Missouri.

Bed No. 4 of the general section underlies considerable areas in the divide between West Charbonneau and Boland creeks, and in the vicinity of Sheep Butte; it is present in the higher buttes, ridges and divides in the Boland Creek drainage basin, in the southern part of T. 148 N., R. 102 W., and most of T. 147 N., R. 102 W.

Bed No. 5 has been largely removed by erosion or burning so that little of it is now left. This coal bed or its clinker caps several buttes near Sheep Butte, and the higher parts of the divide at the head of Boland creek.

The only evidence of the highest coal bed of this region (Bed

No. 6) is today found in the thick layer of clinker forming the summit of Sheep Butte.

On Redwing creek and along the Little Missouri river for several miles above and below the mouth of the creek a thick coal bed is present. It varies in thickness from 11 feet to 12 feet 8 inches. Just above the mouth of Redwing creek the following section is exposed in the bluffs of the Little Missouri river:

	Feet	Inches
8. Coal	5	
7. Shale and sandstone	80	6
6. Coal	11	6
5. Sandstone and shale	25	9
4. Coal	5	6
3. Shale	10	9
2. Coal	1	10
1. Sandstone, exposed above river	12	10

At the bend of the river 2 miles west of the mouth fo Redwing creek the thick coal bed, No. 6 of the above section, measured 12 feet 7 inches. In the bluffs of the river 4 higher coal beds occur in this vicinity. They vary in thickness from 4 to 6 feet. The Redwing Creek coal bed dips toward the east, and this dip carries it below river level 4 or 5 miles below the mouth of Redwing creek. The same bed is seen to extend between 4 and 5 miles up Redwing creek, where it disappears below the level of the valley bottom. At one point where this coal bed is well exposed in a cut bank along the creek, the upper portion of the seam is burned out at one end of the outcrop, leaving only 4 feet 2 inches of coal, while the entire thickness of the coal bed only a few yards distant is 12 feet 8 inches. In the burned out portion, the coal is replaced by the pink clinker which has settled down over the bed, while at the base of this clinker is a layer of ash 6 to 8 inches thick. (See Plate III, Fig. 1.)

COAL BEDS BETWEEN REDWING AND MOUTH OF CHERRY CREEK

Four or five miles below the mouth of Redwing creek, in T. 147 N., R. 100 W., a coal bed 5 feet 10 inches thick appears in the bluffs of the Little Missouri at an elevation of 300 feet above the river. It is doubtless this same coal seam which is present in the river bluffs near the mouth of Squaw creek and is also found along the valley of the latter stream. It is here only 3 feet 7 inches thick where exposed in the bluffs of the river, and lies 210 feet above river level, but where it has been mined on Squaw creek, in sec. 12, T. 148 N.

R. 100 W., the thickness is 5 feet. Above this coal bed, in T. 148 N., R. 99 W., two higher coal beds occur in the bluffs of the river, and doubtless underlie the above township. One of these, which has an elevation of 410 feet above the river, varies in thickness from 5 feet 9 inches to 7 feet 8 inches, while the upper lies 43 feet above the latter, and is 4 feet 4 inches thick.

In the western part of T. 148 N., R. 97 W., in the extreme northwestern corner of Dunn county, a thick bed of coal appears in the high bluffs back some distance from the Little Missouri. It lies about 300 feet above the river and varies in thickness from 9 feet 9 inches to 12 feet 8 inches. The section here is as follows:

Section on Little Missouri river about 2 miles above mouth of Cherry creek:

	Feet	Inches
10. Coal, with three clay partings, varies in thickness from	9 12	9 to 8
9. Shale and sandstone	33	
8. Coal	2	3
7. Shale and sandstone	23	8
6. Coal		11
5. Shale	8	3
4. Coal, varies in thickness from	5 3	8 to 7
3. Shale	24	
2. Coal	1	
1. Unexposed to river, estimated	250	

A detailed section of the upper coal bed, No. 10, is as follows:

	Feet	Inches
Coal	8	
Clay		3
Coal	2	6
Clay		1
Coal		5
Clay		8
Coal		9

A thick coal bed appears in the higher river bluffs between 1 and 2 miles below the mouth of Cherry creek, in the southwestern corner of T. 149 N., R. 96 W. It varies in thickness from 9 to 10½ feet, has an elevation of 360 feet above the river, and is probably the same as No. 10 of the above section.

No thick beds of coal are present in the bluffs bordering lower

Cherry Creek valley. The thickest seam is one occurring near the top of the bluffs, which has a thickness of 3 feet 6 inches.

COAL BEDS ON LITTLE MISSOURI RIVER BELOW MOUTH OF CHERRY CREEK, IN DUNN COUNTY

The coal beds on the Little Missouri river below the mouth of Cherry creek in Dunn county are described in this place in connection with the other beds of lignite along the same stream, in McKenzie county.

Beginning in the northwest corner of T. 148 N., R. 96 W., near the mouth of Burnt (Deep) creek, and extending down the Little Missouri river to its mouth and along the Missouri river at least as far as the west line of T. 146 N., R. 88 W., a distance of 50 miles, a thick coal bed outcrops in many places along the valley. It has burned out extensively along its outcrop, and is then represented by a thick bed of clinker. Since it appears along the southern boundary of the Fort Berthold Indian Reservation throughout the entire distance of 24 miles that the river forms the boundary it may be called the Reservation coal bed.

The coal varies in thickness from 5 feet 6 inches to 14 feet 9 inches, and ranges in elevation from below river level in one place to 100 feet above the Little Missouri.

The Reservation coal bed is the same as bed EE of C. M. Bauer who mapped the outcrop of this and other coal beds on the Fort Berthold Indian Reservation. A complete and detailed description of the lignite deposits of the Reservation south of the Missouri river is contained in the report of C. M. Bauer and F. A. Herald.*

The following is a section of the Reservation coal bed in sec. 8, T. 148 N., R. 96 W., where it lies 100 feet above the river:

	Feet	Inches
Coal		10
Clay	2	
Coal	5	
Clay	1	6
Coal	2	

It will be noted that the bed is here split up into three by clay seams, and is thinner than farther east. No clinker is found much above this point along the river, and this coal bed probably thins out and disappears between here and the mouth of Cherry creek. Where

*Bauer, C. M., and Herald, F. A., Lignite in the Western Part of the Fort Berthold Indian Reservation South of Missouri River, North Dakota: U. S. Geol. Survey Bull. 726, pp. 109-172, 1921.

measured 4 or 5 miles below the above outcrop in sec. 8 the bed is 10 to 11 feet thick and lies 100 feet above the river. About 7 miles southeast, in sec. 33, T. 148 N., R. 95 W., not far from the reservation fence, the coal bed has a thickness of 13 feet 10 inches and is 82 feet above river level. For 3 or 4 miles below sec. 33 there has been so much slumping of the bluffs that the coal bed does not outcrop along the river, and on account of its easterly dip it lies below river level at the mouth of Jims creek. But it is brought above the river again in sec. 22, T. 147 N., R. 94 W., by a gentle anticline. (See Plate XI, Fig. 1.) In this section it rises 9 feet above water level and is 10 feet 2 inches thick, but it again dips below the river within a short distance to appear once more 2 or 3 miles farther east, in sec. 24, T. 147 N., R. 94 W. The bed is here 9 feet 3 inches thick and is 21 feet above water level. About 3 miles southeast, in sec. 33, T. 147 N., R. 93 W., the same bed has a thickness of 5 feet 6 inches and lies 60 feet above the river, while near the reservation fence, in sec. 36 of the same township, its thickness is 6 feet 4 inches and its elevation above river level is 95 feet. This was as far as the Reservation coal bed was traced along the Little Missouri, but as shown from the maps of C. M. Bauer it extends at least as far east as T. 146 N., R. 88 W., or 15 miles below the mouth of that stream. Several higher coal beds appear in the bluffs of the river in T. 147 N., R. 94 W., and T. 147 N., R. 93 W.

The following section of these higher beds is found in sec. 17, T. 147 N., R. 94 W.:

	Feet	Inches
Coal, forms conspicuous clinker horizon	7	
Clay		20-36
Coal, about 330 feet above river level	4	6
Sandstone and shale	50	
Coal	1	
Clay parting		10
Coal	3	
Unexposed, to river	280	

These two beds of coal are present in sec. 19, T. 147 N., R. 93 W., the upper being 10 feet thick, with a 2-foot clay parting, and the lower 4 feet thick. They are separated by 45 feet of sandy shale. Much below these higher beds still another coal bed, No. 4 of the following section, outcrops in secs. 30 and 33, T. 147 N., R. 93 W. It lies only 45 feet above the Reservation coal bed and ranges in thickness from 4 feet to 7 feet 2 inches. In this vicinity there are

thus 4 workable coal beds, the two lower appearing in the following section:

Section of the two lower coal beds in sec. 33, T. 147 N., R. 93 W..

	Feet	Inches
4. Coal, at 110 feet above river	4	
3. Shale and sandstone	45	
2. Coal (Reservation coal bed)	5	6
1. Unexposed to river	60	

The uppermost of the 4 thick coal beds outcrops on the south side of the Little Missouri, in sec. 33, T. 147 N., R. 94 W., where it has a thickness of 15 feet 2 inches and lies about 350 feet above the river. Only 28 feet below this thick bed of coal occurs the second of the higher coal seams of the region, here 5 feet 8 inches thick, and separated from a still lower coal bed 5 feet 6 inches thick by 14 feet of shale.

TOBACCO GARDEN CREEK DISTRICT

In the bluffs bordering the upper valley of Tobacco Garden creek, in T. 151 N., R. 98 W., three coal beds are present and outcrop in the bare clay slopes and buttes of the region. The section of the coal beds in this vicinity is as follows:

Tobacco Garden Section

		Feet	Inches
Shale and fine-grained sandstone, yellow and gray, to top of bluffs.			
Shale, gray, with small concretions		15	
Upper Coal Bed No. 3	This coal has formed the clinker which caps some of higher buttes bordering the valley. Has elevation of 290 feet above Missouri river and 140 feet above Tobacco Garden creek	5	
Shale and sandstone		40	
Middle Coal Bed No. 2	Coal	3	4
Shale and sandstone		50	
Lower Coal Bed No. 1	Coal		8
	Clay parting		5
	Coal		5
	Clay parting		3
	Coal	2	7
	Clay parting		4
	Coal		10
	Clay parting		1
	Coal	1	
Unexposed, to creek level		50	

The upper coal bed which occurs along the valley of Timber Prong creek, the chief tributary of Tobacco Garden in T. 151 N., R. 98 W., and T. 151 N., R. 97 W., and the one which has formed the thick clinker horizon near the top of the bluffs, is doubtless No. 3 of the Tobacco Garden section. This same bed is probably to be correlated with the coal seam which has formed the thick layer of clinker occurring on top of of the wave cut cliffs bordering Dimick lake, in secs. 18 and 19, T. 151 N., R. 96 W. A second coal bed lies 60 feet below the upper bed on Timber Prnog, and this may be No. 2 of the Tobacco Garden section. This lower seam is at least 7 feet thick and has been mined in several places along its outcrop near the base of the bluffs. One locality where mining has been carried on is in sec. 17, T. 151 N., R. 97 W.

The following section is exposed in sec. 10, T. 150 N., R. 97 W., near the valley of North Branch, a tributary of Cherry creek.

North Branch Section

	Feet	Inches
7. Shale, yellow, to top of ridge	25	
6. Shale, brown, carbonaceous	2	3
5. Coal		3
4. Shale	5	
3. Coal, has formed the conspicuous clinker horizon of the region	10	
2. Shale, dark gray	64	
1. Coal	3	

Both Nos. 1 and 3 of the above section are found in the buttes in the northeast corner of T. 150 N., R. 97 W., and the lower coal bed has been mined in sec. 1 of this township. The upper bed (No. 3) is here 9 feet thick, and the lower over 5 feet. These two beds of coal underlie the higher ridges and divides in T. 150 N., R. 97 W., and the adjoining townships on the east and northeast.

Both the upper and lower coal beds of the North Branch section (Nos. 1 and 3) occur along the upper valley of Timber Prong, above Dimick lake, in T. 150 N., R. 96 W. The lower occurs not far above the valley floor, and forms the thick clinker bed occurring on top of the cliffs bordering Dimick lake, while the upper bed has produced the clinker horizon about 80 feet above the lower. The upper coal bed, No. 3 of the Tobacco Garden section, is believed to be the same as the lower coal bed, No. 1, of the North Branch section, in which case there are 4 workable beds of coal in this district.

NORTHERN McKENZIE COUNTY, OR MISSOURI RIVER DISTRICT

Little or no coal appears in the bluffs of the Missouri River valley between the mouth of the Yellowstone and a point several miles above the mouth of Timber creek. Near Baker's Ferry, about 2 miles west of the mouth of the latter creek, a coal bed 8 feet thick occurs 220 feet above river level. The clinker formed by this coal appears in the bluffs for some distance above and below the ferry, and at many points in the large ravine entering the river valley from the west. In many places this thick coal bed lies 30 to 60 feet below the upland surface, and doubtless underlies a large area south and west of its outcrop in the bluffs. To the north the coal has been largely removed by erosion. Across the river, in the bluffs on the east side of the Missouri several miles southeast of Williston, there is a conspicuous clinker horizon formed probably by this same 8-foot coal bed, since it has about the same elevation.

In T. 152 N., R. 100 W., several beds of coal appear in the river bluffs and in those bordering Rough creek and its tributaries. At an elevation of 175 feet above the river is found a coal bed varying from 6 feet in the river bluffs to 10 feet 6 inches three or four miles to the south. A second coal bed with a thickness of 4 feet 3 inches occurs at an elevation of 367 feet above river level. These two coal beds undoubtedly underlie much of the above township, and also those adjoining it on the south and east. The lower and thicker bed is perhaps to be correlated with the 8-foot coal bed occurring at Baker's Ferry, about 8 miles to the northwest.

Several thick coal beds are exposed in the bluffs of the Missouri river in a number of places in T. 153 N., R. 98 W. In the NW. ¼ of sec. 35, of this township, the following section is exposed:

		Feet	Inches
7.	Unexposed to top of bluff		
6.	Coal		10
5.	Shale	37	2
4.	Coal	1	
	Clay parting		14
	Coal		2
	Clay parting		3
	Coal	4	
3.	Shale	32	6
2.	Coal	6	3
1.	Unexposed, to river, about	165	

No. 2 of the above section is doubtless the same bed as the lower coal seam of the Rough Creek area, and this in turn, as previously stated, is perhaps the same as the Baker's Ferry coal bed.

In secs. 25 and 26, T. 153 N., R. 98 W., the following section appears in the bluffs, not far from the old Banks Post Office and store.

Banks Section

		Feet	Inches
11.	Sandstone and shale, with two thin coal beds	41	
10.	Coal	5	4
9.	Shale	16	6
8.	Coal, at 230 feet above river	5	2
7.	Unexposed	35	
6.	Coal	1	6
	Clay parting		9
	Coal	6	
	Clay parting	1	4
	Coal, bottom not exposed, but at least	1	2
5.	Shale, with ferruginous concretions	60	
4.	Coal	7	1
3.	Shale and sandstone, with two thin coal seams	45	
2.	Coal	3	2
1.	Shale and sandstone, with one thin coal seam, to river level	70	

No. 4 of the above section is the same coal bed as No .2 of the previous section, in sec. 35 of the same township.

Numbers 4 and 6 of the Banks section are exposed in the bluff between one and two miles to the north, in sec. 18, T. 153 N., R. 97 W. No. 4 here has a thickness of over 10 feet, with a clay parting 18 inches thick. No. 6 here lies 80 feet above No. 4 and is 8 feet 10 inches thick, with a clay parting 22 inches in thickness. Nos. 8 and 10 both appear in sec. 18, but are here only 2 feet 8 inches and 1 foot 10 inches thick. A higher coal bed is present in sec. 18, with a thickness of 4 feet, and at an elevation of 380 feet above the river.

Numbers 4 and 6 of the Banks section also outcrop in sec. 6, T. 153 N., R. 97 W., but here No. 4 contains numerous clay partings, as shown by the following detailed section of this coal bed:

	Feet	Inches
Coal	2	10
Clay parting	3	3
Coal, impure		2½
Clay parting	1	
Coal		3
Clay parting		2
Coal	4	8
Clay parting	1	8
Coal		10
Clay, blue		11
Coal		2½
Shale, carbonaceous, silicious and hard		9
Coal		10
Unexposed, to river, about	160	

This coal bed is undoubtedly the same as No. 4 of the Banks section, but at that point, it will be noted, this bed contains no clay partings and is composed of 7 feet 1 inch of pure coal.

The two thick coal beds of the Banks section, Nos. 4 and 6, are found on the north side of the Missouri river, in Williams county, where they form conspicuous clinker beds which may be traced many miles.

In sec. 6, T. 153 N., R. 95 W., a thick bed of coal is present and has formed a thick clinker layer. The section of this bed, where it has been mined in sec. 6, is as follows:

	Feet	Inches
Coal	7	
Clay parting		10
Coal, bottom not exposed, but thickness is at least	4	8

The coal is mostly burned out in this vicinity, and its clinker appears in the river bluffs, and in the tributary ravines and badlands. This thick coal bed is perhaps the same as No. 4, of the Banks section. It has been mined in several places on Sand creek.

Several other coal beds appear in the river bluffs in T. 153 N., R. 95 W., in the vicinity of the Davis Ferry. These are shown in the following section:

Davis Ferry Section

		Feet	Inches
13.	Shale, brown	42	
12.	Coal	1	8
11.	Shale, brown	12	6
10.	Coal, has been mined near road to Ferry	4	2
9.	Shale	38	
8.	Coal	3	
7.	Shale, with two thin seams of coal	15	7
6.	Sandstone	50	9
5.	Shale, yellow	17	4
4.	Shale, highly carbonaceous, almost coal	1	
	Clay parting		4
	Coal	2	
	Clay parting		8
	Coal		10
	Shale, highly carbonaceous	2	4
3.	Shale	41	
2.	Coal	1	4
	Shale parting		4
	Coal	5	8
1.	Unexposed, to river level	168	

No. 2 of this section is probably to be correlated with No. 4 of the Banks section.

In the northeastern part of T. 153 N., R. 94 W., in the vicinity of the Brevig Ferry, a coal bed has been mined on a small scale. The section of this bed is as follows:

	Feet	Inches
Coal	5	
Clay parting		6
Coal	1	2

The bluffs on the west side of the Missouri river are low for many miles above and below the ferry, and outcrops are few.

McLEAN COUNTY

L. P. Dove

McLean county lies near the eastern margin of the lignite area of the state and is of more than ordinary interest for the following reasons:

(1) Economical utilization of coals have been the subject of close investigation during the past decade. The present tendency not only in North Dakota but elsewhere is toward the location of large unit steam-driven electrical stations at mines, the power being distributed by high tension lines to distances of 75 and 100 miles and even 200 miles, both for power and heat.

(2) The best market both for power and fuel at present and probably for some time to come will be the eastern half of the State.

(3) It is fairly well served with railroads.

(4) There are no important workable lignite deposits east of this county so far as known except in the Turtle Mountains, hence this area together with a similar area to the northward are in an advantageous position to serve increasing demand for fuel and power.

This area has been studied in more or less detail in the past, especially the Missouri River section. Wilder[1] mentions several localities where lignite is available especially for pumping water for irrigation of flats adjacent to the Missouri river. Smith[2] carried the study further including a more detailed description of the available coal. Various biennial reports of the State Engineer of North Dakota also furnish data on the mines of the region. It was the object of the survey to extend the investigations and gather additional data from the new mines opened in the past ten years. Acknowledgements are due to A. G. Leonard, State Geologist, for data on the area adjacent to the Missouri river west of Underwood. Wholehearted cooperation of mine owners and operators at every mine visited made the work pleasant and facilitated the gathering of data.

Most of the mining in McLean county is carried on in a belt about 15 miles wide lying just east of the Missouri river and adjacent to the Bismarck-Minot branch of the Minneapolis, St. Paul and Sault Ste. Marie railroad. It includes the towns of Wilton, Washburn, Underwood, Coal Harbor, and Garrison. It was the lignite deposits of this district which were studied in particular.

TOPOGRAPHY

The maximum relief of the area from the level of the Missouri river to the highest hills is about 525 feet. The average relief is much less, the surface being in fact a gently rolling prairie except where tributary streams adjacent to the Missouri river have cut deep ravines with bluff-like valley walls.

Essentially all the area lies in the extra-morainic belt of the Wisconsin ice sheet and while largely covered to varying depths with glacial drift with morainic hills, many large areas are almost flat.

[1]Wilder, F. A., U. S. Geol. Survey Water Supply and Irrigation Paper No. 117, 1905
A topographic map, the Garrison Quadrangle, on a scale of one inch to the mile, has been recently issued by the United States Geological Survey. This includes a portion of the area described above.

[2]Carl D. Smith. The Washburn Lignite Field. U. S. Geol. Survey Bull. No. 381, pp. 19-29, 1910.

Much outwash material from abandoned streams that originated in the glacial ice may be noted, especially southeast of Washburn, about Underwood and south of Garrison. Practically all slopes are grassed over or are under cultivation, making exposures of bed rock infrequent. Erosion since glacial time has not changed the topography to an appreciable extent except along the larger streams. Intermittent lakes are numerous and by midsummer are usually dry or marked by white saline mud.

GEOLOGY

The stratified rocks of the region are of Lance[3] (Cretaceous or Tertiary) and Fort Union (Tertiary) age. Over the stratified rocks is spread a mantle of glacial material in part of Wisconsin age and probably in part older.[4]

The following table shows the relationship of the rocks exposed:

Period	Stage of Formation	Description of Material	Localities
Pleistocene	Late Wisconsin stage	Gray to yellow boulder-clay and Outwash material	Altamont morine extending from Max, south-southeast. Gravel in terraces in major valleys and flattish plains, notable ones being those west and southwest of Underwood.
Unconformity	Pre-Wisconsin?	Dark gray boulder-clay and boulder beds	Rather uniform mantle west of Altamont moraine, east of Missouri river.
Tertiary Conformity	Eocene Series Fort Union formation	Gray and dark gray shales, yellow sandstone and lignite	Bed rock over greatest part of the area
Tertiary?	Lance formation. Cannonball marine member.	Gray, dark gray, brown and yellow clays and sandstone	Bed rock in bottom of Missouri river valley in southern part of area

The Fort Union formation contains the workable deposits of lignite in this region, hence a more detailed description of these rocks may be of value.

[3]Stanton, T. W. The Fauna of the Cannonball Marine Members of the Lance Formation. U. S. Geol. Survey, Prof. Paper 128, 1920.

[4]Leonard, A. G. Pre-Wisconsin Drift of North Dakota. Jour. of Geology, Vol. XXIV, 1916, also Bismarck Folio, No. 181, U. S. Geol. Survey, 1912.

The extreme lower portion of the Fort Union was not examined. A rather persistent sandy member or members in part cemented into a dense, hard sandstone forms the topmost layer of a series of buttes in the southern portion of the area, notably the buttes in SE. ¼ of sec. 28, T. 142 N., R. 79 W., and sec. 6, T. 141 N., R. 79 W. Six to eight miles west and northwest of Wilton at about the same horizon but lower in altitude a sandstone forms the rims of the bluffs along the streams tributary to the Missouri river. A similar sandstone forms a ledge along the east bank of the Missouri river at Washburn and this bed may be traced eastward along the north valley wall of Turtle Lake creek. It is probably the same sandstone that is the aquifer in a well of Edward Kugler near the west edge of the SE. ¼ of sec. 6, T. 144 N., R. 82 W., found at a depth of 148 feet and showing a thickness of 60 feet. Locally the sandstones are more closely cemented with lime or limonite forming sandy concretions, some of immense size. Not uncommonly these concretions forming the more resistant portions of the sandstones have been incorporated into the glacial clays. Light gray to ash colored clays and sandy clays make up the bulk of the Fort Union formation. Lignite beds of varying thickness are intercalated with the shales, clays and sandstones.

STRUCTURE

There are few if any large or conspicuous structural features. All the rocks are tilted gently to the north and northwest with dips that apparently do not exceed 10 feet per mile except locally where dips of 15 or 20 feet per mile may be noted. Fig. 5 shows the structure at the Washburn Lignite Coal Company mine.

No faults of any magnitude were noted though a few small faults are exposed in the steep bluff along the Missouri river at Washburn due probably to slumping. One with a vertical displacement of 12 feet was noted. Evidence of faulting of the lignite beds at the Pfister mine 8 miles northwest of Washburn was reported but not verified.

PRE-GLACIAL EROSION

Features other than structure that control the presence or absence and the quality of the lignite are preglacial, and to a less extent post-glacial, erosion. A topography equal in relief and locally more rugged than the present surface was developed in the rocks previous to the coming of the glaciers.

The lignites, shales and sandstones at their outcrops were subjected for a long time to the various agents of weathering and erosion. The blue and gray clays and shales were weathered to a yellow or brownish hue. Vegetation no doubt grew on this old surface. The lignites were burned at the outcrop or if close to the surface and escaped burning, were weathered to a more or less incoherent soft or ashy mass.

The slowly on-coming glacier buried this surface first under a thick mass of slowly moving ice, modifying the hills and hollows somewhat, and on its retreat left a mantle of boulder clay, gravel, sand or silt over this old surface. The broader features preserve this surface but smaller features were probably obliterated. The ideal cross section diagram (Fig. 3) will serve to illustrate the present relation over many such areas.

A study of the land so explored by the drill and the surface elevation, depth to coal and kind of material penetrated, carefully plotted, makes an invaluable aid to later mining and is essential to an approach to correct evaluation of the coal.

Such a record has been kindly furnished by the Washburn Lignite Coal Company and plotted by the writer in Fig. 5. It will be noted that the areas underlain with "soft"[5] coal are probably old valleys and hence may be expected to be longer than wide.

Since the lignite beds that are near the surface are receiving most attention due to their availability and also to the fact that the mining of deep coal beds is commonly beset with the problem of handling large quantities of water, the exploration for coal in a region that has been glaciated is attended with the features above described. Where there has been no glaciation the problem is much simplified as could be seen if the glacial materials in Fig 3 were removed.

A coal that lies close enough to the surface to have the overburden removed by stripping should receive special attention in view of the above conditions. Drilling should be carefully done and the data carefully preserved.

In certain limited areas the swamp material which later was to become coal was partially or totally removed by erosion before burial by the overlying beds. In such few cases the coal usually preserves its hard quality until it gives place abruptly to sand, clay or shale that filled the channel.

[5]The use of the word "soft" and "hard" only applies to whether the lignite is friable or crumbly or whether it is resistant and substantial and has no reference to the common usage of the terms hard and soft coal, for anthracite or bituminous. So far as known the coals of North Dakota are all lignitic.

AREAL EXTENT OF THE COAL BEDS

Since both lack of time, absence of drill or well records and little definite knowledge of pre-glacial erosion makes it impossible to be certain of the presence or absence of coal away from exposures or mines, no attempt will be made to predict the presence of coal except in the most general way. In certain areas it may be rather positively assumed to be absent; in other areas probably present, but the quality and quantity uncertain. A systematic effort on the part of well drillers to preserve accurate logs of wells and file them with the State Geological Survey would be an invaluable aid to the definite location of promising coal areas.

An attempt is made in the accompanying map, Fig. 10, to present the most recent information.

The important mining districts are here grouped for convenience of description into the following: Wilton, Washburn, Underwood, Coal Harbor, and Garrison districts.

WILTON DISTRICT

The most important bed of lignite in the district, the Wilton bed, is the one mined by the Washburn Lignite Coal Company at mine No. 2 about two miles east of Wilton, the shaft being on the SW. ¼ of sec. 5, T. 142 N., R. 79 W. This is one of the largest and best equipped mines in the state. Smaller mines on the same bed are the Lind, SW. ¼ of sec. 6, T. 142 N., R. 79 W., Asplund, SW. ¼ of sec. 4, Peterson, NW. ¼ of sec. 9, and the Eckland in sec. 8, all in the same township. (See analysis No. 5532.) This bed varies in thickness from 8 to 14 feet and is in general of good quality except locally where preglacial weathering and erosion have made it soft or entirely cut it out. A clay parting is locally present about 18 inches from the bottom but is not persistent in extent or thickness. This bed probably underlies a considerable area to the south and east in T. 142 N., R. 79 W. The coal bed terminates to the east rather abruptly in a line of hills trending through the Asplund and Peterson properties and is reported to be absent in the vicinity of Wilton and southward. The valley along the boundary between T. 142 N., R. 79 W., and T. 143 N., R. 79 W., occupied by the Wilton branch of the Northern Pacific railroad, cuts it out. It reappears in the higher ground in T. 143 N., R. 80 W., and T. 143 N., R. 79 W., its position being marked by a line of clinker in secs. 13

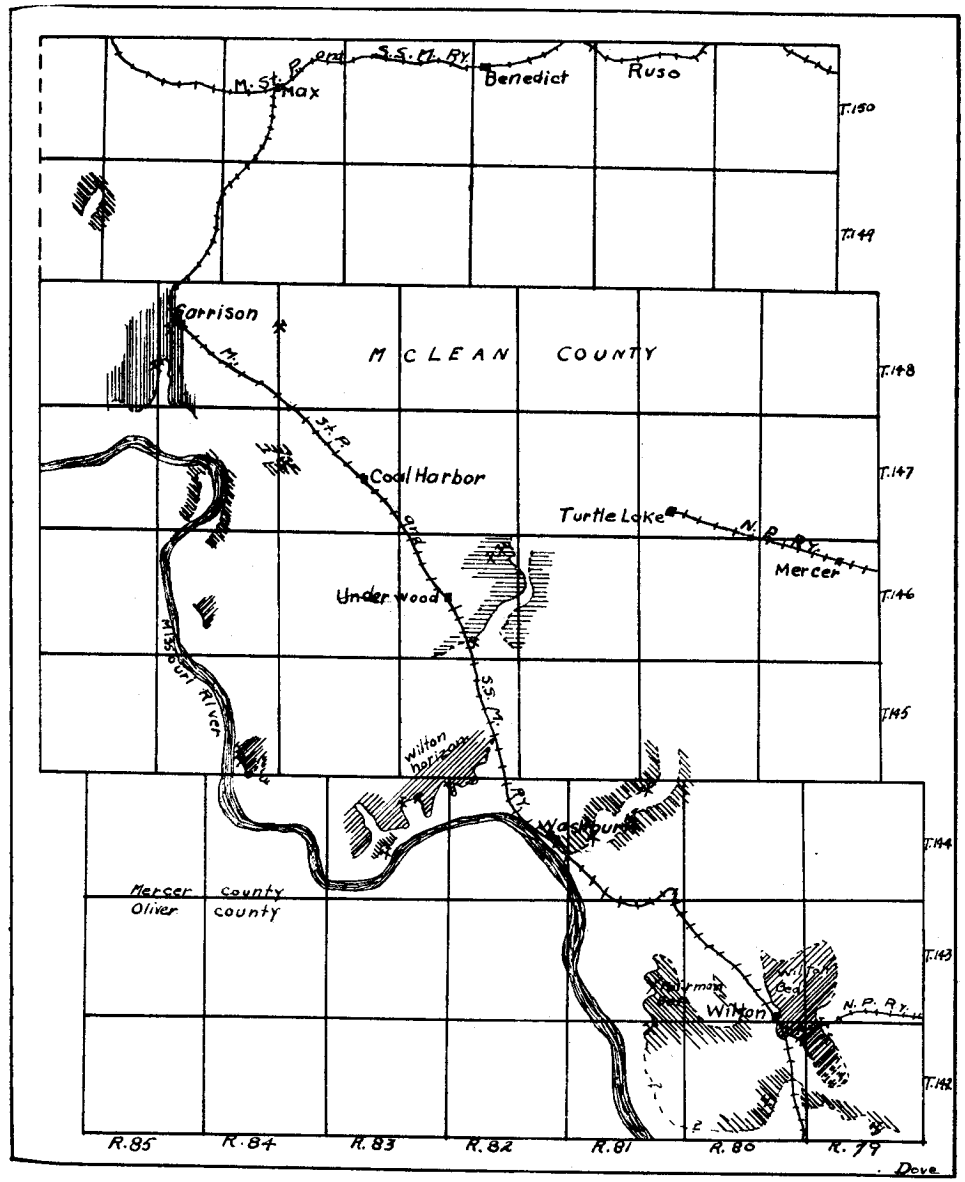


FIG. 10. SKETCH MAP OF THE WILTON-GARRISON DISTRICT.

This map shows the approximate distribution of the coal beds. Since the area is almost wholly covered by glacial drift few beds could be traced continuously but in many cases coal was reported from wells or other borings and thus some information was gained about the extent of the beds at a distance from the natural exposures.

and 14, T. 143 N., R. 80 W., which defines the northern limit in this portion of the area.

About 60 to 80 feet below the level of the Wilton bed another which is locally 6 to 9 feet thick is mined in several localities. This coal is mined at the Yungst-Berger mine in NE. ¼ of sec. 34, T. 141 N., R. 79 W., and could be roughly traced to the Laubach mine in the S. ½ of sec. 27, T. 142 N., R. 80 W., though probably absent from most of the intervening country except in the higher portions. This seems to lie at about the same horizon as a coal bed exposed along the road about 2½ miles west of Wilton and on the north line of sec. 31, T. 143 N. R. 80 W., where there are some old coal pits but no exposure when visited. At about this level coal was formerly mined in the NE. ¼ of sec. 27, T. 143 N., R. 81 W., at the Fairman mine.

WASHBURN DISTRICT

In the immediate vicinity of Washburn but little lignite is found. A bed one foot thick underlain with three feet of black sandy impure lignite outcrops in the cellar under the residence of Mr. Peterson about 1 mile southeast of Washburn. Several outcrops of lignite were noted in the valley of Turtle Lake creek. On the farm of Eric Larsen, sec. 10, T. 144 N., R. 81 W., the following section has been exposed in a pit:

	Feet	Inches
Lignite, good	1	
Lignite, black, impure		4 to 8
Lignite, good exposed	2	

A stripping pit where several hundred tons of lignite have been mined for local use is located on sec. 2, T. 144 N., R. 81 W. The following section was exposed on the SW. ¼ of the NW. ¼ of sec. 2:

	Feet	Inches
Drift	1	
Clay, gray and yellow, sandy	1	8
Clay, black	1	
Lignite, good	1	
Lignite, soft, smutty	1	
Sandstone, brown, friable	4	

This is probably at the same horizon as the exposure on the Eric Larsen farm.

A cut in the roadside about the center of the north line of sec. 20, T. 144, R. 81 W., exposes a 2-foot bed of lignite at about the same horizon as above.

A friable cross-bedded gray to yellow sandstone locally cemented to a hard resistant rock may be traced for several miles along the valley of Turtle Lake creek. Where this sandstone is cemented it locally forms steep cliffs which protrude into the valley through the rather thin mantle of glacial drift.

The most important district adjacent to Washburn is that beginning about 5 miles west of town and occupied by the Satterlund and Kugler mines. The coal bed varies in thickness from 8 to 11 feet and is in general solid and resistant to tools. The Satterlund mine has been operated for many years and the quality of the coal is well known. The Kugler mine is but recently opened and appears to be in the same bed. Samples from the Kugler mine indicate the quality of this coal is essentially the same as taken several years ago from the Satterlund mine.

Two beds of lignite outcrop along the road in the SW. ¼ of sec. 8, T. 144 N., R. 82 W., separated by 60 feet of friable sandstone and sandy clay. The lower of these lies about 100 feet above low water in the Missouri river. Both of them are traceable by seeps and clinker in secs. 5, 6, 7, and 8. The lower bed seems to correlate with the Satterlund-Kugler bed, but so far as could be learned is thin at the outcrop. The sketch map, Fig. 10, shows the probable areal distribution of these beds.

Several pits expose a bed of lignite in the west half of sec. 10 and the east half of sec. 11, T. 144 N., R. 82 W., and at the Youngquist mine in the SW. corner of the NE. ¼ of sec. 11, 7 feet of a good grade of lignite was noted. No good exposures of the same bed could be found on the Pfister property in the NW. ¼ of sec. 10 though considerable quantities have been mined. This horizon is traceable by clinker and seeps southward along both sides of the coulee that extends northwestward from the Missouri river, but no fresh exposures were noted. This horizon seems to be that of the Satterlund-Kugler bed.

On the farm of Ed. Furst in the NE. ¼ of sec. 17, T. 144 N., R. 83 W., a few hundred yards below the barn 3 feet 8 inches of good lignite is exposed in a strip pit, the full thickness not being visible. The bed is reported to be 6 feet thick and is reported in the well at the house.

Near the center of sec. 21, T. 144 N., R. 83 W., the following

section was exposed in the creek bank about 50 feet above low water in the Missouri river:

	Feet	Inches
Clay, yellow, sandy	8	
Lignite, thin, impure	1	2
Shale, yellow, sandy	10	
Lignite, weathered, at least	2	6
Shale, black, bituminous	3	

During high water in this creek, blocks of lignite are broken off. The full thickness and quality of the lignite here could not be accurately determined.

An old stripping pit exposes 6 feet of weathered lignite near the center of the north line of sec. 36, T. 145 N., R. 83 W. The sketch map, Fig. 10, shows the portion of sec. 36 that is possibly underlain with this bed of lignite. The elevation of this bed is about 240 feet above low water in the Missouri river. Glacial drift overlies it closely, hence its area and quality are uncertain.

UNDERWOOD DISTRICT

Adjacent to the town of Underwood at least one bed of lignite is mined. It varies from 5 to 14 feet in thickness. A typical composite section from the Hansen mine on the E. ½ of the SW. ¼ of sec. 18, T. 146 N., R. 81 W., is as follows:

	Feet	Inches
Shale, gray, sandy, with alternating bands of ironstone concretions 4-12 inches apart	9	
Shale, dark gray	1	6
Shale, gray, sandy, with small concretions grading downward into micaceous, shaly, thin-bedded sandstone	4	8
Shale, gray, jointed		8
Lignite, impure		
Shale, dark gray, jointed, soapy and free from grit	1	4
Lignite, with no clay partings of consequence	8	8
Shale, black, gray or brown, with impure lignite		
Unexposed	11-12	
Lignite, reported	5-7	

The lignite bed 8 feet and 8 inches thick in the above section is also being mined just west of the Hansen property at the Fjeddal mine on sec. 18 where conditions are very similar. Probably this same bed or one at about the same horion is being mined on the Ray Bartley farm in sec. 11, T. 146 N., R. 82 W. where this bed is 7 feet 4 inches

thick. A bed of lignite reported to be 6 feet 6 inches in thickness is being mined on the Frederick farm in the SW. ¼ of sec. 1. This bed is cut out by the coulee that trends north and south just east of the township line but probably continues for a limited distance east of the coulee. Several other stripping pits and shaft mines have produced from the same bed, most of them being shut down at the time of the writer's visit.

West and north of the coulee, southeast of Underwood, this coal bed lies at a depth ranging from 25 feet to 110 feet below the surface, dipping gently to the northward, while the land slopes southward. It thickens westward where a thickness of 12 to 14 feet has been reported one mile south of Underwood and 20 feet about 5 miles west. South of Underwood along the railroad in secs. 27, 28 and 33 it ranges from 12 feet to 13 feet in thickness. Immediately about Underwood, where it is the thickest, considerable water is present in the coal, in fact the coal bed is an important water horizon. Southward in secs. 27 and 33 it is dry. On the SW. ¼ of sec. 34 a small stripping has been operated on what is probably the same bed and here about 7 feet 6 inches of coal was exposed with the bottom not visible. A thin clay parting separates this bed into an upper member 5 feet thick and a lower member 2 feet 6 inches thick. The overburden is glacial drift and clay shale.

It seems probable that this coal bed underlies a considerable portion of the region between Underwood and the Missouri river as a bed was reported in wells at about this horizon.

COAL HARBOR DISTRICT

Several exposures of coal are available for study in the valley of the Missouri and its tributaries west of the station of Coal Harbor, and near old Coal Harbor. The generalized section of the area between Wolf Creek in T. 147 N., R. 84 W. and Mannhaven is as follows:

	Feet	Inches
1. Alternating beds of white to gray sandstone and sandy shale and thin seams of lignite 4-40 feet apart	100	
2. Alternating yellow and gray sandy shale	50	
3. Shale, yellow, sandy	8	
4. Lignite and clay in thin seams	2	6
5. Clay-iron concretions, buff to red	3	
5. Shale, gray and brown, alternating	15	
7. Lignite	1½-2	
8. Clay	1	
9. Lignite	3-4	

10. Shale, gray, and sandstone with thin beds of lignite in upper portion	25-47
11. Lignite at very low water level in sec. 22 of T. 147 N., R. 84 W. At mines in NW. ¼ sec 34, two miles south, 23 feet above the water level	7-8½

No. 11 of the above section is mined at the Joe Mann mine in the NW. ¼ of sec. 34 and the 8-foot bed at Mannhaven is doubtless the same bed.

The coal mined at the Eskes mine is No. 7, 8, and 9, of the above section. Wilder[6] reports a 4-foot bed of lignite in the bluffs back of Hancock. This is probably also 7, 8 and 9 of the above section.

Two mines, the Montgomery and the Brewster in sec. 35, T. 145 N., R. 84 W. are operating in a coal bed 8 feet thick which lies about 30 to 40 feet above low water in the Missouri river, and is probably also No. 11 of the above section. A bed reported to be 16 feet thick is found in wells in secs. 30 and 32, T. 145 N., R. 83 W. and seems to lie at about the horizon of the coal mined in sec. 35 above. A heavy bed of lignite is reported from a well 5 miles southwest of Underwood which may be the same bed, allowing for a gentle westerly dip of the strata.

At the Montgomery mine the coal contains a large percentage of black coal with cubical cleavage and is more sub-bituminous in appearance than most lignite. The coal is 8 feet thick with no clay partings.

GARRISON DISTRICT

The Garrison Coal Light and Power Company is operating a mine just southwest of the town of Garrison where the following composite section was observed in the mine.

	Feet	Inches
Lignite, good	3	
Clay, blue gray, jointed with thin seams of lignite and limy concretions up to 2 feet long in lower 8 inches	4	
Lignite, impure		6-12
Clay, pure in upper portions and impure in lower portion with thin seams of lignite	3	6
Lignite, very hard and resistant. Being mined. Average	6	6
See analysis No. 5533.		
Impure, brownish clay and petrified logs and lignite		

[6]The Lignite of North Dakota and its Relation to Irrigation, U. S. Geol. Survey Water Supply Paper, No. 117, 1905.

It is reported that the two upper beds of lignite coalesce southward.

In Garrison creek valley, which extends southward from Garrison to the Missouri river, the coal bed worked by the Garrison Coal, Light and Power Company, is being mined by a rather large scale stripping operation in secs. 18 and 19. During the late summer of 1922, Stevens Brothers, contractors, of St. Paul, uncovered about five acres of this 6-foot coal bed. The stripping was confined to the terrace in the valley of Garrison creek, the coal lying at or slightly above water level in the creek. This terrace is from 40 to 80 rods wide and the overburden which is being removed is made up of materials as follows:

	Feet	Inches
Gravel, coarse to fine, glacial drift in part	2-6	
Clay shale, yellow	4-6	
Lignite		8-18
Clay shale, gray	2-2½	
Lignite		6-24
Clay shale, gray to blue	8-10	
Lignite, the bed mined	6-6½	

The overburden ranges from 16 to 25 feet in thickness with an average of about 22 feet. Stripping was largely done by the use of elevator graders to dump wagons, the waste being hauled to low spots where the coal is gone. A steam driven dragline operated from a mast was also used in stripping.

A spur track from the railroad at Garrison serves the two tipples which are equipped to receive the coal as hauled from the pits in dump wagons, and by gravity it goes to screens and thence to box car loaders or directly into open cars.

Approximately 50,000 tons of coal were uncovered when these strippings were visited about November 1, 1922.

A coal bed that seems to lie at about the same horizon as the above coal is being mined in the northeast corner of sec. 25, T. 148 N., R. 85 W. and sec. 30, T. 148 N., R. 84 W. where a thickness of 6 feet 2 inches was noted. The creek bed is here cut below the coal and further down the valley the bed has burned, forming a salmon pink clinker which, due to its superior resistance, has formed a terrace in the valley. This clinker horizon is tracable along the main valley of the Missouri in secs. 35 and 36, T. 148 N., R. 85 W. and secs. 5 and 6, T. 147 N., R. 84 W.

Five miles east of Garrison a bed of lignite has been mined for

some years at the Johnson mine which was closed when visited by the writer.

Northwest of Garrison on the NE. ¼ of sec. 12 T. 149 N., R. 85 W. is a strip pit showing the following section:

	Feet	Inches
Glacial gravel	5	
Clay, blue	1	3
Lignite	6	6
Clay seam, not persistent	1	
Lignite, good	1	6
Clay, blue, reported		

See Plate XII, Figs. 1 and 2.

This pit when visited was being unwatered by Aiken and Taylor, leasees. Indications seem to point to a large level area underlain by this coal with a relatively light overburden of from 8 to 30 feet. These are factors that would contribute to favorable conditions for stripping on a large scale.

NORTHWESTERN McLEAN COUNTY DISTRICT

The lignite resources of that portion of McLean County west of range 87 is discussed at some length in a report by Max A. Pishel,[7] published in 1912 by the United States Geological Survey.

A review of the more important and thicker beds described in the above report is given here.

Essentially all parts of this area are a considerable distance from the Sanish branch of the Minneapolis, St. Paul and Sault Ste. Marie railroad.

Projected extensions of the Northern Pacific and Great Northern railroads follow the north bank of the Missouri river from about 5 miles south of Garrison to the mouth of the Little Missouri river. Should either of these be built the more important lignite beds along the north bank of the Missouri river would assume some importance.

In the larger area included in the report Pishel says "Twelve beds of lignite were counted in the columnar section exposed in sec. 25, T. 150 N., R. 93 W. none of them less than 1 foot thick. Although there are six horizons at which lignite 30 inches or more in thickness is found, not more than three such beds have been found at any one place. In the region between Elbowoods and Rising Water creek no lignite of economic value at present was found, and the writer

[7]Max A. Pishel. Lignite in the Fort Berthold Indian Reservation, North Dakota, North of Missouri River. U. S. Geol. Survey Bull. No. 471, pp. 170-186, 1912.

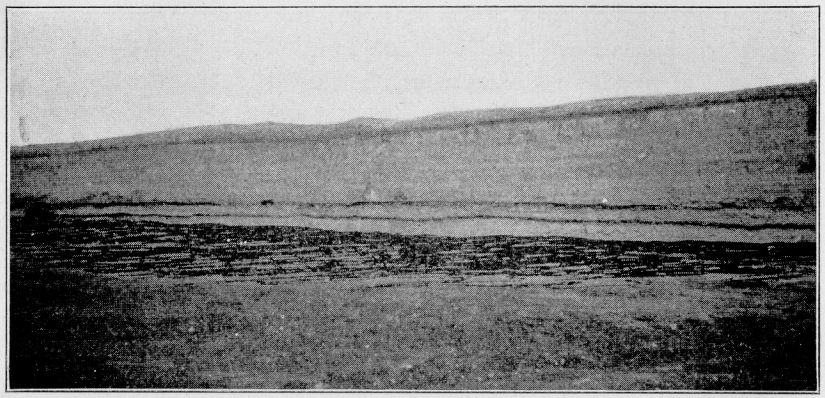


Fig. 1. Several acres of coal near Garrison, N. D., stripped in 1922 by Stevens Bros. Coal is here 6 feet thick. Overburden is 20 to 24 feet thick, of which the upper half is glacial materials and the lower half is clay shale and thin beds of lignite.

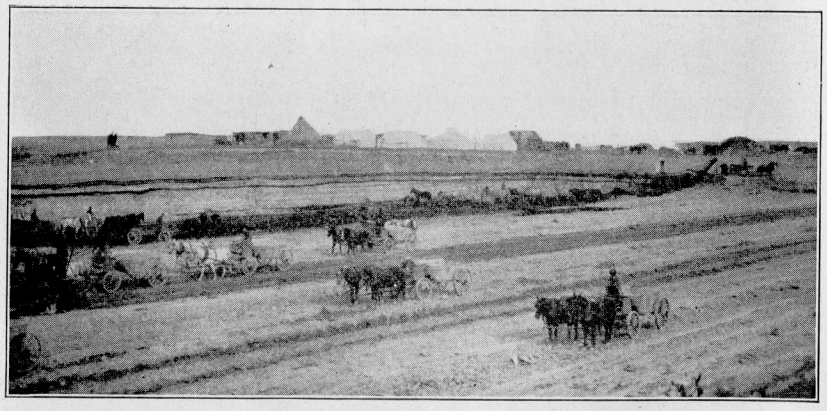


Fig. 2. Stevens Bros. stripping near Garrison showing use of elevating grader and dump wagons for removing overburden. The coal was dug by small steam shovel and hauled to tipple in dump wagons.

feels confident, in light of the few outcrops and the fact that clinker beds are entirely wanting, that no lignite bed 30 inches or more in thickness exists in this area in the strata above river level. The fields in which such beds are known—the Armstrong district and the Big Bend district—are thus separated by an area in which beds 30 inches thick or more are not known to occur."

Beds 6 feet thick or more are found only in the following localities in the Armstrong district.

Bed 1a, the lowest as designated by Pishel, was traced along the banks of the Missouri river and appears to range in thickness from a few inches to over 7 feet about three miles west of Armstrong, thinning westward or is split by clay partings so as to injure its value.

Concerning Bed 2, Pishel says "In the northeastern part of T. 147 N., R. 87 W., Bed 2 lies high up under the flats which are so conspicuous in this particular locality and is not exposed. However, from the center of the township, west to within three miles of Elbowoods it can be traced almost continuously by its clinker beds. Throughout this district the clinker left by Bed 2 is heavy, indicating a rather thick bed or pure lignite, or both." This bed appears to be about 6 feet thick about 6 miles east of Elbowoods and may be as thick or thicker north of Armstrong. Along the east line of T. 150 N., R. 91 W. bed 2 is exposed along the east side of Shell Creek valley but does not seem to attain a thickness of 6 feet or over in any sections exposed.

MERCER COUNTY

A. G. Leonard

Two of the largest mines in the state are located in this county and on account of the large output from these mines Mercer county has for several years ranked third in its production of coal, being exceeded only by Burleigh and Burke counties.

Beulah-Zap Coal Bed

While there are a number of coal beds in this region, perhaps the most important and extensive is the one which outcrops in many places along the valley of the Knife river and Spring creek, and since it is mined at Beulah and Zap, it may be called the Beulah-Zap coal bed. The area underlain by this coal is traversed by the Killdeer branch of the Northern Pacific railroad. See map plate XIII.

The Beulah-Zap bed ranges in thickness from 13 to 24 feet in the vicinity of Beulah and Zap, to 6 feet at the Ingold mine south of Golden Valley. The average thickness is probably over 12 feet. This coal bed extends from about 2 miles west of Hazen west almost if not quite to the Dunn county line, or nearly 24 miles east and west. It extends from near the northern edge of T. 145 N., R. 86, 87 and 88, to the Knife River valley south of Zap, and to the southern edge of T. 143 N., R. 88 W., south of Beulah, or 18 miles north and south. It underlies

NOTES ON PLATE XIII, SHOWING AREA UNDERLAIN BY BEULAH-ZAP COAL BED

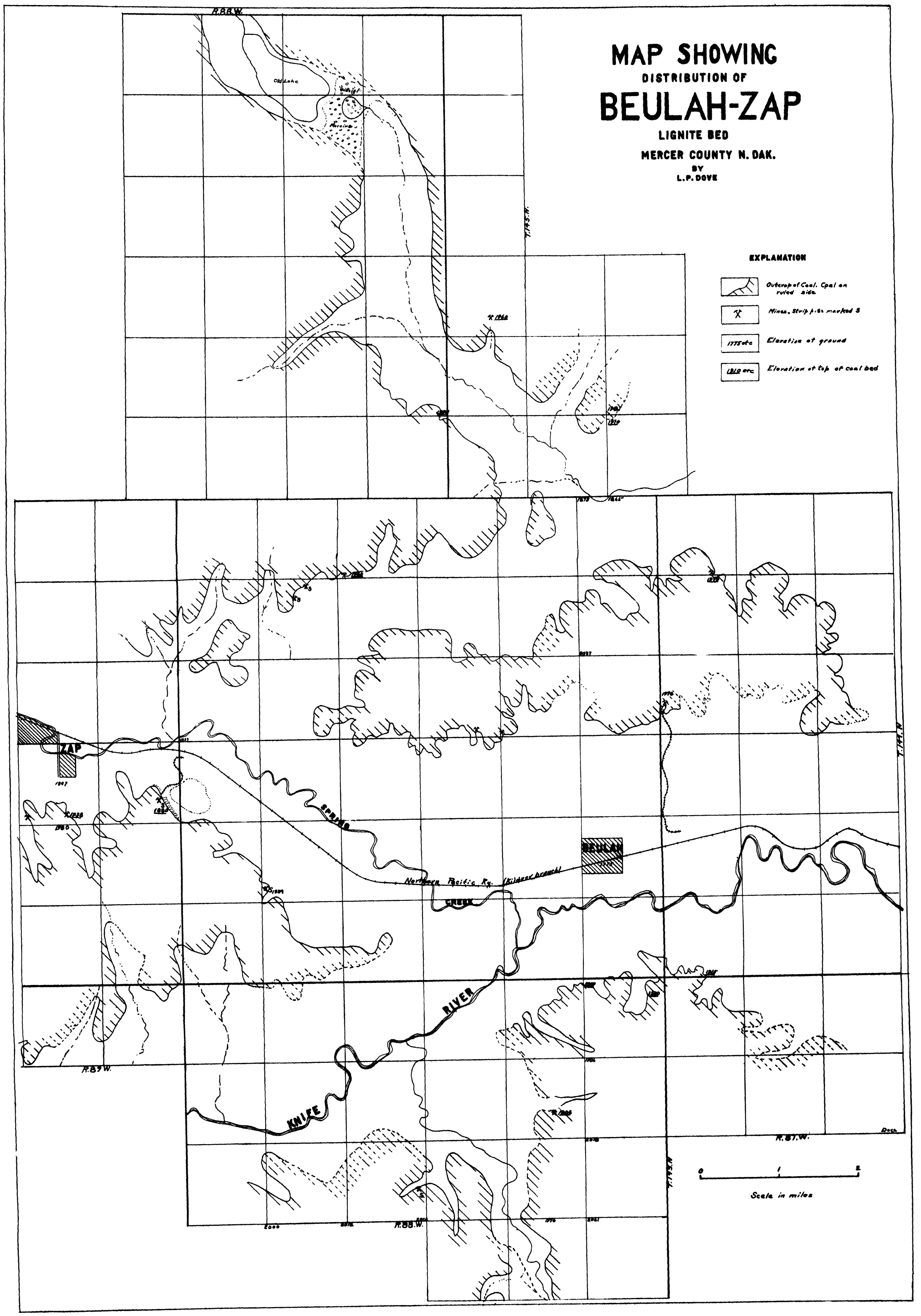
The horizontal control for the area is the land survey. All measurements were made by stadia and checked by section corners which were found in almost every instance. The vertical control is based on the elevation of the base of rail in front of the depot at Beulah, 1775 feet above sea level. Spirit levels were run out to the outcrops of the coal north and south of Beulah and carried by telescopic alidade around the outcrop. At a distance from the railroad, outcrops were sketched from section lines. Essentially every forty acres on the outcrop was visited.

The Beulah coal bed is not level. Besides minor undulations of a few feet to 10 feet there is a general westerly dip. A westward plunging, broad anticline with its axis nearly east and west, makes the coal bed highest in the vicinity of secs. 10, 11, 14 and 15, T. 144 N, R. 88 W., where the coal bed appears to be entirely missing, due to preglacial erosion. Westward the dip is gentle until near the west edge of the above township where it dips more rapidly to the vicinity of Zap. While anticlines are of interest due to the fact that they may be oil or gas bearing, this anticline probably does not merit consideration for the following reasons:

1. It is not large and extensive.
2. It does not appear to be closed sufficiently to the east, probably allowing oil and gas that might have been present to escape in that direction.
3. There are no known oil or gas sands or reservoirs within 4,000 feet of the surface, making any test very expensive and uncertain.

The Beulah-Zap coal bed reaches its maximum thickness so far as known in the western part of T. 145 N., R. 87 W., where it is reported to be 24 feet thick. A thickness of 22 feet is reported from the Sailer mine near the south edge of sec. 6, T. 144 N., R. 87 W., thinning to 12 to 17 feet westward and southward. It is reported to be 17 feet thick in secs. 1 and 2, T. 143 N., R. 88 W. At the Pratt Brothers stripping in sec. 24, T. 144 N., R. 89 W., it is 8 to 9 feet thick.

An old preglacial or inter-glacial valley about one mile in width extends from two miles northeast of Zap to the Antelope creek valley. This old valley is now occupied by small creeks, swamps or sloughs. In sec. 32, T. 145 N., R. 87 W., this valley is joined by a similar valley from the northwest. Both of these old valleys are cut well below the level of the coal bed which may be traced on both sides of them. The drainage in the valley which extends northwestward to the north edge of T. 145 N., R. 88 W., is divided in secs. 11 and 12 of this township by a glacial moraine. It appears that the water originally flowed southeastward but was dammed by this moraine and ponded reversing the flow northward to the Missouri river north of the moraine. This glacial moraine has concealed the coal for a distance of about two miles.


MAP SHOWING
DISTRIBUTION OF
BEULAH-ZAP
LIGNITE BED
MERCER COUNTY N. DAK.
BY
L.P. DOVE
EXPLANATION
Outcrop of Coal. Coal on ruled side.
Mines. Strip pits marked S
1775 etc
Elevation of ground
1310 etc
Elevation of top of coal bed
R.88.W.
R.87.W.
T.144.N.
T.143.N.
ZAP
BEULAH
SPRING
CREEK
KNIFE
RIVER
Northern Pacific Ry. (Kildeer branch)
Scale in miles

the surface in part or all of 10 townships, and probably covers some 500 square miles or over. This coal bed lies 145 feet above the railroad at Beulah, and is therefore present unless burned out wherever the upland surface rises 160 to 200 feet or more above the Knife River valley, or the railroad at Hazen and Beulah.

The following mines are in the Beulah-Zap coal bed: Krem, Stewart (old Dilger), Schmidt, Kesler, Lucky Strike at Zap, and Ingold.

It is possible that the upper of the two coal beds which outcrop along Goodman valley is the Beulah-Zap coal bed. The Myers and Reigel mines are in this bed.

At the Krem mine in the NE. ¼ of sec. 20, T. 145 N., R. 86 W. the Beulah-Zap bed is 13 feet thick and lies 54 feet below the surface.

This coal bed doubtless underlies the following sections of T. 145 N., R. 86 W.: secs. 19, 20, 21, 22, 23, 15, 16, 17, 18, 28, and 29. The bed was struck in a well one mile south of the Krem mine, and also in the SW. corner of sec. 20. Clinker from this coal occurs in sec. 19 and the bed has been mined by stripping in the valley near the north edge of sec. 17. This same bed was formerly mined in sec. 22.

At the Schmidt mine in the SE. ¼ of sec. 19, T. 145 N., R. 87 W., the Beulah-Zap bed is 23 feet thick, and here lies 25 to 30 feet below the surface, though the cover grows thicker farther back from the ravine in which the mine is located, so that over considerable areas the coal is at a depth of 75 to 100 feet and over.

Clinker from the burning of this bed appears near the east line of sec. 14, and also in the SE. corner of sec. 23, T. 145 N., R. 88 W. A well in the SE. corner of sec. 25, of the same township, is reported to have passed through 22 feet of coal not far below the surface. A thick clinker bed formed by the burning of the Beulah-Zap coal bed is also present in many places along sides of Antelope valley near the southern edge of T. 145 N., R. 87 W. The same clinker horizon is found 1¼ miles north of Beulah.

In the vicinity of Beulah there are two thick coal beds. The lower or Beulah coal bed lies 45 feet below the surface, and is 11 to 12 feet thick. This is the bed which was formerly mined by the Beulah Coal Company, just east of town. The upper or Beulah-Zap coal bed lies 190 feet above the lower bed, or 145 feet above the railroad at Beulah. This upper coal is being mined at the Kesler mine, in the NE. ¼ of sec. 12, T. 144 N., R. 88 W., 3 miles north of Beulah. The Beulah-

Zap bed is here 18 feet thick, and it outcrops along the side of a ravine which extends north to Antelope valley. This upper coal bed can be traced almost continuously by its clinker between the Schmidt and Kesler mines.

The lower coal bed formerly mined by the Beulah Coal Company contains a clay seam 6 to 12 inches thick. The section of the coal bed is as follows:

	Feet	Inches
Sandstone, soft	10-20	
Clay shale	0-3	
Coal	7-8	
Clay		6-12
Coal	3-4	

The clay was hoisted from the mine. About 3 feet of coal was left for the roof.

Analysis No. 5563 is from the sample of the Beulah-Zap coal bed at the new mine of the Beulah Coal Company, in sec. 18, T. 144 N., R. 87 W.

At the Kesler mine the cover is a soft sandstone, and 6 to 8 feet of coal are left for the roof so that little timbering is required.

The Stewart (old Dilger) mine is located in a ravine in the SE. ¼ of sec. 11, T. 143 N., R. 88 W., 3 miles south of Beulah. At the time it was visited this mine was filled with water so that the coal seam could not be examined. The bed mined here has burned out extensively on the south side of the Knife River valley and has formed a thick clinker horizon. The bed at the Stewart mine is reported to be 15½ feet thick. It is here overlain by one foot of shale, and overlying the shale is 25 feet of soft sandstone.

In his well in the SE. ¼ of sec. 2, T. 143 N., R. 88 W., Mr. Murry reports that a 17 foot coal bed is found. In sec. 36 of the same township a coal bed 9 feet thick has been mined, this doubtless being the Beulah-Zap coal bed. The same bed has been mined in sec. 16 where it is said to be 5 to 8 feet thick. The west half of sec. 12, which is University land, is doubtless underlain by the same bed. Sec. 8 is also University land and a lower bed at river level has been mined on this section when the Knife river is low.

Opposite the mouth of Brush creek, in sec. 4 and in the SE. ¼ of sec. 33, T. 144 N., R. 88 W., the top of the bluff bordering the Knife valley on the north is capped with a clinker bed formed by burning of the Beulah-Zap coal bed. The clinker formed by burning of this

bed outcrops at many points on either side of Antelope valley and its tributary valleys in T. 145 N., R. 88 W., and T. 145 N., R. 87 W. This clinker is also present in the SE. ¼ of sec. 19, T. 145 N., R. 86 W. Much clinker from this bed is found in secs. 4, 9 and 10 of T. 144 N., R. 87 W., on the sides of ravines leading into Antelope valley. This thick coal bed thus extends east to within 2 or 3 miles of Hazen, or to the point where the surface is so low that the coal has been eroded.

Near the northern edge of T. 144 N., R. 88 W., a broad valley extends from Spring creek to Antelope valley. The thick clinker bed formed by the Beulah-Zap coal seam was traced along the sides of this valley to Zap.

The Lucky Strike mine is located one mile south of Zap, in the SW. corner of sec. 23, T. 144 N., R. 89 W., on the side of a ravine tributary to Spring creek valley. This mine was opened in June, 1918, and is on the Beulah-Zap coal bed which here has an elevation of 75 feet above the railroad at Zap. The coal bed here has a thickness of 8 to 12 feet. It is overlain by 6 feet of shale, above which is a soft sandstone. The lignite is of exceptionally good quality.

The Lucky Strike mine ships considerable coal to the eastern part of North Dakota and a little to points in Minnesota.

A bed of coal which is reported to have a thickness of 5 to 7 feet has been struck in wells about 54 feet below the Beulah-Zap coal bed. The latter extends south of Zap at least as far as the Knife river valley, and it is not known how much farther south it is found.

The Ingold coal mine is in the NE. ¼ of sec. 35, T. 144 N., R. 90 W., and the bed here has an elevation of about 60 feet above the railroad at Golden Valley. The coal seam has a thickness of 6 feet and is doubtless the Beulah-Zap bed. It is only about 3½ miles from the nearest clinker outcrop in Spring creek valley. This same coal bed extends west into secs. 27 and 34, T. 144 N., R. 90 W., where it has been mined by stripping in a number of places on either side of the ravine which crosses these sections. The thickness could not be determined, but it is probably about the same as at the Ingold mine, 1½ miles east.

The Beulah-Zap coal bed appears to become thinner toward the west and it perhaps does not extend much farther in this direction than the Dunn county line.

Since a coal bed 12 feet thick contains 20,400 tons per acre, or

13,056,000 tons per square mile, the Beulah-Zap coal bed contains at the very lowest estimate 2,611,200,000 tons, on the basis of an area at the present time of 200 square miles. Before it had been so extensively eroded it covered more than twice this area.

Two beds of coal outcrop on the sides of Goodman valley for several miles above its junction with the valley of Spring creek. The lower bed, which is 6 feet thick, lies not far above creek level, and has about the same elevation as the railroad where it crosses Spring creek one mile west of Golden Valley. The upper bed lies 50 feet above the lower and varies in thickness from 4½ to 6 feet. The Golden Valley mine, in the SE. corner of sec. 9, T. 144 N., R. 90 W., the Stone mine in the SW. ¼ of sec. 10, and the Haven mine (now abandoned) in the SE. ¼ of sec. 4 are all in the lower coal bed. The Reigel mine, in the SW. corner of sec. 3, the Myers mine, in the SW. ¼ of sec. 9, and a strip pit in the NW. corner of sec. 10 are on the upper coal bed. The cover of both these coal beds is shale and the mines have to be well timbered to prevent caving.

The upper coal bed mined in Goodman valley is perhaps the Beulah-Zap bed, though this could not be determined with certainty.

COAL NEAR STANTON

A coal bed is present in the bluffs between 2 and 3 miles south of Stanton. It has a thickness of 10 to 12 feet and lies about 130 feet above the railroad of Stanton. This bed is mined at the Thuger mine, in the NE. ¼ of sec. 23, T. 144 N., R. 85 W., and at the Serr mine, in the SE. ¼ of sec. 13 of the same township. At the Serr mine there is a clay seam 4 inches thick in the bed two feet below the top, but this seam is not found in the coal at the Thuger mine. The coal is a firm, hard, black lignite of excellent quality and low in ash.

This thick coal bed was traced by its clinker into sec. 20, T. 144 N., R. 84 W., and it probably underlies sections 19, 20, 28, 29, and 30 of this township. No outcrops were observed west of the Thuger mine, but it is not at all unlikely that the coal bed extended at least several miles west and south of that mine. The bed does not extend far north of the mine, since the surface slopes in that direction and the coal has been eroded during the formation of the Knife River valley.

A coal bed is shown by its clinker to be present in the bluffs of the Missouri 2 to 3 miles below Deapolis, on the north side of the river. This bed appears to lie 130 to 150 feet above the river and it is perhaps the same thick bed which is mined south of Stanton.

COAL NEAR HAZEN

A coal bed varying in thickness from 3½ to 5 feet occurs north and south of the Knife river in the vicinity of Hazen, at an elevation of 50 feet above the railroad. South of the river it is mined at the Koulberg mine, in the NE. ¼ of sec. 31, T. 144 N., R. 86 W., and the Otness mine in the SE. ¼ of sec. 20 of the same township. In these mines the bed is 5 feet thick. At the Otness mine the coal is overlain by 2 to 3 feet of carbonaceous shale which makes a poor roof. The thickness of the cover of shale and sandstone is 12 to 20 feet.

The Hazen mine is located one mile north of town in the NW. corner of sec. 8, T. 144 N., R. 86 W. The coal bed is here 3½ feet thick but the coal is of very good quality. It has a cover of 30 to 40 feet of shale and a little drift. At the Gallagher mine, about one mile west of the Hazen mine, the cover is stripped from the coal. The bed is here 4 feet thick, overlain by 4 feet of black, carbonaceous shale and 20 feet of drift. These four mines in the vicinity of Hazen are believed to be in the same bed of coal, which is thinner north of the Knife river than farther south.

MORTON COUNTY

L. P. Dove

For convenience in description the coal beds of Morton county may be considered under three districts, as follows: New Salem-Glen Ullin district, Hebron district, and Little Heart river district.

NEW SALEM-GLEN ULLIN DISTRICT

The most important coal beds of Morton county are those in what may be called the New Salem-Glen Ullin district. This comprises the area within about ten miles of the main line of the Northern Pacific railway, and includes roughly the district extending from Judson to the vicinity of Glen Ullin.

The material for this report is taken from several sources. In 1922 there appeared a report on the area east and south of New Salem by Eugene T. Hancock[1] giving the results of the field data gathered by his party in 1914. Earlier A. G. Leonard, State Geologist, examined the region about Hebron, Glen Ullin and New Salem and his

[1]Hancock, Eugene T. The New Salem Lignite Field, Morton County, N. D. U. S. Geol. Survey Bull. No. 726, pp. 1-39, 1922.

report on "The Geology of South-Central North Dakota" was published in the Sixth Biennial Report of the North Dakota Geological Survey.

In 1920 and 1922 the writer spent some time in this field examining particularly the region north of the railroad between New Salem and Glen Ullin.

The reader is referred to the foregoing publications for greater detail, the immediate object being to emphasize the areas where lignite deposits of importance are known rather than to furnish details of the distribution of beds without regard to their thickness and availability. A bed of lignite less than 4 feet thick is mined underground with great difficulty at a high cost and unless under a very light cover cannot be stripped profitably. In general to be mined underground to the best advantage the bed should range from 6 to 12 feet thick since this allows 2 feet or more of lignite to be left for a roof to support the usual clay shale which in itself makes a poor roof. Particular attention therefore will be directed to beds over 6 feet thick, reasonably close to the railroad.

In the vicinity of New Salem, Hancock has designated five coal beds which are of importance. He has called these, beginning with the lowest, beds A, B, C, D, and E. These lie at distances of about 45, 100, 155, 230, and 254 feet, respectively, above the base of the Fort Union formation. See Fig. 11.

BED A, OR "DEEP VEIN"

Recent deep drilling has demonstrated the presence of a thick bed of lignite lying about 210 feet to 220 feet below the general upland surface about New Salem. During the summer and winter of 1921, a mine was opened in this bed by a shaft near the railroad just west of New Salem. The shaft is single compartment, 10 feet by 12 feet and 190 feet from collar to the top of the coal. The coal ranges from 9 to 12 feet in thickness. This mine (1922) maintains a daily output of from 100 to 120 tons.

This bed has been variously reported from drill holes as varying from 9 feet to 19 feet in thickness. It is reported to have a thickness of 19 feet on the property of the Consolidated Lignite Collieries Company northwest of New Salem. If the data are reliable this bed attains its greatest thickness in T. 139 N., R. 85 W., and thins eastward, southward and northward.

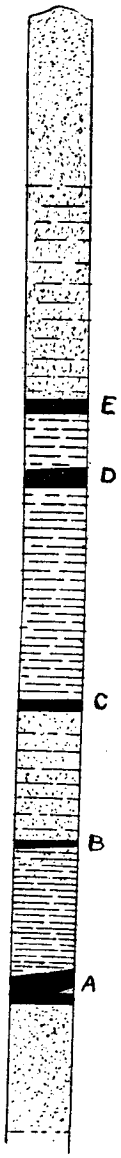


Fig. 11. Columnar section in the vicinity of New Salem showing the coal beds and formations from the base of the Fort Union upward.

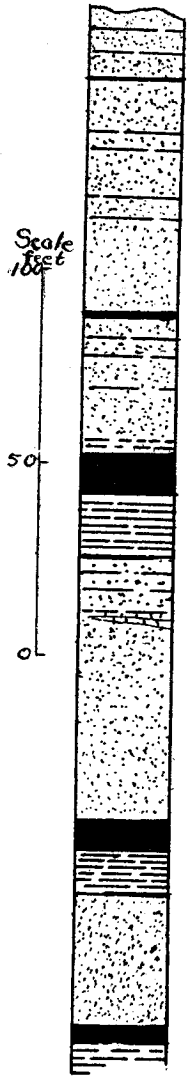


Fig. 12. Columnar section of the coal beds and formations in the vicinity of the Spring Valley Products Co. mine south of Glen Ullin. Coal bed about the middle of the section being mined.

BED B

Bed B while extensive attains a workable thickness only in a few places where measured. It lies nearest the railroad in the valley about Sims where it was worked extensively a number of years ago. There is some doubt about the correlation of the lignite beds about Sims with those 1½ miles south of Almont and those eastward but it seems probable that the bed formerly mined about 2 miles south of Sims and nearer town is bed B. The thinness of this bed and its tendency to be broken by shale partings does not make this bed particularly promising. No important coal bed appears to be reported at the horizon of bed B from any of the deeper drill records about New Salem.

BED C

This bed lies about 50 feet above bed B and outcrops along the valley about Sims. Where measured at its outcrop it nowhere shows a thickness of over 4 feet except in secs. 5 and 8, T. 138 N., R. 85 W., where it is over 5 feet thick.

A coal bed found in a prospect shaft at the old Dakota Products Company mine northeast of New Salem lies at about the horizon of bed C and is reported to be 6 feet thick. This bed is being mined at a few places in the northwestern corner of T. 138 N., R. 85 W., where it has supplied considerable coal for a local trade.

BED D

This coal has been mined extensively about New Salem for many years. Two of the larger mines are now operating in this bed and several smaller mines and strip pits have taken coal from this horizon. An interval of 30 feet of clay separates it from bed E above. This clay interval thins to the northwestward to 16 feet or less.

The coal varies in thickness from about 5 feet in sec. 15, T. 139 N., R. 85 W., to 7 to 9 feet in sec. 7 of the same township, thus appearing to thicken to the northwest. It is cut out by the ravines both to the north and south of the railroad and hence usually lies high enough in the side hills to be easily drained. The overlying clay is gray, with slip joints that makes a fairly satisfactory roof when dry but must be timbered in entries. The coal itself is solid but changes in the upper portion to a finely laminated shaly coal from 6 to 8 inches thick and in general separated from the main body of coal by a clay parting ½ to 2 inches thick. The upper coal and shaly coal is block jointed and falls easily from the roof making it impossible to

leave this portion of the bed for a safe roof as is commonly done elsewhere in North Dakota. This is especially true of the coal in sec. 7, T. 139 N., R. 85 W. Both here and in sec. 15 small faults occur. One reported as having a northwest-southeast trend in the Bloodgood mine has sufficient throw to cut off the coal to the northeast. No prospecting has been done as yet to determine the direction of movement. A series of small step faults are visible in the entries of the Consolidated Lignite Coal Company mine on sec. 7. They have a general north and south trend and have been cut across by both main entries. Aside from some water which finds its way down these fractured zones, no difficulty is found in driving through this ground. A series of zig-zag white sandstone dikes cut the coal in the latter mine to the east of the faults. As these white sand streaks cut both roof and coal without noticeable vertical displacement of the coal it is thought that they are probably the result of shrinkage cracks after the formations were consolidated being filled by sand washing into the cracks.

Bed D appears to thin southward from New Salem and is reported to range from 2 feet 6 inches to 4 feet in thickness in the southwestern part of T. 139 N., R. 85 W., and the northwestern part of T. 138 N., R. 85 W.

At an elevation of about 2175 feet above sea level a prominent clinker horizon begins in sec. 18, T. 139 N., R. 86 W., just east of Spring creek. This clinker horizon may be traced westward to the vicinity of sec. 14, T. 139 N., R. 88 W., where it has an elevation of about 2150 feet above the sea. The coal bed which has burned to produce this clinker is about the horizon of bed D or E, and is here designated as D. A bed which may be roughly in the position of bed C is so designated, lies about 70 feet below. Bed C is exposed in the NE. ¼ of sec. 24, T. 139 N., R. 87 W., and again in sec. 24, T. 139 N., R. 88 W.

But little of bed D is left and these areas only underlie the high divides. A gentle north and westerly dip carries this bed below the surface, near the south line of sections 11, 12 and 14, T. 139 N., R. 88 W., where it is being mined in two places by stripping. The coal bed here is about 7 feet thick.

An area of a few hundred acres about the Twin Buttes in sections 18 and 19, T. 139 N., R. 87 W., is undoubtedly underlain with bed D, likewise the higher land in sections 11, 14, 13, 23 and possibly

25 and 26, may have remnants of this bed. The bed appears to be 6 feet or more thick in this area.

A coal bed that lies at an elevation of about 2150 feet above sea level or 70 to 80 feet above the railroad in the immediate vicinity of Glen Ullin is being mined north of town and has been mined southwest of town. It is uncertain which bed this is since another bed occurs at a distance of about 125 feet above the railroad which appears to be correlated with bed D above described. If this is true the bed mined in the vicinity of Glen Ullin is bed C.

Drilling by the Spring Valley Products Company in sections 21, 22, 27, and 28, T. 138 N., R. 88 W., most of which was done from the flat land in the divides between Curlew creek and Heart river, shows two coal beds of importance. The upper one, ranging from 5 to 13 feet in thickness, is being opened at the mine of the company in the SW. ¼ of sec. 22. At the old mine in the SE. ¼ of sec. 21, a siliceous layer forms the roof for the coal. This coal bed at the mine has an elevation of 2307 feet. About 70 to 80 feet below the one described is a lower bed ranging from 5 to 8 feet in thickness. A generalized columnar section of this area is shown in Fig. 12.

BED E

Bed E is the highest thick coal found in the higher divides about New Salem. It is exposed and has been mined to some extent near the south line of sec. 21, ½ mile south of New Salem, where it is at least 5 feet 4 inches thick. It may be traced by clinker to sec. 33, 2 miles south of New Salem, but appears to thin southward, where it is only 2 feet thick.

Northwestward bed E appears to thicken and if correlations are correct it is reported to have a thickness of 9 feet 6 inches in the air shaft of the Consolidated Lignite Collieries mine in sec. 7, T. 139 N., R. 85 W. It will be noted that only 20 feet of clay shale separates bed D from bed E north and west of New Salem. This interval is reported to thin westward.

In the high divide southwest of Almont, a bed of coal has been stripped at the Ramsland mine in sec. 6, T. 137 N., R. 86 W., and is thought to be bed E. Here an extreme thickness of 6 feet 9½ inches to 6 feet 11 inches is reported. It is thought, however, to be quite lenticular and may be represented by only 14 inches of coal near the northern edge of sec. 7. Northward from sec. 6, in sec. 31, T. 138 N., R. 86 W., this same bed has been mined by stripping

where it is reported to attain a thickness of 9 feet and 4 inches. This same bed may be traced northwestward by clinker from the latter location.

LITTLE HEART RIVER DISTRICT

The coal bed mined in this district occurs in the Lance formation, which lies below the Fort Union. It is the latter formation which contains all the other coal beds of Morton county.

The lignite bed is exposed in the valley of the Little Heart river and tributary valleys in the eastern portion of T. 137 N., R. 81 W. The coal lies about 100 feet above the Missouri river or a little over 1750 feet above sea level, and has a maximum thickness where mined of 6 feet 7 inches, though in most places it is not over 5 feet thick.

At the mine in the NE. ¼ of sec. 25, T. 137 N., R. 81 W., the section of the coal bed is as follows:

	Feet	Inches
Shale		
Coal		2-3
Clay		5
Coal	1	7
Clay parting		3-4
Coal	5	

The coal is mined by drifting in along the bed from the outcrop, the 5-foot coal bed and overlying clay parting are removed and the 19-inch coal seam is left to form the roof. Coal has been mined here many years and farmers are reported to come to this mine for their coal distances of 15 to 20 miles from the south and southwest.

This coal has been mined by running drifts into it in five or six other places along its outcrop in the valley in secs. 24 and 25, T. 137 N., R. 81 W. In the SE. ¼ of sec. 24 the section of the bed is as follows:

	Feet	Inches
Shale		4
Coal		4
Clay		7
Coal		7
Clay		2
Coal		5
Clay		7
Coal	4	5
Clay		

What is doubtless the same coal bed has been opened up along its outcrop at several points in the ravine in the NE. ¼ of sec. 26. The coal is here thinner, ranging from 3½ to 4 feet, and the clay part-

ing over the lower bed is thicker. The coal bed has also been mined in the NE. ¼ of sec. 22 of the same township.

All the above localities are south of the Little Heart river, but the same coal bed has been opened up in a number of places on the north side of the river, particularly in the south half of sec. 14, T. 137 N., R. 81 W., where the bed is at least 3½ feet thick. It has been mined in the NE. ¼ of sec. 14.

Where this coal bed has been prospected to the north and northeast it is found to be thinner and the coal is split into several seams by partings of clay. It has been uncovered by stripping along its outcrop in sec. 7, T. 137 N., R. 80 W., and the coal here measured only one foot in thickness.

The Little Heart coal bed does not extend more than one or two miles north of the river, since it grows thinner in this direction and splits into several thin seams with clay partings between. The coal bed has been extensively eroded in the valley of the Little Heart river and its tributaries, the main valley having been cut to a depth of 50 to 100 feet below the coal horizon. South of the river it is known to extend into secs. 25 and 26, T. 137 N., R. 81 W., and how much farther has not been determined. The surface rises rapidly to the upland level, there the coal, if present, lies at a depth of 250 to 300 feet, and there are no well borings which have gone down to this depth. It is not improbable that the Little Heart coal bed underlies the southwestern sections of T. 137 N., R. 80 W., and the southeastern sections of T. 137 N., R. 81 W. The best place to prospect for the coal would be in the valley followed by the Telegraph road down to the crossing of the Little Heart river, or toward the base of the slope in sec. 27, T. 137 N., R. 81 W.

HEBRON DISTRICT

So far as known, the uppermost coal beds of the Fort Union formation in Morton county are those present 4 or 5 miles north of Hebron, in the extreme northwestern corner of the county. These probably lie over 600 feet above the base of the formation, and are believed to occur well above those found in the New Salem-Glen Ullin district. A coal bed 5 to 8 feet thick is found in the northeastern corner of T. 140 N., R. 90 W., at an elevation of about 2450 feet above sea level. This has been mined at their clay pit in sec. 2 by the Hebron Pressed and Fire Brick Company. It is mined in sec. 8 at the Hornisch mine, in sec. 3 at the North Star mine, and in sec. 4

at the Madison mine. It is probably this same bed which has been mined in sec. 24 of the same township.

Coal is also present in the northeastern corner of Morton county, in the western part of T. 140 N., R. 82 W., near the headwaters of one of the branches of Otter creek. It is shown in outcrops that occur in sections 17, 20, 29 and 31. The coal bed is 4 feet thick and lies so near the surface that it is mined by stripping off the cover.

OLIVER COUNTY

A. G. Leonard

Several beds of coal are known to occur in Oliver county. The Beulah-Zap bed, which underlies a large area in Mercer county, doubtless extends into the northwestern corner of Oliver county. In the vicinity of Beulah and Zap this bed varies in thickness from 13 to 24 feet. One hundred and ninety feet below the Beulah-Zap bed is a second coal seam with a thickness of 11 to 12 feet, and this also probably occurs farther south and east, in Oliver county. This is the bed mined at Beulah. Both these beds of coal are described under Mercer county.

A coal bed outcrops along the valley of Square Butte creek 5 to 6 miles southeast of Center, where it has been mined in several places by stripping off the overburden. The bed varies from 5 to 10 feet in thickness and has a clay parting 3 to 10 inches thick 3 feet above the bottom. In sec. 2, T. 141 N., R. 84 W., where the bed has been mined, it has a thickness of 10 feet. At the Spring Valley mine, in sec. 12, T. 141 N., R. 84 W., it is 5 to 8 feet thick, and at the Tripp mine, in sec. 29, T. 142 N., R. 83 W., the thickness of the coal is 7 to 9 feet, with a 10-inch clay parting.

Three miles northwest of Center, at the Pleasant Valley mine, in sec. 8, T. 142 N., R. 84 W., there are two coal beds. The upper is 7 feet thick and is separated by 4 feet of clay from the lower bed, which has a thickness of 10 feet.

Near the northern border of the county a coal bed 7½ feet thick is present, and is exposed at the Barlow mine, about 4 miles west of Fort Clark, in sec. 4, T. 143 N., R. 84 W.

The following coal beds are found in the northeastern townships of the county: In sec. 10, T. 143 N., R. 82 W., about 3 miles

[1]Carl D. Smith. The Washburn Lignite Field, North Dakota. U. S. Geol. Survey Bull. No. 381, p. 25.

south of Hensler, a bed 6 feet 4 inches thick has been mined. In sec. 9 the same bed shows 5 feet of good coal. About 6 miles west, in sec. 8, T. 143 N., R. 83 W., a coal bed at the same horizon was formerly mined, the bed having a thickness of 3 feet 10 inches. In sec. 2, T. 143 N., R. 83 W., there is a bed of coal 100 feet above the Missouri river. It is 4 feet 4 inches thick, with a thin clay parting near the bottom.

In secs. 33 and 36, T. 141 N., R. 86 W., a coal bed 6 feet thick is reported, and in secs. 3 and 11 of the same township there is a 5 foot bed. Coal is said to be abundant in sec. 28, T. 141 N., R. 83 W. A bed 6 feet thick is reported in sec. 9, T. 142 N., R. 86 W., one of the same thickness in sec. 3, T. 143 N., R. 87 W., and a 7-foot coal bed in sec. 9, T. 142 N., R. 86 W. A well in the NE. ¼ of sec. 21, T. 142 N., R. 86 W., shows 4½ feet of coal at a depth of 30 feet below the surface. In a strip pit near the road, in the NW. ¼ of sec. 26, T. 142 N., R. 87 W., a coal bed over 9 feet thick is exposed, the upper portion being of poor quality.

STARK COUNTY

A. G. Leonard

Most of the coal produced in Stark county is obtained from three coal beds which outcrop along the Heart river, in the northwestern part of the county.

So far as known, no beds of importance are found in the eastern half of the area. Several of the larger mines of the state are located in Stark county, which ranks among the leading coal producing counties in North Dakota.

The more important coal beds are included in two districts, namely the Belfield-South Heart district, and the Lehigh district.

BELFIELD-SOUTH HEART DISTRICT

Two coal beds 50 to 60 feet apart occur in western Stark county. The lower has burned out extensively in the vicinity of Fryburg, and may be called the Fryburg coal bed. It outcrops on Norwegian creek south of Belfield and has been mined at several points along the valley of this creek. The coal is here 10 to 11 feet thick. It is probably this same coal seam which is mined at Zenith, where it is several feet below river level and has a thickness of 16 to 22 feet.

The upper coal bed, which may be called the Heart River coal

bed, outcrops along the valley of Heart river and its clinker bed is conspicuous along the Red Trail between Zenith and South Heart, and farther east. This bed is mined on Coal Mine creek at the Gross and Lerfald mines; on North creek at the North Creek mine and another mine one-half mile northwest, in sec. 27. This coal bed varies in thickness from 10 to 12 feet and over. It extends from near Belfield to a point at least 4 miles east of South Heart, and perhaps farther. It also doubtless extends a number of miles north and south of the Heart valley. See Fig. 13.

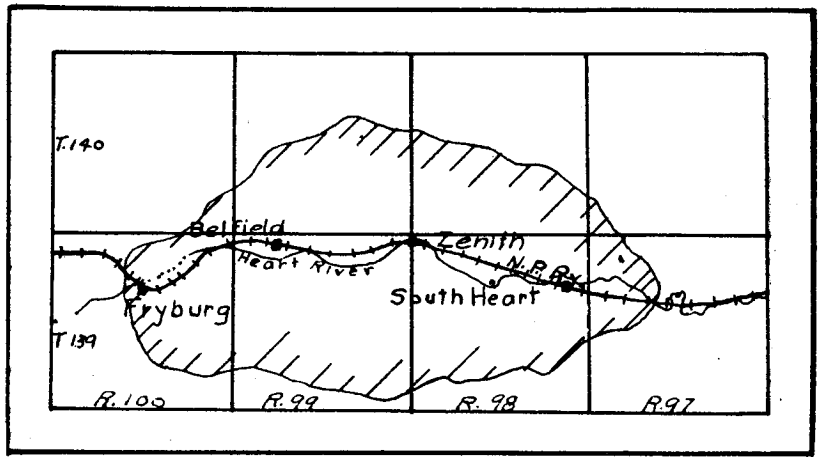


Fig. 13. Sketch map showing approximate area underlain by Fryburg and Heart River coal beds.

These two coal beds are favorably located with reference to the railroad since the Northern Pacific traverses the area underlain by them.

FRYBURG COAL BED

This bed of lignite was traced from the edge of the badlands near Fryburg east along Norwegian creek to a point near the west line of sec. 21, T. 139 N., R. 99 W., where it disappears below creek level. But it is believed to be this same bed which is mined at Zenith, so that it doubtless extends at least that far east and probably farther, though it lies below the bottom of the Heart River valley, and would be found only in wells. Some of the wells in South Heart get their water from a coal bed which is reported to lie at a depth of 30 to 40 feet below the surface, and this is perhaps the Fryburg

coal bed. In this case it extends as far east as South Heart. What is doubtless the same seam of coal was struck in a well about two miles south of Zenith at a depth of 38 feet.

The Fryburg bed is mined on Norwegian creek in the NE. ¼ of sec. 19, T. 139 N., R. 99 W. The base of the coal is here two feet above the creek bottom. The bed is shown by its clinker to rise toward the west, so that at the west side of the same section it lies 12 to 15 feet above the creek. The bed is mined in the cut bank of the creek by stripping off the overburden, which here has a thickness of 8 to 12 feet. The section of the Fryburg coal bed, where it is mined in sec. 19, T. 139 N., R. 99 W., is as follows:

	Feet	Inches
Shale	8-12	
Coal, containing pyrite near top	6	
Clay parting		1-2
Coal	1	2
Clay parting		2
Coal	1	
Clay		6
Coal	2	
Clay parting		1
Coal	1	2
Shale, to creek bed	2	

The same bed is mined in the cut bank near the west line of sec. 20, T. 139 N., R. 99 W., and it also outcrops near the west line of sec. 21 of the same township.

The Fryburg coal bed doubtless underlies the ridge or upland between Norwegian creek and the Heart river, and also the higher upland surface in T. 139 N., R. 100 W. It is not known how far east this coal seam extends, but it is probably the one mined at the Zenith mine and struck in shallow wells at South Heart.

The Zenith mine in sec. 6, T. 139 N., R. 98 W., is one of the large shipping mines of the state and has been worked for many years (see analyses Nos. 5536 and 5537). The coal bed here has a thickness of 16 to 22 feet, and lies at a depth of 45 to 70 feet below the surface. The coal is reached by a slope 1000 feet long, up which the cars are hauled by a steam hoist. The main entry is nearly 5000 feet long. There is considerable water in the mine and it is necessary to operate the pump continuously. The mine is located on a short spur track of the Northern Pacific railroad.

It is quite likely that the Fryburg coal bed underlies T. 140 N., R. 98 W., and T. 139 N., R. 98 W., as well as T. 140 N., R. 99 W., where it would be found about 50 feet below the Heart River coal bed.

It is probably the Fryburg coal bed which was struck in the boring made for the Northern Pacific Railway Company at South Heart by J. F. McCarthy. The boring reached a depth of 424 feet and the log of the upper portion is as follows:

	Feet
Shale	42
Coal (Fryburg coal bed)	12
Shale	15
Coal	4
Shale	100
Coal	2

Below the 2-foot coal bed only one thin coal seam was struck in this well.

HEART RIVER COAL BED

This extends from near Belfield east a distance of at least 11 or 12 miles, and it is known to occur for some miles north and south of the Heart river. A number of mines are located on this coal bed, among which are those on Coal Mine and North creeks. It underlies portions of 5 or 6 townships in the northwest corner of Stark county. See Fig. 13.

The Gross mine is located in sec. 34, T. 140 N., R. 99 W., on Coal Mine creek, a tributary of the Heart river. The coal seam is here 6 to 8 feet thick, lies about 20 feet below the surface, and is reached by a slope.

The Lerfald mine is one to two miles northwest of the Gross mine, on the same creek, and in sec. 28 of the same township. (See analysis No. 5538.) The coal is mined by stripping off the overlying shale, which varies in thickness from 6 to 12 feet. The section of the coal bed is as follows:

	Feet	Inches
Coal	8	6
Clay parting		6
Coal	1	6
Clay parting		6
Coal, not mined, but reported as	1-2	

The coal is mined down to the lower clay parting, but the upper foot is soft and weathered. The lower 9 feet of lignite is of good quality. Most of the output of the Lerfald mine is sold in Belfield.

The North Creek mine is located in the SW. ¼ of sec. 26, T. 140 N., R. 98 W., in the valley of a small tributary of North creek. The coal is mined by stripping off the overburden, which consists of

6 to 8 feet of shale. This mine has not been worked much for several years, and only the upper 5 to 6 feet of the seam is exposed, but the coal is reported to have a thickness of 12 to 15 feet. The same bed is mined by stripping in the east half of sec. 27 of the same township, and about half a mile from the North Creek mine, but here also only the upper 6 feet are exposed.

The Heart River coal bed was not traced north of secs. 26 and 27, T. 140 N., R. 98 W., but it undoubtedly extends several miles farther north, and probably underlies much of that township, and also those adjoining it on the east, west and south, where it has not been burned out or removed by erosion. No other coal bed of importance appears along the valley of the Heart river between South Heart and Dickinson.

Coal is mined on a small scale in a number of places in southwestern Stark county, in all cases by stripping off the overburden. In the NE. ¼ of sec. 9, T. 138 N., R. 98 W., a mine has been opened on a coal bed reported to be 4 feet thick. It is separated by 6 inches of clay, from a lower seam 2 feet thick. Coal has been mined in the SE. ¼ of sec. 36, T. 139 N., R. 99 W., in the valley of the branch of Heart river, and also in secs. 6 and 7, T. 138 N., R. 98 W. The seam lies low in the valley, and the holes from which coal has been dug were filled with water, so that the thickness was not determined. One of the larger mines in the region about Daglum is located in sec. 21, T. 137 N., R. 98 W.

THE LEHIGH DISTRICT

THE LEHIGH COAL BED

The Lehigh coal bed underlies a number of sections in the northwest corner of T. 139 N., R. 95 W. It is now being mined in sections 7 and 8 of this township, but it does not outcrop along the Heart river either east or west of the above sections, so that its extent could not be definitely determined.

At the Lehigh mine the coal bed is 30 feet above the Heart river, but it dips toward the north, so that about a quarter of a mile north of the mine, on the north side of the Heart, it is just above the river, and it is also at river level at the Pittsburg mine. At the Benek mine the coal bed is 10 feet or more below the river. Not only does the Lehigh coal bed dip toward the north, but it also dips toward the east and west, so that it is carried below the level of the Heart river

and is exposed only for a short distance. It only rises above river level at the Lehigh mine. It undoubtedly extends many miles in all directions from sec. 8, and prospect holes would probably show its presence over a considerable area both north and south of the Heart river.

The Lehigh coal bed ranges in thickness from 8 to 14 feet, and in the southern portion of sec. 8, T. 139 N., R. 95 W.,and farther south, the overburden varies from 7 to 30 feet, its average thickness probably being 15 feet or less. On the north side of the valley, near the northern edge of the same section where the surface is higher, the cover is much thicker, reaching over 100 feet in places.

Three mines at Lehigh are mining this coal bed, namely the Lehigh, Pittsburg, and Benek mines.

The Lehigh mine, the oldest of the three, is located in the south half of sec. 8, T. 139 N., R. 95 W., on the south side of the Heart river. The mine has been operated for many years by the Consolidated Coal Company, the coal bed being reached by a short slope and lately by drifting in along the bed. The coal has also been mined by stripping off the overburden with a steam shovel and loading the coal onto dump cars with a second shovel. This lignite bed lies near enough to the surface so that the cover of shale and gravel can be readily removed and the mine worked as an open pit. (See Plate IX, Fig. 2.)

The Pittsburg mine is located in the NW. ¼ of sec. 8, T. 139 N., R. 95 W., on the north side of the Heart river valley. The tipple is on the south side of the river and the mine is just across the river. Short spur tracks connect both the Pittsburg and Lehigh mines with the Northern Pacific railroad. (See analysis No. 5539.)

The Benek mine is located west of the Pittsburg, in the NE. ¼ of sec. 7, T. 139 N., R. 95 W. (See analysis No. 5540.) This same coal bed was formerly mined near the southern edge of sec. 7 but the workings have been abandoned for many years. About 4 miles west of here, near the eastern edge of Dickinson, an 8-foot coal bed has been mined. It lies 10 to 15 feet above the Heart river and is probably the Lehigh coal bed.

No very thick beds of coal are known in eastern Stark county. A bed with a thickness of 5 feet is mined just north of Richardton, and thin beds of coal outcrop on Green river, in the vicinity of Gladstone, but so far as known no beds of importance are present in this part of the county.

On the Heart river south of Richardton three coal seams are present, each of them about 3 feet thick. The lower is at river level, the middle bed lies 45 feet above, and the upper occurs in the higher bluffs along the Heart. There are almost no outcrops of these coal seams, and practically no clinker is seen along this portion of the valley. The middle bed has been mined on a small scale one-half mile east of the bridge, in sec. 28, T. 138 N., R. 92 W. The coal is here 3½ feet thick, with a thin clay parting near the top of the bed.

WARD COUNTY

A. G. Leonard and H. N. Eaton

Coal is mined in many places in Ward county but most of the mines are either on the edge of the Missouri plateau in the southeastern corner of the county or are found along the Des Lacs River valley, where they are distributed at intervals from the vicinity of Kenmare to Burlington and beyond. The coal beds of this area may be considered as occurring in four more or less well defined districts, as follows: Kenmare district, Baden-Donnybrook district, Foxholm-Burlington district, and the Southeastern district.

KENMARE DISTRICT

One coal bed is mined in this district. It may be called the Des Lacs coal bed and it covers an area extending from 6 miles north of Kenmare to the south end of Middle Des Lacs Lake, and doubtless many miles east and west of the valley. This coal bed outcrops along the sides of the Des Lacs valley for a distance of at least 8 or 9 miles and lies for the most part at an elevation of 15 to 25 feet above the level of the lake, although at one point is is about at lake level. This bed ranges in thickness from 4 to 6 feet. Mining is carried on for the most part by running drifts in along the coal seam, though in a few mines the coal is reached by shafts.

The Des Lacs coal bed has been and is being mined in many places, most of the older mines having been abandoned. One of the most northerly is the Farmers mine, in the NW. ¼ of sec. 20, T. 161 N., R. 88 W. The coal here lies 16 feet above lake level and averages 5½ feet in thickness. A little over one mile south the coal bed is a little below the surface of the lake but has nearly the same thickness. At the mine in sec. 6, T. 160 N., R. 88 W., the coal bed is reached by a shaft at a depth of 108 feet. The most southerly of the mines in this district, those of the Fosmarck Coal Company and the Mellon Coal Company, are located in sec. 28 of the same township and range, or about two miles south of Kenmare. The coal here ranges in thickness from 3 feet 8 inches to 4 feet.

BADEN-DONNYBROOK DISTRICT

The coal beds in this district are for the most part quite thin, ranging from 1 to 3½ feet, and only in one place, in sec. 14, T. 159 N., R. 88 W., near Baden, does the coal reach a thickness of 5 feet 10 inches. Many small mines have been opened in these lignite seams, but the latter are too thin to have very great value when there are so many thicker coal beds in the region.

FOXHOLM-BURLINGTON DISTRICT

This district is an important one and contains a number of well equipped mines. The coal bed mined in this area outcrops along the sides of the Des Lacs and Mouse river valleys from near the Great Northern bridge 4 miles west of Minot, almost to Foxholm, a distance of about 12 miles. Drill holes show that this Burlington coal bed, as it may be called, does not extend far south of the Great Northern bridge, but thins out rapidly in that direction. It probably continues some distance west of Des Lacs, since in a shaft and boring one mile west of that town a coal bed 10 feet thick was struck at a depth of 336 feet, and this is probably the Burlington coal bed. This seam was also reached by a shaft 3 miles east of Des Lacs, where it had a thickness of 11 feet 9 inches. A short distance south of Foxholm this coal bed disappears below the bottom of the Des Lacs valley, so that it is not known how much farther it extends toward the north, nor has it been determined how far east of the Mouse river the coal seam reaches. But it is known to underlie an area of at least 36 square miles, and probably considerably more. It ranges in thickness from 7 to 10 feet and over, and much the larger portion of it averages 10 feet.

The number of tons per acre of a 10-foot coal bed is about 17,000, and as the Burlington bed probably covers at least 36 square miles, it contains 390 million tons.

Since the Burlington coal bed outcrops along the sides of the Des Lacs and Mouse river valleys, though it is almost everywhere covered by glacial drift, it is mined with few exceptions either by drifting in along the seam, or by running a slope down to the coal.

The following are some of the more important mines of this district:

Foxholm coal mine, located in NW. ¼ of sec. 2, T. 156 N., R. 85 W. This is one of the few shaft mines in the region, the shaft being 40 feet deep, and the coal bed here averaging 9 feet in thickness. The Midway Coal Company's mine is in the SE. ¼ of sec. 33, T. 156 N., R. 84 W. This is a drift mine, which is lighted by electricity and the pump is driven by electric power.

Burlington City mine, in NE. ¼ of sec. 2, T. 155 N., R. 84 W., is a drift mine equipped with electric motor and cable haulage for the cars. The coal bed has a thickness of 10 to 11 feet. Other mines near Burlington are the Larson mine, in sec. 3, T. 155 N. R. 84 W.; the Colton mine, in the SE. ¼ of sec. 1, T. 155 N., R. 84 W., and the Hunnewell mine, in the NE. ¼ of sec. 1, T. 155 N., R. 84 W.

SOUTHEASTERN DISTRICT

COTEAU COAL BED

In the extreme southeastern corner of Ward county is a thick bed of coal which underlies parts of eight or nine townships. This bed lies near the eastern margin of the lignite area of the state and for many years has been mined in a number of places. The mines are 10 to 12 miles southwest of Velva, and about the same distance south of Sawyer. Since this coal bed lies near the edge of the rough, hilly, morainic belt known as the Missouri Coteau it has been named the Coteau coal bed. (See Fig. 14.) It also lies near the eastern margin of the Missouri Plateau or Great Plains province, which occupies over half of western North Dakota. Many streams tributary to the Mouse river have their sources well up on the slope leading from the Missouri Plateau down to the lower plain bordering it on the east, and these streams have eroded good sized ravines. It is in these ravines or coulees that the mines are located, since the coal bed outcrops near the head of these coulees and can be readily mined by running drifts or entries in along the seam. The coal bed varies in thickness from 10 to 18 feet, and averages about 14 feet. It has an elevation of approximately 350 to 400 feet above Velva, or 1850 to 1900 feet above sea level. Where this bed runs back under the Missouri Plateau, it lies at a depth of 200 to 300 feet below the surface.

The coal of this bed is an exceptionally good grade of lignite. Much of it is black and less woody in appearance than most of the

lignite of the state. At the present time the greatest drawback to the wide use of this coal is its distance from the railroad.

The mines on the Coteau bed will be described in order from southeast to northwest. The Quist mine is located in a ravine in

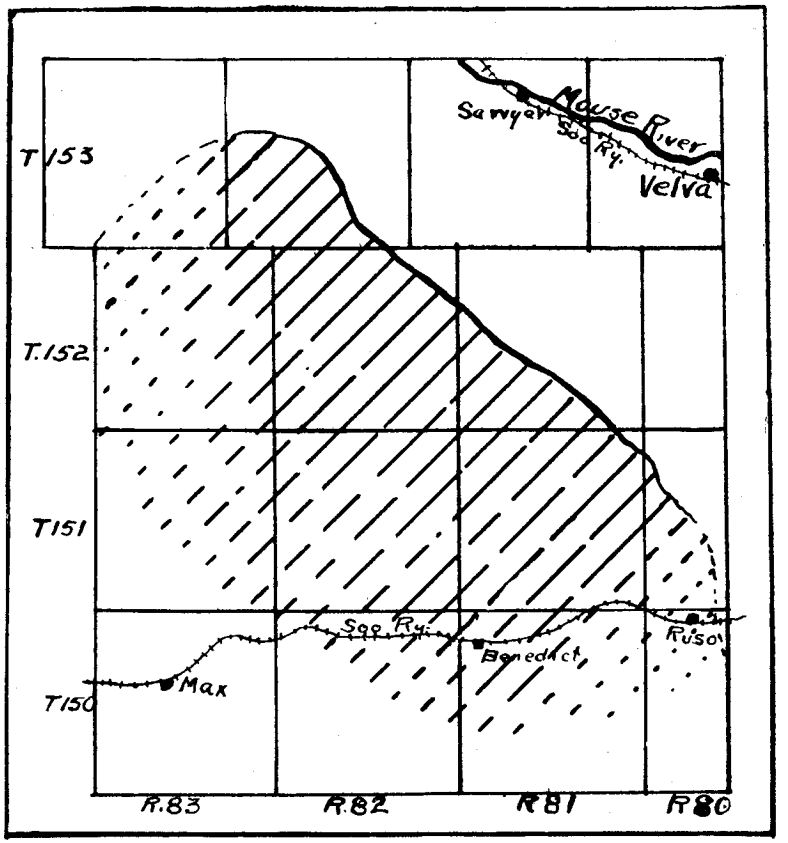


Fig. 14. Sketch map showing the approximate area underlain by the Coteau coal bed.

the NE. ¼ of sec. 1, T. 151 N., R. 81 W. (See analyes Nos. 5541 and 5542.) The bed is 13 to 14 feet thick, but the upper 3 or 4 feet is composed largely of slacked coal, and below are several layers of dirty, impure coal, so that only certain layers of the entire seam contain good clean lignite. Here as well as elsewhere the cover is glacial drift, which varies in thickness from 12 to 20 feet. The coal has been

mined both by driving short entries in from the face of the outcrop, or by stripping off the cover. Some clinker from the burning of this coal is found in the SW. corner of sec. 36, T. 152 N., R. 81 W., and the coal bed probably underlies the higher southern half of sec. 36, but it is doubtful whether it is present in the lower northern half of the section, having been removed by erosion.

The Sam Kanewisher mine is in a deep coulee in the SW. ¼ of sec. 35, T. 152 N., R. 81 W. (See analyses Nos. 5543 and 5544.) The bed is 14 feet thick and the cover is a very tough, hard boulder clay. A drift is run in along the seam, and 7 to 8 feet of lignite is removed, the upper 3 to 4 feet being left to form the roof. Coal was formerly mined in the extreme northwest corner of the same section, in the old Red Flag mine. The Coteau bed probably does not extend more than about half a mile north of this corner of sec. 35, since the surface is below the level of the bed, and the latter has been eroded.

The Leeson East mine, or mine No. 1, is in the SW. ¼ of sec. 27, T. 152 N., R. 81 W. The coal is here 18 feet thick and the cover in places is drift, varying in thickness from 15 to 25 feet. Much of the mining here has been by stripping, though several short entries have been driven. (See analyses Nos. 5545 and 5546.)

The Wood mine is located in a coulee in the southeast corner of sec. 21, T. 152 N., R. 81 W. No measurement of the entire thickness of the bed could be secured here, but it is reported to be 10 to 12 feet thick, the section of the seam being as follows:

	Feet
Coal	10 to 12
Clay	4
Coal	4½

The coal is overlain in places by blue shale, above which is drift. Much stripping has been done, an overburden of 10 to 25 feet being removed. Most of the coal is now being mined by a short slope, and is hauled up in cars by wire cable to a loading platform. The Coteau bed in this vicinity appears to have a slight dip toward the north and west.

It could not be determined whether sec. 16, one mile north of the Wood mine, is underlain by this coal bed. There are no outcrops and if the coal is present it would be under a thin cover and perhaps eroded in places. A large coulee crosses sec. 17 and passes near the northwest corner of sec. 16, but no clinker or other evidence of coal

was seen along this coulee, except in the extreme southwest corner of sec. 17.

The old Murray mine is in the NE. ¼ of sec. 29, T. 152 N., R. 81 W. The coal bed is here 12 to 14 feet thick. Some stripping has been done, but most of the coal is now mined by a drift. At the mouth of the entry the cover is drift. This mine is rather wet but no pump is used.

The Leeson West mine is located on a large coulee, in the NE. ¼ of sec. 19, T. 152 N., R. 81 W. The coal has no clay partings or seams, and appears to be uniform from top to bottom. The cover is shale, and at the air shaft the overburden is 70 feet thick. The bed is here reported to have a thickness of 16 feet. The lower 7 or 8 feet of lignite are mined and the rest is left for the roof. This is one of the largest mines of the district, and most of the coal is mined by drifts run in along the bed. (See analyses Nos. 5547 and 5548.)

The Tree-Bausch mine, which is one mile south of the Leeson West, in NW. ¼ of sec. 30, is located on the same coulee. It was not being worked at the time of our visit. The coal is here at least 10 feet thick, but the bottom is not exposed. (See analysis No. 5549.)

The old Stafford mine was for a number of years one of the important mines of this region and much coal was hauled to Sawyer and shipped. It has not been worked for 6 to 7 years. The mine is located in a deep coulee, in the NE. ¼ of sec. 15, T. 152 N., R. 82 W. The coal bed is reported to be 18 feet thick. There were three drifts, which are said to run back 500 feet, but these have now caved in so that the mine cannot be entered. The coal seam lies 5 to 10 feet above the bottom of the ravine, and 70 to 75 feet below the upland surface.

Coal has not been mined along the coulee southwest of sec. 15, but has been mined in the south half of sec. 10, and in the NE. ¼ of sec. 11. At the latter locality it was mined by stripping off a few feet of overburden just above creek level. Coal is here brought to the surface by gophers and is seen about their holes.

The deep coulee in which the Stafford mine is located cuts across the southeast corner of sec. 16, and the coal bed probably underlies this section, though no outcrops are found.

A deep coulee crosses the north half of sec. 24, T. 152 N., R. 82 W., and the Coteau coal bed has here been mined at several points. It has a thickness of 16 feet and lies 60 feet below the up-

land. The largest is the Bartoshevich mine in the SE. ¼ of sec. 24, T. 152 N., R. 82 W., on a branch of the main ravine. The coal is mined by drifting in along the bed from its outcrop near the bottom of the coulee. The bed here dips gently to the south. A mine was opened in this coal bed in the NW. ¼ of sec. 24 but it was too near creek level and was abandoned on account of the water. A new opening on the north side of this ravine has exposed the top of the coal at an elevation of 15 to 20 feet above the creek, so that here also the bed shows a southward dip.

The Coteau coal bed extends an undetermined distance south of the Soo railroad through Ruso and Benedict, and is doubtless present in the northern part of T. 150 N., Rs. 81 and 82 W., as shown in Fig. 14.

Several mines have been opened in the large coulee which crosses T. 153 N., R. 82 W., and joins the Mouse River valley two or three miles above Sawyer. The Coteau coal bed is here 11 to 12 feet thick and lies near the bottom of the ravine, or about 75 feet below the upland surface.

The Walker mine was located in the SW. ¼ of sec. 27, T. 153 N., R. 82 W., but it is no longer worked and the old drifts have caved in. The Bigley or Mammoth Springs mine is in the same section, about one-quarter of a mile east of the Walker mine. The coal is mined by stripping off the cover, which here in the coulee ranges from 3 to 8 feet. The overburden is drift for the most part, but in places 2 to 3 feet of shale overlies the coal. From the strip pit several short drifts have been run in along the bed. (See analysis No. 5550.) Coal has been mined here on the Bigley place for about 20 years.

The Coteau coal bed passes below the bottom of the coulee a short distance west of the old Walker mine, and one-half mile west, near south line of sec. 28, it was struck in a well at a depth of 30 feet. This same bed of coal is reported to have been struck near the middle of the south line of sec. 15, T. 153 N., R. 82 W. It is quite likely that the Coteau bed underlies sec. 16, though no outcrops or clinker were seen along the sides of the coulee which crosses the southern edge of the section. But the fact that it is found in sec. 15 indicates that it extends almost if not quite to sec. 16, only half a mile farther west.

Coal is also reported to have been found about 6 miles below the Bigley mine, near the bottom of the same coulee, but this report was

not verified. Should this be the case it is probably a lower coal bed which occurs near the edge of the Mouse River valley.

Knowing the average thickness of a coal bed and the area covered by it, it is possible to estimate the amount of coal it contains. A coal bed 14 feet thick, which is the average for the Coteau bed, contains 23,800 tons per acre, or 15,232,000 tons per square mile. Since this coal bed with this thickness has an area of at least 140 square miles, it contains approximately 2,132,000,000 tons of lignite. But the Coteau bed doubtless underlies also three additional townships with an average thickness of 10 feet, so that its total tonnage is probably about 3, 284,000,000 tons.

WILLIAMS AND MOUNTRAIL COUNTIES

L. P. Dove and H. N. Eaton

For convenience of description three districts are recognized. (1) The Williston district. (2) The Hanks district. (3) The White Earth River district.

THE WILLISTON DISTRICT

The information for the report on this district is largely taken from the following sources:

"The Lignite of North Dakota and Its Relation to Irrigation" by F. A. Wilder.[1]

"The Williston Lignite Field, Williams County, North Dakota," by F. A. Herald.[2]

"The Nesson Anticline, Williams County, North Dakota," by A. J. Collier.[3]

A topographic map known as the Ray quadrangle on a scale of 2 miles to the inch and with a contour interval of 50 feet was published by the United States Geological Survey in 1911. This map includes a portion both north and south of the Missouri river in eastern Williams county.

It will be the aim of the writer to summarize the information on the more important coal beds. For details the reader is referred to the above publications, especially Bulletin 531 of the United States Geological Survey, which contains maps and sections. Plate XIV is prepared for the convenience of the reader.

[1]Water Supply and Irrigation Paper No. 117 U. S. Geol. Survey, 1905.
[2]U. S. Geol. Survey Bull. No. 531, pp. 91-157, 1913.
[3]U. S. Geol. Survey Bull. No. 691, pp. 211-217, 1919.

The Williston district lies immediately north of the Missouri river and east of the Montana-North Dakota boundary. It is served by the main line of the Great Northern railway. Williston is a thriving town and the center of a large tributary agricultural area. Trails and wagon roads make essentially every portion of the district accessible during most of the year.

It is probable that every part of the district is underlain with lignite at no great depth. Beds thick enough to work are exposed or lie at shallow depths in several localities so that no part of the district is far from ample supplies of fuel. The area a few miles east and southeast of Williston has been the most intensively developed, and a number of mines have been operating here for many years. Four coal beds have been traced in T. 154 N., R. 100 W., and adjacent townships. (See Fig. 16.)

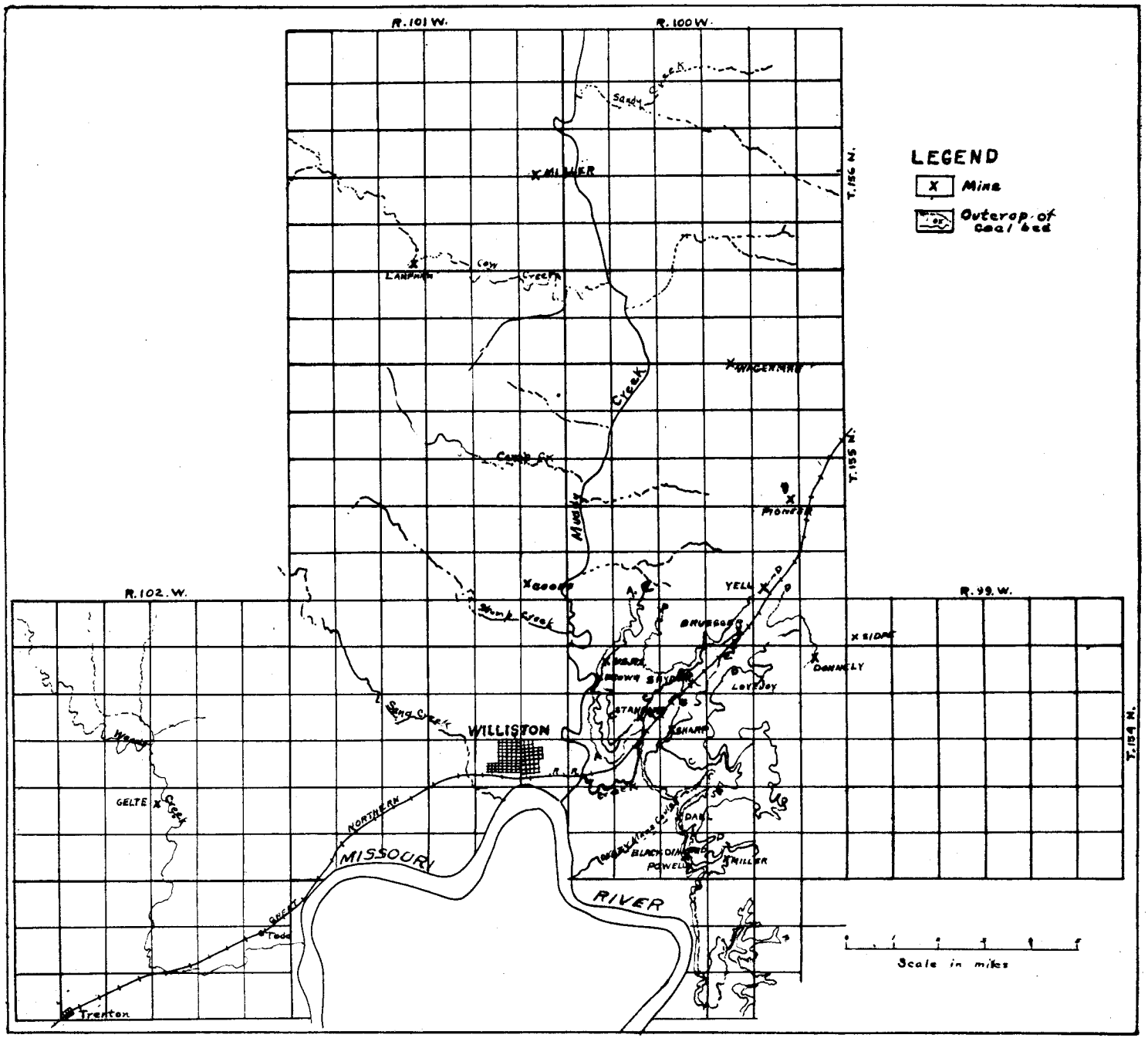
The lower is designated by Herald as bed A. It varies in thickness from 2 feet 7 inches to 8 feet, thickening northward. Since it lies at nearly the level of the flood plain of the river exposures are not frequent.

There is an interval of 13 to 50 feet of shale between bed A and bed B which is next higher. Bed B has been extensively worked at the U. S. Reclamation Service mine in sec. 7, T. 154 N., R. 100 W. Here this bed is 10 feet thick. Several other mines have also operated on this bed. South of Crazy Mans coulee this bed thins to about 3 feet. Bed C lies from 20 to 60 feet above bed B with an average of about 40 feet. It has a rather uniform thickness of from 6 feet 6 inches to 10 feet. Greater thicknesses have been reported. The Bruegger mine and old Black Diamond mine were in this bed.

Bed D is about 85 feet above bed C, and is made up of two benches. The parting of gray shale ranges from 2 to 4 feet in thickness in the southern part of the township, while in the northern part the parting is thinner and is made up of clay, thin seams of lignite and carbonaceaus shale.

In the SW. ¼ of sec. 11, T. 154 N., R. 100 W., the section is as follows:

		Feet	Inches
Lignite (Old Lovejoy mine)		6	7
Shale, gray		6	
Bed D	Lignite	1	3
	Shale, gray	3	4
	Lignite		5
	Shale, carbonaceous		2
	Lignite	2	1



MAP OF WILLISTON DISTRICT,

Williams County.

Showing locations of lignite mines and outcrops of important beds. Adapted from Plate 10, Bulletin 531, United States Geological Survey.

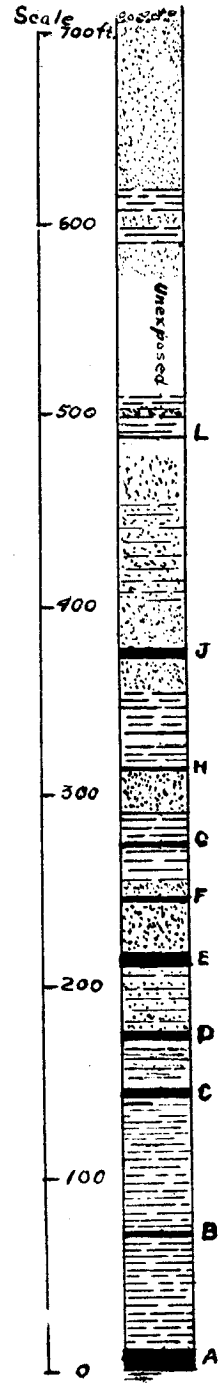


Fig. 15. Columnar section of coal beds in Fort Berthold Indian Reservation, McKenzie county, in T. 152 N., R. 95 W. (U. S. Geol. Survey).

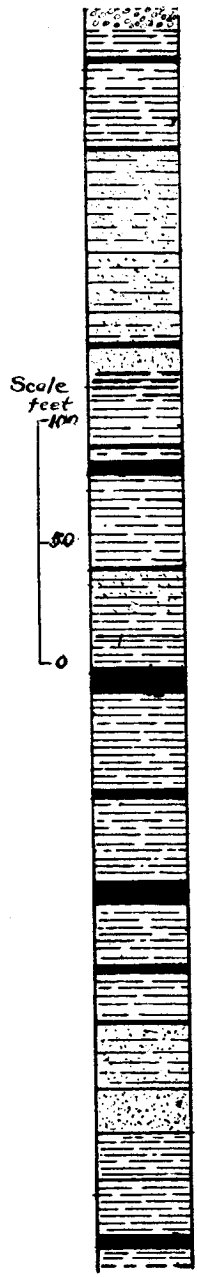


Fig. 16. Generalized section of Williston lignite fields (U. S. Geol. Survey).

Other beds above bed D were noted in this township but are not thicker than 2 to 3 feet.

Bed D was traced northward along the east side of Muddy creek through T. 155 N., R. 100 W., and was less than 6 feet thick where it could be measured. It was further traced in T. 156 N., R. 100 W., where no great thickness was noted.

On the west side of Muddy creek in sec. 36, T. 155 N., R. 101 W., a maximum thickness of 14 feet is reported. Thicknesses of 6 to 8 feet are reported from Camp creek in secs. 15 and 16. In this township the old preglacial surface in many places is at about the position of these coal horizons and thus boulder clay directly overlies the lignite beds. It is pointed out elsewhere that where there is extensive glaciation the distribution of a coal bed lying near this old surface is uncertain.

T. 156 N., R. 101 W., is probably underlain with thick beds of lignite although exposures are infrequent on account of the mantle of glacial drift. Several exposures were examined along Cow creek where strippings have exposed lignite beds over 5 feet thick in several places, and reports of 11 feet of coal are recorded.

In T. 154 N., R. 101 W. beds of lignite were formerly mined in secs. 5, 6, 7, 8 and 16. At the old Head mine in sec. 7 a bed is reported to be 10 feet thick. Water is said to be flowing from practically every lignite exposure in the township. In a series of drill holes put down by the United States Reclamation Service no thick beds of lignite were encountered in the SE. ¼ of sec. 31 or the SW. ¼ of sec. 24. None of these holes went below 122 feet, however.

In the valley of Painted Woods creek the thickest bed reported is 5 feet 7 inches in the McCoy or Adams pit in the southern part of sec. 28, T. 154 N., R. 102 W. As the report was made mostly on natural exposures thicker beds may be present. In the valley of Eight Mile creek no thick beds are exposed. This area seems to be an unusually barren portion of the Fort Union so far as lignite is concerned.

In the valley of Little Muddy creek at least one bed is present near the surface. Its outcrop extends through secs. 1, 2, 12, 14, and 23, T. 154 N., R. 104 W. It averages abount 5 feet in thickness and in one location about one quarter mile west of the Montana line shows a thickness of 6 feet 10 inches.

No thick beds are exposed in either Fiegley coulee north of Buford nor Garden coulee northwest of Buford.

THE HANKS DISTRICT

Hanks is a village on the branch line of the Great Northern railroad from Stanley to Grenora, and is in the northwestern part of Williams county. The district embraces a portion of townships 158 and 159 N., and ranges 101 and 102 W. as shown in Plate XV.

The area is a gently rolling upland in which Scoria creek has eroded a deep valley which is the most striking topographic feature of the region. This valley is steep walled and averages 175 to 200 feet in depth and from a mile to two miles in width. The sides of the valley are so abrupt that the roads take advantage of tributary valleys or low jutting shoulders to get in and out. The slopes are grassed over except in the immediate vicinity of Hanks where the Fort Union strata are exposed and the Hanks coal bed has burned at the outcrop, giving rise to clinker or "scoria" masses of large size, whose superior resistance to weathering has formed clinker capped buttes as outliers in the valley. The bottom of the valley is filled to a variable depth with outwash gravels from the glacial ice, and wash from the valley walls.

THE HANKS COAL BED

Due to the natural exposure of the Hanks coal bed at easily mined depths this locality has produced coal for local trade for many years. Since the Great Northern extended its line to Grenora a considerable quantity of coal has also been shipped. At present (1920) the following coal mines are operating in the near vicinity of Hanks; the Hanks Coal Company mine one-half mile south of town, (see analysis No. 5551), the Olaf Lien mine one-half mile north of town and the Black Beauty mine owned by Fred Gotham, while several mines a greater distance from Hanks are open in the winter but ship less due to greater distance to haul by team. None of the above mines had railroad connection when visited in the summer of 1920, but hauled their product to the siding at Hanks by team.

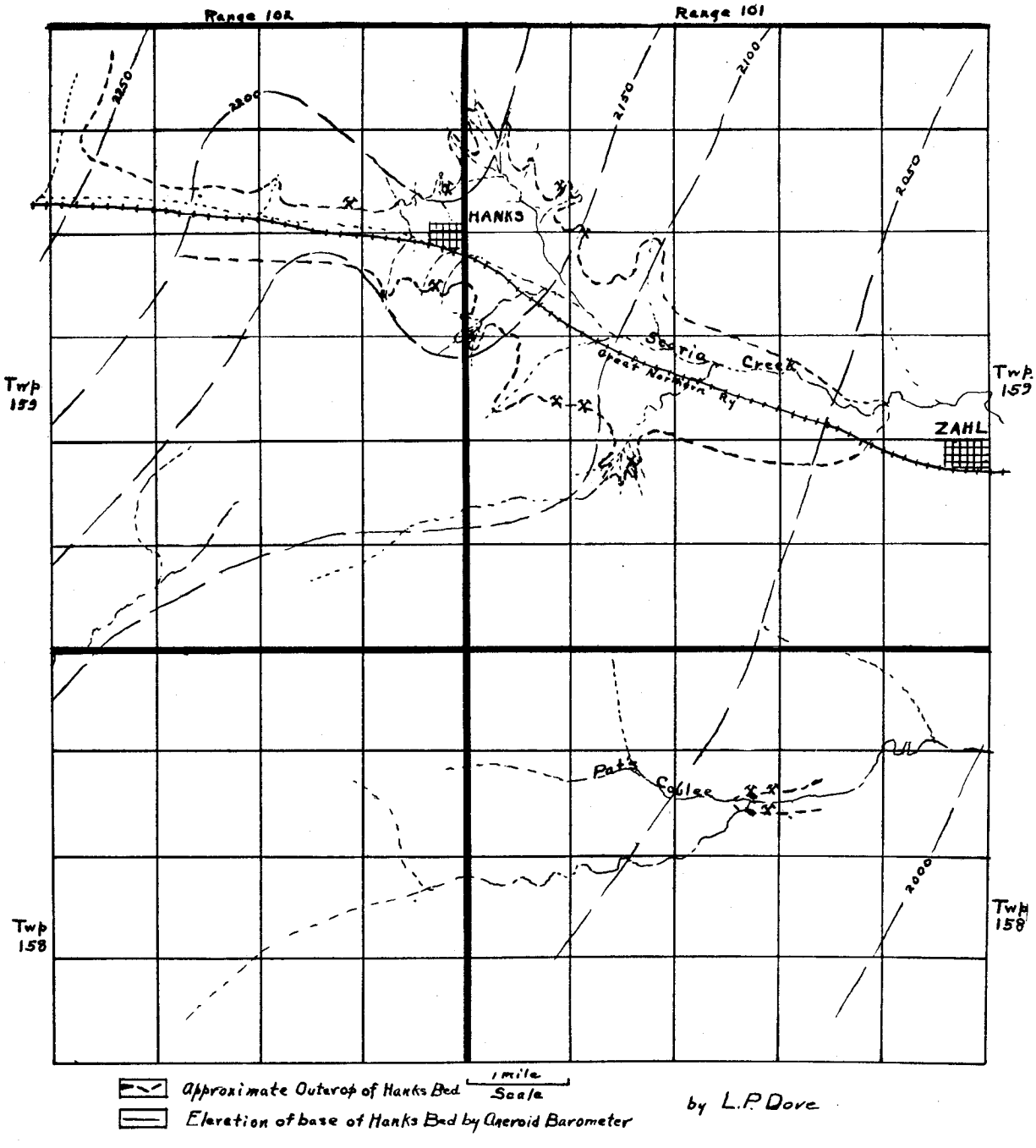
All the mines visited were opened by drifts into the side hill at the outcrop of the Hanks bed which is here some 70 feet above the bottom of the valley, thus allowing ample fall for gravity tipples to wagons. No machines or electrical equipment are used but all coal is mined by hand and hauled by horses or mules to the tipple.

Another small area in sec. 9, T. 158 N., R. 101 W., is producing coal for local demand, most of it being marketed at Zahl. The Nordlien, (see analysis No. 5552), the Johnson and the Norveson mines are

opened in a coal bed that is probably the Hanks bed. The coal here is about 8 feet thick, overlain by 20 feet of gray shale which grades upward into a crumbly sandstone. A slight dip to the southeast makes some trouble with water when entries run in this direction. The coal is here only a few feet above the bottom of Pats coulee but is safe from ordinary high water.

The Hanks bed averages about 7½ feet in thickness and when sufficiently distant from the outcrop is solid and hard. Locally it carries rather large quantities of sulphur in the form of pyrite or marcasite but this is not persistent. No shale or clay bands are persistent and the bed presents no unusual conditions of mining. Sufficient coal is left to form a solid roof in entries and little timbering is necessary except in the rooms. The coal bed is essentially level for the short distance at present mined except local folds, one of which was noted in the Olaf Lien mine. This has the appearance of a rather sharp local syncline or down fold which for short distances makes rather prohibitive grades in a main entry and also serves as a basin for collecting troublesome amounts of water. This is probably only a local structural feature. By noting contours drawn on the base of the Hanks bed in Plate XV it will be seen that there is a general dip of the bed to the southeast with local variations. Dips as high as 40 feet to the mile were noted but probably extend for only small distances. In mines this regional dip will not prove troublesome unless entries become very long then problems in drainage may arise that will make it necessary for this dip to be taken into account. Fortunately, however, the coal is dry where mined and with but few exceptions water has not made trouble. Such water as has caused trouble is largely that from rains and snow at the immediate mouth of the drifts or inclines. It is to be expected that water will be found in more abundance down the dip to the eastward.

Extent and Amount of Coal. Well records back from the outcrop of the Hanks bed at Hanks show this bed is probably present over most of the area represented in Plate XV. Westward the bed rises until it intersects the surface at about the center of secs. 4 and 9, T. 159 N., R. 102 W., but is here concealed by glacial drift. South of the coulee no data are available but it is likely the crop line swings southwestward. The easterly dip of the bed carries it below the level of Scoria creek approximately in sec. 22, T. 159 N., R. 101 W. Thus the valleys of Scoria creek and Pats coulee are both cut below the coal through a



MAP OF THE HANKS DISTRICT

Williams County

Sketch map showing the approximate line of outcrop of the Hanks coal bed in the valley of Scoria creek, also the location of mines and exposures of coal. A series of structure contours have also been drawn to show the gentle southeasterly dip of the coal bed. The figures on the contour lines give the elevations above sea level based on aneroid barometer readings.

part of their length. Assuming this bed to be present in all other portions of the area, an assumption that seems to be well grounded except where possibly concealed valleys have cut it out, this coal probably underlies about 78 square miles, shown on Plate XV. Allowing an average thickness of 7 feet this would show as available 628,992,000 tons. Assuming that 60 per cent could be recovered by the usual methods of mining the yield would be about 377,000,000 tons.

None of the mine workings in the district are extensive. Main entries extend only a few hundred feet into the hill and the areas worked out so far total only a few dozen acres.

WHITE EARTH RIVER DISTRICT

This district includes the western part of Mountrail county and a small portion of the southeastern corner of Williams county. It is drained by the White Earth river and the shorter streams that flow southward into the Missouri river.

Brief mention is made of the lignite deposits of the region in the following reports:

L. H. Wood[4] gives a short description of the lignite in White Earth Creek Valley and also mentions a few localities along the Missouri river where lignite is found.

F. A. Wilder[5] examined the flats adjacent to the larger streams and also lignite beds that might furnish fuel for pumping water for irrigating the flats.

A. J. Collier[6] visited the areas adjacent to the Missouri river and published a columnar section showing the important coal beds.

A plane table survey to determine the structure of the east side of the Nesson anticline was begun by the authors and later completed by L. P. Dove with the assistance of E. E. Foster and W. F. Keye. See Fig. 16.

In the following discussion of the distribution and thickness of the coal beds, they are considered by townships. Plate XVI is a sketch map that shows the general relations.

T. 158 N., R. 93 W.

A 4-foot bed of coal is being mined by stripping a few feet above White Earth river in sec. 19. Water is abundant and troublesome. No considerable flat area is present with light enough overburden to

[4] Wood, J. H., Lignite Deposits of Ward County, Second Biennial Report, N. D. Geol. Survey, pp. 137-139, 1902.
[5] Wilder, F. A. U. S. Geol. Survey. Water Supply and Irrigation Paper No. 117, 1905.
[6] Collier, A. J., The Nesson Anticline, Williams County, North Dakota, U. S. Geol. Survey Bull. No. 691, pp. 211-217, 1918.

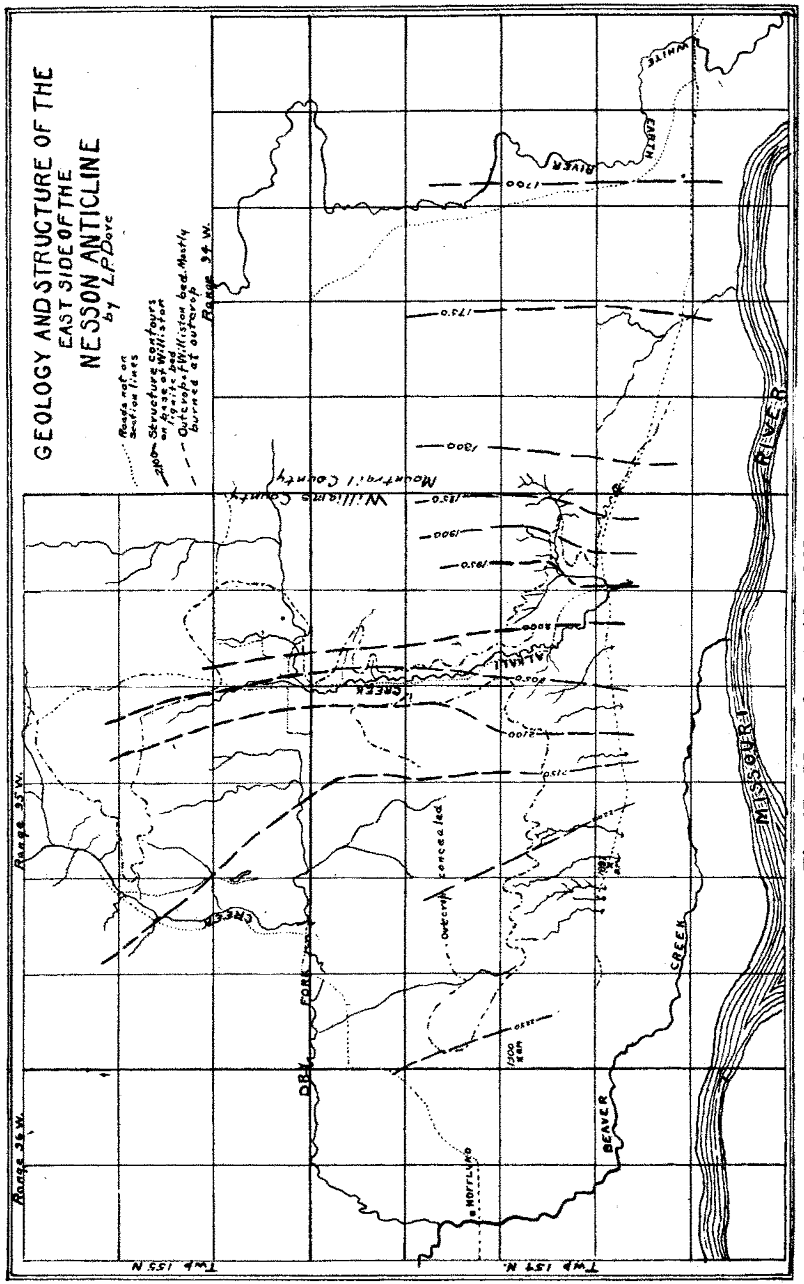


Fig. 17. Map of east side of Nesson anticline.

pay to strip on a large scale. The bed is too thin to mine underground.

T. 157 N., R. 93 W.

A few thin beds of lignite are exposed in several old strippings where a few tons have been removed. A coal bed 5 feet thick is reported in the SE. ¼ of sec. 19.

T. 157 N., R. 94 W.

A 4½-foot bed is reported from the SE. ¼ of sec. 12, and thin seams 6 inches to 2 feet thick on the east side of the valley of the creek which flows through secs. 16, 21, and 28.

T. 156 N., R. 94 W.

Several pits and mines have been operated in this township. The most intensively developed region is that bordering the river in secs. 9, 10, 15, and 16. (See analysis No. 5553). The Porger mine in sec. 15, is one of the most important. Here the coal ranges from 6 to 7 feet in thickness. Several thin beds are tracable in the valley and have been mined by shallow strip pits or short entries. There appear to be but few beds of sufficient thickness to open on a large scale as the beds are thin and not persistent. A thickness of 4½ to 5 feet was noted at an old stripping on the SW. ¼ of sec. 26. Coal beds with a thickness of from 6 inches to 4 feet are quite common.

T. 155 N., R. 94 W.

A few tons of lignite have been mined from small strip pits bordering the valley where thin beds outcrop. About the middle of sec. 33 a bed 3½ feet thick is exposed by a slump. Thicknesses of 1 to 2 feet are exposed in the fresher valley walls both on the east and west side of the valley.

T. 154 N., R. 94 W.

This township is probably underlain with the eastward extension of the Williston bed except secs. 19, 30, 31, and 32. This bed is exposed and mined near the center of the south line of sec. 18 where it shows a thickness of about 8 feet. The bottom here has an elevation of 1810 feet above sea level and traced westward it rises and is burned extensively with only occasional outcrops where a fresh slump or nearly vertical wall has exposed it. Eastward it dips below the flood plain of the Missouri river, which has probably cut it out in the sections mentioned above. No data are at hand to show whether it persists in thickness eastward. An unverified report shows a heavy coal to be present in wells in secs. 4 and 5 and it is possible this may be the same bed.

Other thin coal beds are present, one of the best exposures being found in sec. 21 where several confluent streams have exposed two or more beds. One of these is located 4 to 5 feet thick and has burned, forming considerable clinker.

T. 154 N., R. 95 W.

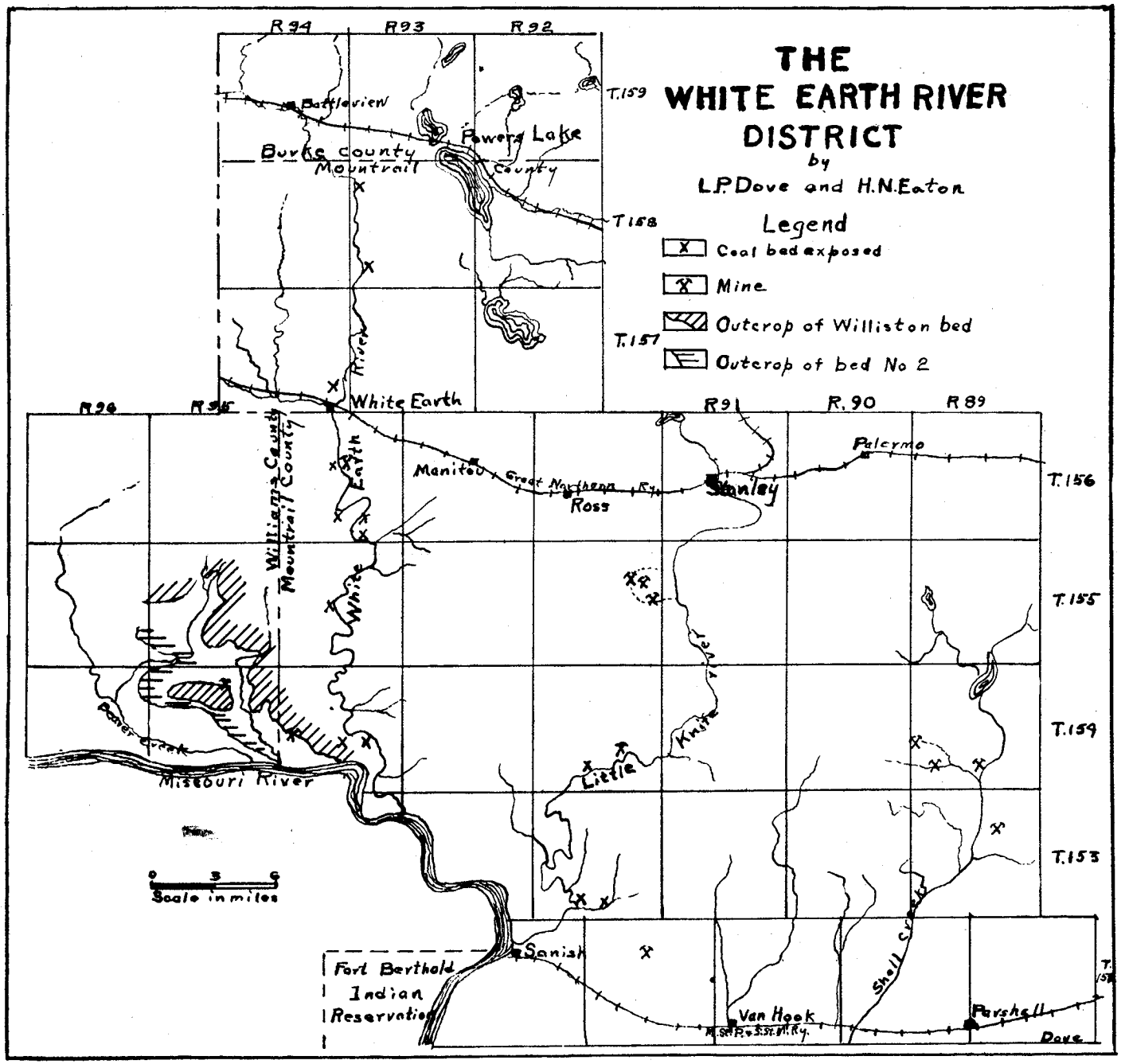
The heavy bed called the Williston bed[7] rises to the westward where it attains an elevation at the base of 2212 feet above sea level near the east line of sec. 16, showing a rise of 402 feet in about 4 miles or an average of about 100 feet per mile. It has burned so extensively along the outcrop that few fresh exposures could be found. The clinker from this bed caps the high bluffs extending through secs. 7, 8, 9, 10, 15, and 16. The bed is exposed in a few places along the valley of Alkali creek in secs. 2, 3, 10, and 11 and also in the valley that extends through sec. 13. In sec. 11 it shows a thickness of 11 feet. Wherever exposed the bed is of uniformly good grade.

Several other coal beds are present in this township though none which were noted had the thickness of the Williston bed over large areas. A bed at an interval of about 240 feet below the Williston bed in secs. 16 and 17 is locally 5 to 8 feet in thickness and a bed 4 to 5 feet in thickness is present 200 feet below the Williston bed. Other beds ranging from a few inches to 4 feet in thickness are also present in the section but do not persist for any distance.

A columnar section made up and generalized from many exposures is shown in Fig. 18 and for comparison the section as published by Collier with correlations as suggested by the writers. It will be noted that the lower portion of the section is largely somber gray or drab shales and sandstones while the upper portion is lighter in color due to considerable amounts of light colored limy shales and clays which in places are coated superficially by white salts or alkali. The predominance of the light colored rocks of the upper part of the section exposed in the valley of White Earth river no doubt suggested the name White Earth.

It will be noted that at intervals of from 40 to 100 feet there are beds of lignite. None of these seemed to persist in thickness like No. 6 or the Williston bed. This was easily traced and was used as a key bed for drawing the structural contours shown in Fig. 17. Locally, however, other beds attain workable thickness particularly No. 2 in

[7] Collier, A. J., The Nesson Anticline, Williams County, North Dakota. U. S. Geol. Survey Bull. No. 691, pp. 211-217, 1918.


THE
WHITE EARTH RIVER
DISTRICT
by
L.P. Dove and H.N. Eaton
Legend
Coal bed exposed
Mine
Outcrop of Williston bed
Outcrop of bed No 2
R 94
R 93
R 92
R 96
R 95
R 91
R. 90
R 89
T.159
T.158
T.157
T.156
T.155
T.154
T.153
Battleview
Powers Lake
Burke county
Mountrail
County
White Earth
Williams County
Mountrail County
White Earth River
Manitou
Great Northern Ry.
Ross
Stanley
Palermo
Beaver Creek
Missouri River
Little Knife River
Shell Creek
Sanish
Fort Berthold
Indian
Reservation
Van Hook
Parshall
Dove
0 3 6
Scale in miles

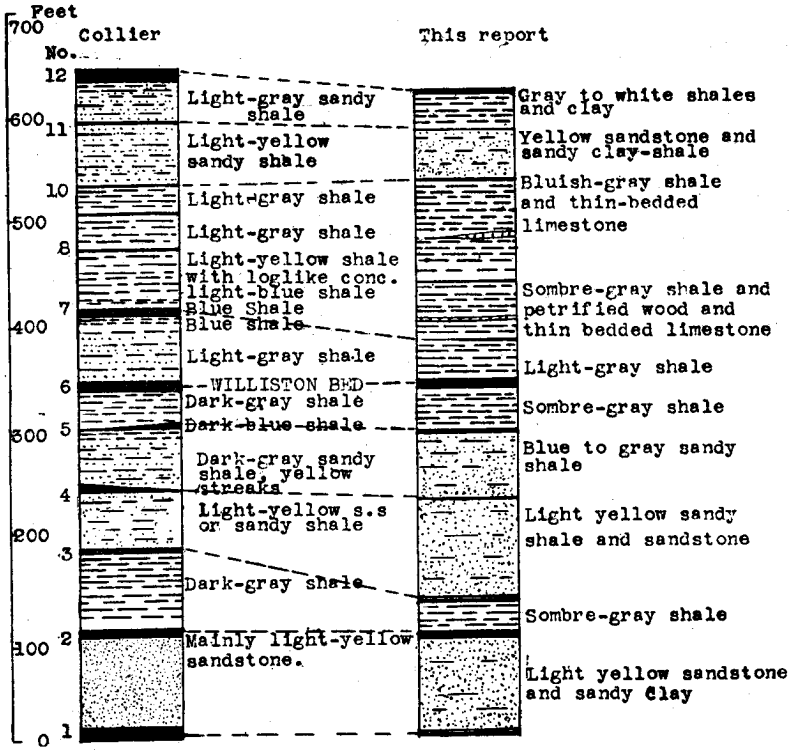


Fig. 18. Generaized columnar sections showing the sequence of beds along the Missouri river in the vicinity of Nesson (left), as compiled by A. J. Collier, Bulletin 691, U. S. Geological Survey, and the sequence in the vicinity of Alkali creek, T. 154 N., R. 95 W., as compiled by Leonard P. Dove and H. N. Eaton.

secs. 16 and 17, T. 154 N., R. 95 W. Since the nearest railroad is about eighteen miles away, no lignite is mined except to supply a local demand. The mine of Mr. George Timmel in sec. 19, T. 154 N., R. 94 W. is the only one kept open the year round. See analysis No. 5554. This mine is opened by a tunnel a few hundred feet in length from the level of the flood plain. The coal is here about 10 feet thick and of good quality. About 7 feet is mined, the upper 3 feet being left for a roof. This is bed No. 6 or the Williston bed.

Of particular interest are two or three thin beds of limestone and several horizons containing large quantities of petrified stumps and logs noted above, and below what may be bed No. 12 in sec. 13, T. 154 N., R. 95 W.

The coal bed which may be No. 12 varies in thickness from 3 to 6 feet, and contains in places large quantities of petrified logs, stems and leaves or grass.

T. 153 N., R. 93 W.

In the bluffs of the Missouri river and also in the tributary valleys several thin coal seams are present. A bed locally 5 to 6½ feet thick is being mined in small strip pits near the northwestern corner in sec. 6 and in the southwestern corner of T. 154 N., R. 93 W.

The bluffs of the Missouri river are in large part steep and exposures of thin coal beds from a few inches to 2 or 3 feet thick are fairly common. No beds seem to be thick enough or near enough to the surface to have burned to form clinker. A partial section of the bluff in the SW. corner of sec. 23 is typical of the coal beds.

	Feet	Inches
Carbonaceous shale	3	
Unexposed	25	
Coal	1	6
Unexposed	5	
Coal	1	6
Carbonaceous shale	1	
Coal	2	
Unexposed	25	
Coal		6
Unexposed	10	
Coal	5	

T. 153 N., R. 92 W.

Several thin beds of lignite outcrop along the coulee that extends eastward from the Little Knife river in secs. 33 and 34 where one of the heavier beds has burned. No fresh exposure of the entire thickness of this bed was observed though at a small strip pit in sec. 33 it is mined locally. Another small strip pit near the center of sec. 10 shows 2 feet of coal exposed. Several other small pits have been opened but no heavy bed discovered so far as known.

T. 154 N., R. 92 W.

The thickest coal bed observed is being mined in the SE. ¼ of sec. 22 at the Carkuff mine where a thickness of 7 feet 7 inches was observed and the full thickness not shown. A slight clay parting is present 1 foot 4 inches from the top. This coal bed is near the bottom of the valley of the Little Knife river which is here incised nearly 200 feet. Several acres with a relatively light overburden (3 to 20 feet) would be available by stripping. Water is encountered since it is here so near the level of the stream. The quality of this coal seems to be good.

T. 155 N., R. 92 W.

Several small mines have been opened in thin beds of coal in secs. 13 and 7, T. 155 N., R. 91 W. The Kale, Carkuff, Alger, and Anderson mines are operating on two thin beds separated by a clay band. The lower coal ranges from 1 foot 10 inches to 4 feet in thickness, overlain by clay 6 inches to 20 feet thick. The upper bed ranges from 6 inches to 2 feet in thickness. These mines assume considerable importance as the thick mantle of drift northward conceals the coal beds in that direction with the result that these mines serve aconsiderable territory about Stanley and Ross.

T. 152 N., R. 92 W.

In the NE. ¼ of sec. 16 the following section was exposed at the Osborn stripping:

	Feet	Inches
Yellow till	12	
Yellowish gray sandstones grading downward into grayish yellow argillaceous clay. Clay iron stone concretions and numerous plant imprints in lower portion	25	
Grayish white clay (fire clay?)	2	6
Coal	1	9
Clay	1	6
Coal	10	

The Lignite of North Dakota, its Character, Composition and Utilization

By Earle J. Babcock,

Dean of The College of Engineering,

University of North Dakota.

THE LIGNITE OF NORTH DAKOTA, ITS CHARACTER, COMPOSITION AND UTILIZATION

By Earle J. Babcock

North Dakota is fortunate in possessing an enormous supply of fuel in the form of lignite coal; and this is going to prove one of the greatest inducements the state has to offer for the establishing of industries.

When any cheap power can be secured, there is a very great incentive to the establishing of manufacturing industries.

Power, however, is derived from fuel as well as from water, and, in addition, this same fuel supplies domestic needs. As a result there is a great industrial development in those regions, possessing deposits of coal, oil or gas. Pennsylvania gives us an example of industrial development due, in a large degree, to mineral deposits of fuel within the state. Other instances might be mentioned where development is largely dependent upon supplies of fuel. With cheap fuel and modern improved machinery it is a very easy matter to obtain almost any desired amount of power so cheap as to afford a great stimulus to manufacturing.

And so it is well that our attention be called to the benefits to be derived from the proper utilization of our great lignite deposits. In the future our coal and clay resources are destined to form the basis for a development which will gradually convert North Dakota into a rich mining and manufacturing, as well as agricultural, state.

Something is known of the vast deposits of lignite coal which are found within the state of North Dakota, but the immense value of these deposits is little appreciated. There is a very large area in the western part of the state which is underlain with deposits of lignite. North Dakota has enough coal, if properly developed and used, to supply her needs and those of her neighboring states for many generations. Indeed, North Dakota has one of the largest coal areas of the states of the Union. The total tonnage of lignite deposits of the United States is estimated by the U. S. Geological Survey at over 965 billion (965,902,400,000) tons, of which over 633 billions (633,329,800,000) are estimated in the deposits of North Dakota, included in an area of approximately 28,000 square miles. (See map Plate I.)

When we stop to consider what these figures mean as to the

immensity of these deposits and their value to our people, we naturally ask why we are not deriving larger benefits from this great resource and why we are yearly sending out of our state millions of dollars which might be retained at home in the development of this and other resources.

While many mines have been opened up in different localities, the deposits are for the most part undeveloped. The annual output of lignite mined in the state has now reached over a million (1,000,000) tons, a large increase having been made in the last four or five years.

Whether the outcrops which have been discovered, are fragments of immense coal basins, which have been broken up by water action, and covered with newer formations, or whether they are the deposits of numerous woody swamps of the same geological period, we may not at present determine with certainty. There may have been a general continuity to the original deposits of the same horizon, but it seems not improbable that these different beds were laid down in several old elevated swamps of geologic time.

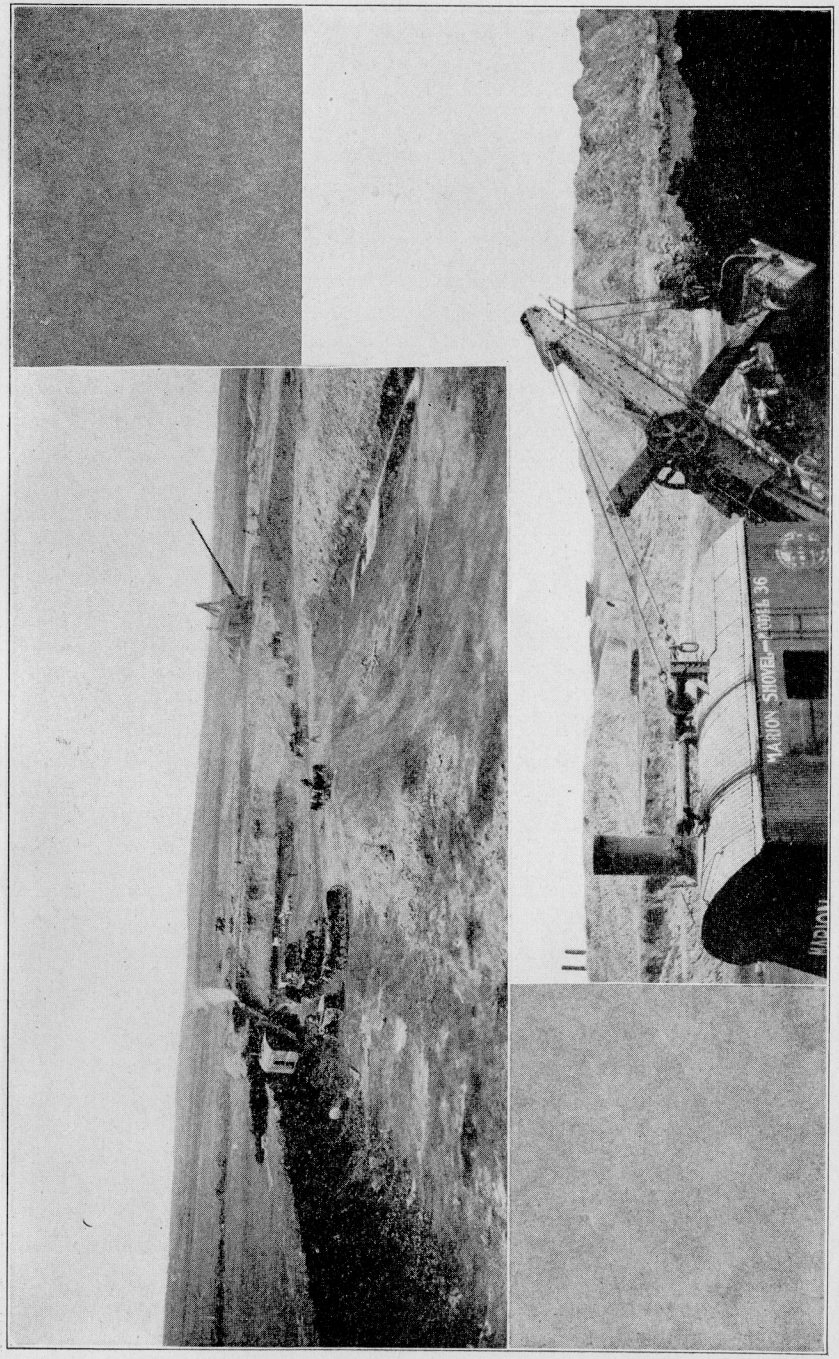
The accompanying map of North Dakota shows the general area in which the larger part of the lignite deposits may be found. (Plate 1.)

There are several distinct seams indicating longer or shorter periods of deposition, or a greater or less activity in vegetable growth corresponding in each to the thickness of the deposition. The deposits often outcrop along the banks of streams, or from the sides of bluffs, and may be traced along valleys, frequently for some distance. The seams most commonly worked, usually lie from 50 to 200 feet below the surface, and vary in thickness from 7 to 20 feet.

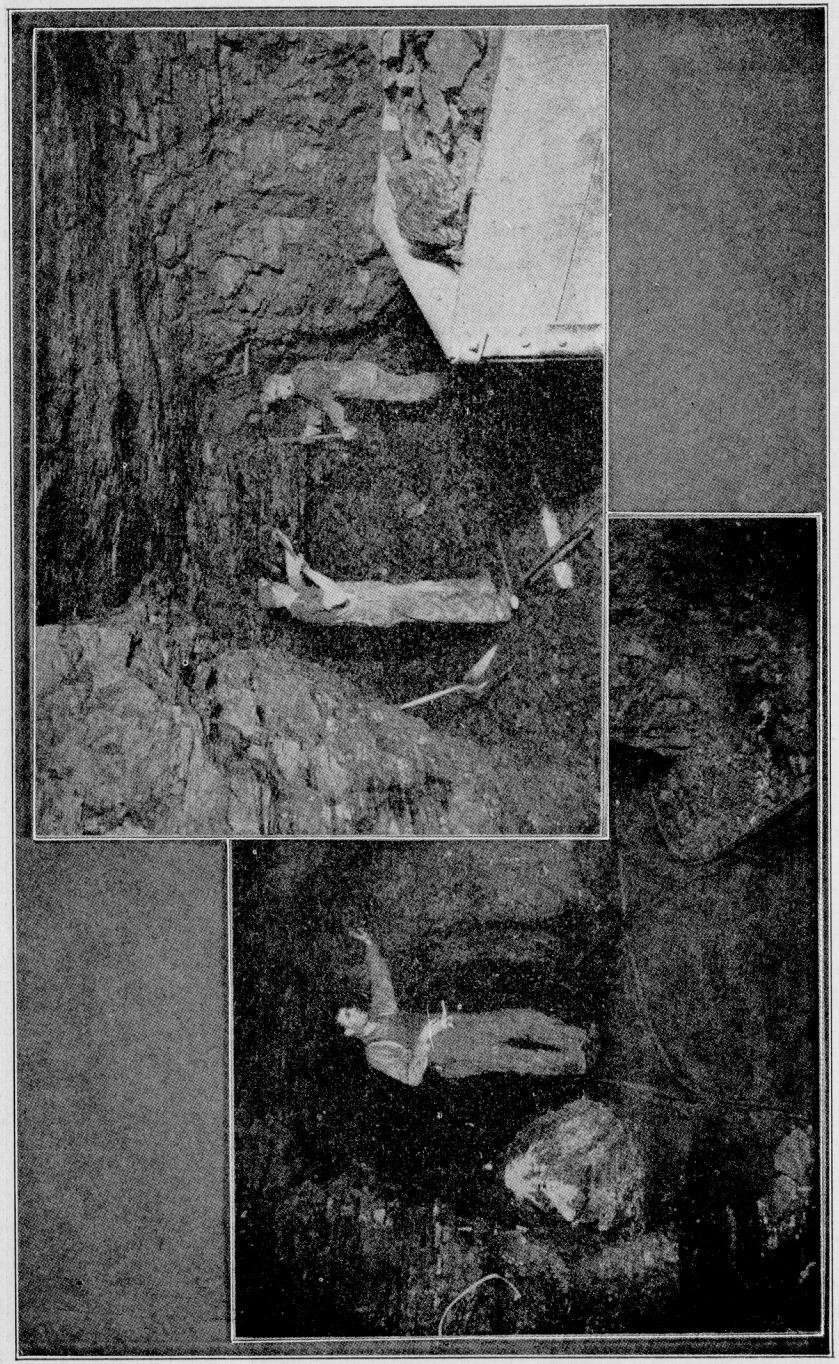
In some of these deposits good lignite is found so near the surface and with such a small overburden of clay and soil that the coal can be mined in open cuts by steam shovels. This method of mining lignite is being economically and successfully employed in several localities in the state. (Plate XVII.)

The roof and floor of these coal seams are of clay, which may in some places prove of considerable economic value. The beds are usually nearly horizontal and show no evidence of tilting or pressure such as is often found in coal deposits of mountainous districts. Therefore, we cannot expect anything more than the normal improvement in quality of the lignite which usually takes place in passing from the surface into the body of the deposits. (Plate XVIII.)

Although the lignite is in a general way similar throughout this



STRIPPING AND MINING LIGNITE BY STEAM SHOVEL



TUNNELS AND ROOMS IN LIGNITE MINES. NOTICE THICKNESS OF COAL

district, still it varies somewhat in its physical, as well as chemical properties, in different localities. In general appearance this coal is between a cannel-coal and the brown lignite of many other districts. Large blocks can be readily split along the line of deposition. When freshly mined lignite contains a high per cent of moisture which, if allowed to rapidly evaporate, by exposure to sun and wind, causes a tendency of the lumps to split and check into rather small pieces. This characteristic, however, is not so noticeable if the lignite is stored in basement or under other suitable storage conditions. Usually the coal is of a brownish black color, sometimes it becomes more compact, darker and of more lustre.

In a general way, it may be said that the varieties of coal, from a chemical point of view, depend largely upon the proportion of fixed carbon, volatile matter and ash. Coal consists chiefly of organic matter, but contains varying proportions of inorganic, or incombustible substances which were originally in the frame work, and sap of the plant, or which were carried in as foreign material, during the period of deposition. When coal is burned, the organic matter is consumed, and passes away as gas, while the inorganic part is left behind as ash. The relative proportion of this ash determines, to a considerable degree, the purity and the value of the coal. A coal which contains less than 5 to 7 per cent of ash, may be considered usually as quite free from foreign impurities. If more than 10 per cent is found, the coal may be considered more or less contaminated in its formation, that is, it was mixed with foreign matter, generally in the form of clay and other impurities which worked their way into the deposits either during the period of deposition, or after the accumulation of the coal.

The purity of a coal is a very important element in determining its fuel value. Different varieties of coal may show a very considerable difference in purity and ash content. Bituminous and anthracite coals are often used with as high as 10 to 16 per cent of ash. In many such coals there is a large loss in the excess ash and clinkers, and also in the accompanying imperfectly burned coal. A difference of 2 or 3 per cent in the earthy matter of two coals may be the source of a very serious difference in their fuel value.

The quantity and character of ash varies considerably in lignite from different deposits. Potash and soda are usually present in the lignite ash, in fairly large proportions, as will be seen by the ash analyses following. Sometimes these are so blended with silicia, iron,

etc., as to tend to form rather easily fusible silicates, and occasionally lignites of this character tend to clinker on the grates, under high fires. Most of the lignites of North Dakota do not give trouble in this respect when used under ordinary conditions.

In the case of lignite to be used for powdered fuel, or to be concentrated by carbonizing and briquetting, the ash content should not be too high or too easily fusible. This is especially important in case of briquetting because of the higher concentration and heat value of the briquets. For these reasons considerable attention has been given to the *composition* and *fusion point* of the lignite ash.

Although the quantity and character of the ash varies in the lignite from different mines, generally, North Dakota lignites are low in ash and very free from earthy impurities, as revealed by chemical analyses.

One of the most objectionable impurities existing in some coals is sulphur. It is undesirable for almost all purposes for which coal may be used. It tends to lessen the heat, it gives off obnoxious gases and corrodes grates and flues. The remarkable freedom of our North Dakota lignite from sulphur is no small advantage.

The combustible matter of coal may be regarded essentially as made up partly of fixed carbon (not easily driven off as gas) and partly of volatile matter (easily converted into gas). This fixed carbon in wood can be converted into charcoal and in certain grades of bituminous coals it can be made into coke. Anthracite usually contains from 75 to 85 per cent fixed carbon and bituminous coal from 50 to 75 per cent. In some grades of soft coal the gas may run high and the fixed carbon relatively low, but produce a good coke. In such cases the coal may be used for gas manufacture.

In a general way it may be said that, for domestic heating, the value of a ton of lignite will equal nearly two-thirds of a ton of eastern coal, although its theoretical value may not be quite that.

While lignites, like other coals, vary considerably in fuel value, the following will give a fairly good idea of the composition of North Dakota lignite with moisture as mined.

Moisture	About	36.0	per cent
Volatile matter	"	27.0 to 29.0	" "
Fixed carbon	"	30.0 to 28.0	" "
Ash	"	5.0 to 7.0	" "
Sulphur	"	0.7	" "
Heating value	"	6,600	B. T. U.

Some of the better grades of lignite run much lower in ash and sulphur and about 10 per cent higher in B. T. U. (about 7,000).

From these comparisons the purity and value of our lignites can be readily seen. It is true that freshly mined lignite has a rather high proportion of moisture, but aside from this our North Dakota lignite is usually very free from objectionable impurities. In fact it is so pure in its composition that it can be concentrated into a briquetted form of such high grade as to become a most excellent substitute for anthracite, quite equal to it as a general domestic fuel.

The fundamental principles, of what seems to be a successful and sufficiently inexpensive process for the commercial briquetting of lignite, have been worked out at the School of Mines of the University of North Dakota and its Sub-Station. During the past two or three years about 5,000 tons of lignite have been treated in the experimental plant and converted into very high grade briquets, an excellent substitute for authracite. They not only possess remarkably high fuel value, but also are of convenient size, clean, strong and stand well storage and handling. They have been thoroughly tested and used in all kinds of stoves and furnaces, and have proved highly satisfactory. All these excellent qualities are brought out in this concentrated form of fuel on account of the unusual purity of the original lignite. Plate XIX.

The method of lignite briquetting which has been developed in the research work of the School of Mines of the University of North Dakota covers, first, the expulsion of the moisture; second, the removal, saving and utilization of the volatile gas and tar; and, third, the binding together of the concentrated residue or char into a strong, durable briquet of proper size for domestic use. Because of the ease with which the gas is produced, the low price of the original lignite, the value of the residue for briquets and the low cost of this excess by-product gas, it should be capable of considerable utilization for heating and power purposes, which would aid in cheap power production and the development of other industries.

As has been stated, the results of a great variety of careful and exhaustive tests have shown that the briquets, properly made from concentrated lignite residue, produce a most excellent fuel, for all practical purposes approaching the efficiency of anthracite. The extent and character of the work and the results obtained seem to indicate very clearly that this method of lignite treatment and briquetting can, in the near future, be put on to a commercially satisfactory basis. Al-

though the general principles involved in the process are not complicated, the proper selection of coal best suited for the production of the highest grade residue or char for briquetting, and the proper observation of many details in connection with the location, construction and operation of a plant are essential to success.

While it is not the purpose here to discuss the methods of carbonizing and briquetting, there seems to be so much promise in this phase of developing our lignite resources that it has been thought desirable to include in this report, along with the analyses of the lignite from various mines, tests to show the quantity and quality of the gas and residue which could be obtained from the lignite. These results will be given in connection with the analyses from various mines or deposits.

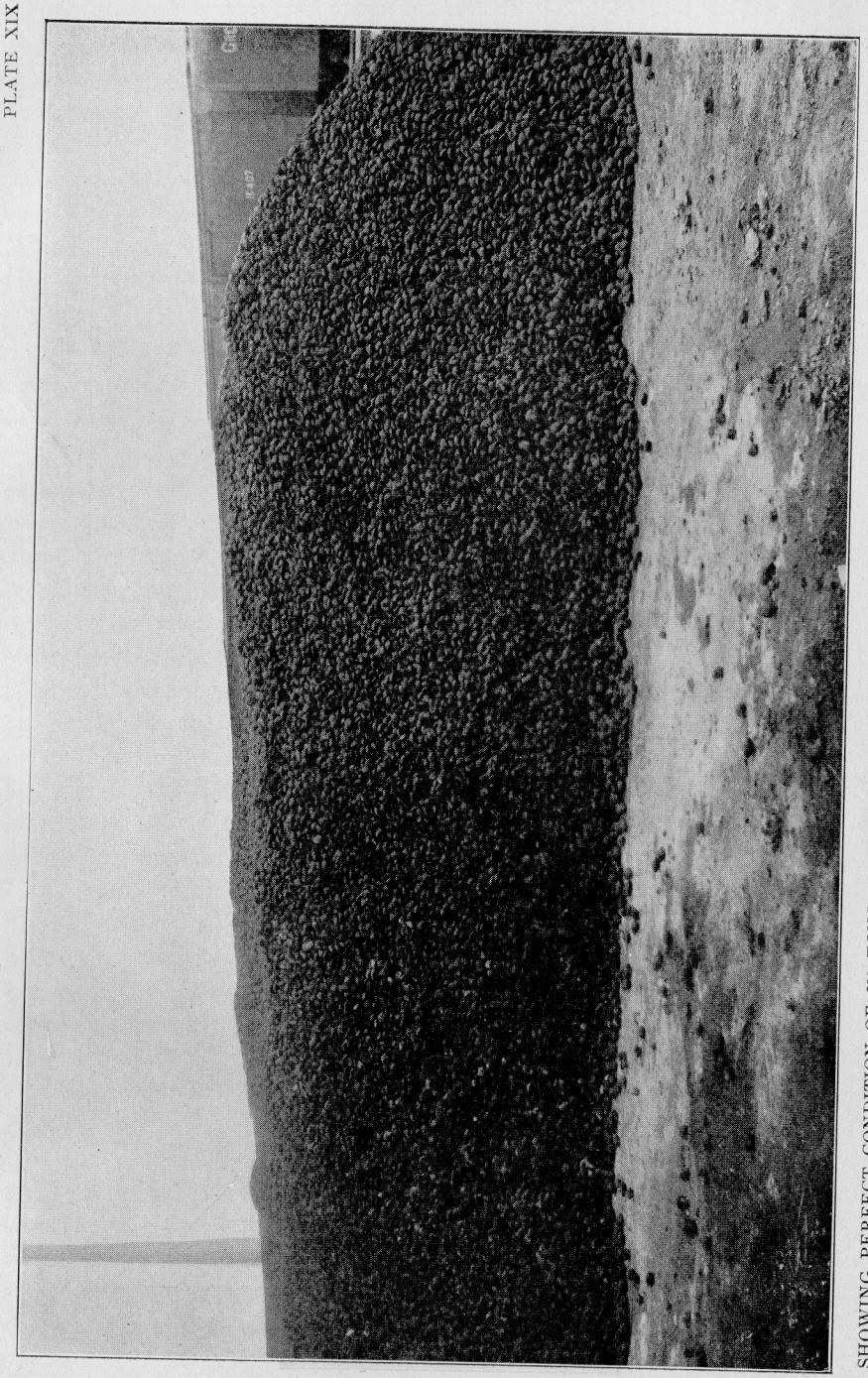
A large amount of very thorough, technical and practical work on the treatment and briquetting of lignite has been done in connection with the investigations of the School of Mines and several reports have been issued by the School of Mines, and are available, which give quite fully the methods of treatment and the results obtained.

This is another phase of the lignite industry that may in the near future be put on a commercial basis, if technical skill, care and good judgment as to location, size and details of construction and operation are employed. This does not mean that lignite can not be used successfully in its natural condition, but rather it should be considered only one of the many ways in which the use of lignite can be widened.

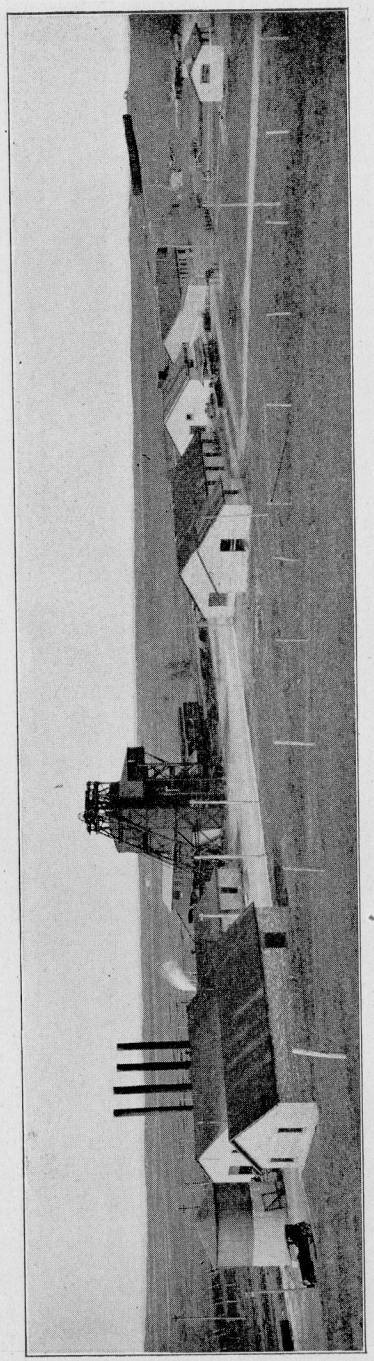
Lignite screenings and small lumps can be burned far more advantageously than is generally supposed, in large heating and power plants, notably if these plants are provided with some of the more recent designs of grates and stokers especially adapted to the use of this type of lignite.

Another method for the further utilization of lignite, on which some very promising preliminary work has been done, and which has for some time been advocated by the writer, is its use in the powdered form. There is little doubt that the most perfect combustion of many higher gaseous coals like lignite could be secured by burning them in pulverized form in properly constructed combustion chambers. This method would not be suited to household and domestic uses, but would be well adapted to use in larger heating and power plants.

Such a method has been used with bituminous coals in connection with certain industries for several years, but only recently has the



SHOWING PERFECT CONDITION OF 200 TONS OF LIGNITE BRIQUETS AFTER EXPOSURE FOR MONTHS IN A WEATHERING TEST



TIPPLE, POWER HOUSE AND OTHER BUILDINGS OF THE WASHBURN LIGNITE COAL COMPANY AT WILTON

method been adapted by means of smaller units, to more general use in only moderately large power and heating plants. Our investigations indicate that with proper modifications this method may prove well suited to lignite use. If dried lignite were employed, this method should produce relatively high heating efficiency, for in a proper combustion chamber, besides the combustion of fixed carbon, this method of firing would utilize nearly all of the volatile gases, which have high calorific power, a portion of which are lost by the ordinary methods of burning.

It is largely due to a lack of familiarity with the composition, character and real value of lignite that it is not much more extensively used.

The notion many people have that lignite cannot be stored is erroneous. While it is true that lignite tends to break down rather easily when exposed to weather, this tendency can be overcome to a considerable extent, in domestic use, by observing proper care in storing it. During the summer months, sun and wind dry it out and tend to reduce it to rather fine lumps. This slacking process can, however, be largely overcome by storing the lignite in cellars, concrete or brick bins, root cellars, etc. In this manner of storing the crumbling can be greatly lessened because the moisture present in the coal will not, under these conditions, dry out rapidly. There is no loss in the heating value caused by ordinary storage of this kind. A little reduction in the size of the lumps should cause no difficulty in burning, and in many cases would prove advantageous.

Lignite coal usually is in rather large lumps, when it is sold as "run of mine" coal, and many of these lumps will need to be broken before they can be handled to best advantage in the stove, if they have not slacked sufficiently. A very good size for ordinary use is that which is screened, at many of the mines, into about two to six inch lumps. Screened sizes below two inches can be obtained at very reasonable rates, and for many purposes prove very satisfactory and economical.

The conditions, which control the proper size for best results, are much the same for lignite as for other coals. There is usually a size which is best suited for the grate, fire box, and design of a particular stove, furnace or other heating plant. Too large lumps do not afford sufficient oxidizing surface, but at the same time give too open a fire body. A fire box properly filled with lumps of reasonably small and

uniform size gives a uniform distribution of air and a uniform combustion and body of fire.

As with any coal, stoves and furnaces should be provided with ample stack draft but arranged for easy control so that the air can be properly distributed and directed up through the coal for rapid burning, or diverted and reduced, as may be needed when it is desired to hold the fire at low heat.

Grates should not be too coarse, nor should there be too much shaking or poking. Care with reference to these points will prevent loss from fine unburned coal being wasted with the ash. Many people waste coal by having too large or too small a fuel body. With too much fuel there is liable to be excess loss of heat in the flue gases, while with too small a body of burning fuel, especially with soft coals containing much volatile matter, there may be incomplete combustion of the gases.

When people become accustomed to the use of lignite, they find it can be burned with good success in the ordinary cooking stove or range, in various types of heating stoves and in hot water and steam heating plants.

It is very seldom necessary to make changes in stoves or heating plants, although some are naturally better adapted to burning lignite than others. Generally speaking best results can be obtained in stoves or furnaces having fairly large grate area and a little reserve capacity. It will be necessary to fire either heating plants or stoves a little more frequently than with anthracite, soft coal or coke, because the fuel value of the lignite in its natural condition is somewhat less than the same weight of standard anthracite or eastern bituminous coal.

With good judgment and a little experience lignite coal can be utilized far more successfully and economically, than most people realize. If proper storage facilities can be provided, those who are to burn lignite will do well to put in a portion, say one-third of their requirements, if convenient, in the summer or early fall, in order to have fuel on hand when the cold weather begins and to help in avoiding congestion of transportation facilities and of mine production later.

There are many reasons why the people of North Dakota and adjoining regions should quite generally use lignite. This can be done successfully and usually with a marked saving to the consumer. The more general use of our lignite should be encouraged as a matter of economy, and as a means of aiding the development of this and other

industries in our state. Industrial development is largely dependent on cheap and abundant power, and for this reason our enormous deposits of lignite will eventually prove of great value to building up manufacturing and other enterprises.

ANALYSES

The analyses which follow, as will be seen, do not cover the entire lignite area of North Dakota. The analyses from many other deposits and mines have been covered in previous reports . The samples, of which the analyses are given in this report, were gathered, with one or two exceptions, by different field men of the Survey and turned over to the School of Mines to be analyzed and tested. These are supposed to be average samples of the coal that was open for testing at the time this was done, but it should be remembered that lignite deposits, like all coal deposits, vary from place to place in the deposits, therefore, a single analysis from a lignite mine or deposit may not necessarily represent the character of the coal which may be obtained from a different place and at another time, and it may not represent an average of the mine or deposit.

Reliable averages can be obtained only from the analyses of a fairly large number of samples from various parts of the deposit worked. However, the results that are given in the following tables of analyses and tests of lignite, of ash, of char, of gas, etc., will give a pretty good idea of the composition and character of the lignites of the districts covered and the possibility of their use for gas production, briquetting, powdered fuel, etc. In these respects these tests are quite complete and present an unusually large amount of valuable information.

Laboratory No. 5514
Description: Sec. 8, T. 129, R. 94, S.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	36.38
Volatile Matter	25.83
Fixed Carbon	29.91
Ash	7.88
Sulphur	1.81
British Thermal Units per lb. (B. T. U.)	6730

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	12.90
Alumina (Al_2O_3)	14.88
Iron Oxide (Fe_2O_3)	13.12
Calcium Oxide (CaO)	25.00
Magnesium Oxide (MgO)	8.80
Sodium and Potassium Oxides (computed as chlorides)	3.80
Other constituents and variations in combinations	21.50
Fusion Temperature of the ash, degrees F	2300

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.31
Fixed Carbon	77.22
Ash	19.47
Sulphur	3.32
British Thermal Units per lb. (B. T. U.)	12174

The lignite, with moisture as received, yielded 8690 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.4
Illuminants	2.4
Oxygen	1.2
Carbon Monoxide	20.4
Methane	6.8
Hydrogen	37.3
Nitrogen	13.5
Heating value, British Thermal Units per cubic foot, unpurified, gross	295

Laboratory No. 5515
Description: Sec. 1, T. 133, R. 88, S. ½

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	25.34
Volatile Matter	29.00
Fixed Carbon	27.67
Ash	17.99
Sulphur	1.49
British Thermal Units per lb. (B. T. U.)	6668

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	48.00
Alumina (Al_2O_3)	4.38
Iron Oxide (Fe_2O_3)	11.20
Calcium Oxide (CaO)	20.94
Magnesium Oxide (MgO)	2.21
Sodium and Potassium Oxides (computed as chlorides)	5.30
Other constituents and variations in combinations	7.97
Fusion Temperature of the ash, degrees F	2100

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.12
Fixed Carbon	61.51
Ash	35.37
Sulphur	2.13
British Thermal Units per lb. (B. T. U.)	9710

The lignite, with moisture as received, yielded 10040 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	17.7
Illuminants	3.0
Oxygen	2.3
Carbon Monoxide	21.6
Methane	9.9
Hydrogen	37.1
Nitrogen	8.4
Heating value, British Thermal Units per cubic foot, unpurified, gross	339

Laboratory No. 5516

Description: Sec. 26, T. 140, R. 102, N.E. ¼ and N. ½ of S.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	29.57
Volatile Matter	24.02
Fixed Carbon	25.73
Ash	20.68
Sulphur	14.03
British Thermal Units per lb. (B. T. U.)	5767

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	4.76
Alumina (Al_2O_3)	9.56
Iron Oxide (Fe_2O_3)	66.10
Calcium Oxide (CaO)	7.76
Magnesium Oxide (MgO)	1.87
Sodium and Potassium Oxides (computed as chlorides)	8.06
Other constituents and variations in combinations	1.89
Fusion Temperature of the ash, degrees F.	2065

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.30
Fixed Carbon	55.05
Ash	40.65
Sulphur	13.50
British Thermal Units per lb. (B. T. U.)	9034

The lignite, with moisture as received, yielded 6950 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	24.6
Illuminants	1.6
Oxygen	1.2
Carbon Monoxide	21.6
Methane	5.5
Hydrogen	35.1
Nitrogen	10.4
Heating value, British Thermal Units per cubic foot, unpurified, gross	265

Laboratory No. 5517

Description: Sec. 10, T. 130, R. 98, N.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	40.82
Volatile Matter	24.34
Fixed Carbon	24.39
Ash	10.45
Sulphur	3.35
British Thermal Units per lb. (B. T. U.)	5880

ANALYSIS OF THE ASH

	Per cent
Silica (SiO_2)	17.60
Alumina (Al_2O_3)	39.21
Iron Oxide (Fe_2O_3)	7.59
Calcium Oxide (CaO)	16.60
Magnesium Oxide (MgO)	7.74
Sodium and Potassium oxides (computed as chlorides)	3.04
Other constituents and variations in combinations	8.22
Fusion Temperature of the ash, degrees F.	2135

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent
Moisture	0.00
Volatile Matter	8.68
Fixed Carbon	64.33
Ash	26.99
Sulphur	5.68
British Thermal Units per lb. (B. T. U.)	10840

The lignite, with moisture as received, yielded 7160 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.2
Illuminants	2.5
Oxygen	2.3
Carbon Monoxide	20.7
Methane	11.6
Hydrogen	34.3
Nitrogen	9.4
Heating value, British Thermal Units per cubic foot, unpurified, gross	336

Laboratory No. 5518
Description: Sec. 15, T. 132, R. 102, S. ½

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	36.67
Volatile Matter	26.92
Fixed Carbon	30.09
Ash	6.32
Sulphur	1.24
British Thermal Units per lb. (B. T. U.)	6788

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	17.73
Alumina (Al_2O_3)	8.76
Iron Oxide (Fe_2O_3)	6.88
Calcium Oxide (CaO)	33.64
Magnesium Oxide (MgO)	5.45
Sodium and Potassium Oxides (computed as chlorides)	4.20
Other constituents and variations in combinations	23.34
Fusion Temperature of the ash, degrees F.	2360

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	2.90
Fixed Carbon	77.73
Ash	19.37
Sulphur	2.28
British Thermal Units per lb. (B. T. U.)	12200

The lignite, with moisture as received, yielded 9860 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent
Carbon Dioxide	17.4
Illuminants	2.6
Oxygen	1.8
Carbon Monoxide	21.0
Methane	9.5
Hydrogen	34.4
Nitrogen	13.3
Heating value, British Thermal Units per cubic foot, unpurified, gross	317

Laboratory No. 5519
Description: Sec. 3, T. 162, R. 95, S. ½

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	35.32
Volatile Matter	26.42
Fixed Carbon	32.96
Ash	5.30
Sulphur	.61
British Thermal Units per lb. (B. T. U.)	7010

ANALYSIS OF THE ASH

	Per cent
Silica (SiO_2)	25.22
Alumina (Al_2O_3)	15.49
Iron Oxide (Fe_2O_3)	7.71
Calcium Oxide (CaO)	24.70
Magnesium Oxide (MgO)	6.20
Sodium and Potassium Oxides (computed as chlorides)	18.50
Other constituents and variations in combinations	2.18
Fusion Temperature of the ash, degrees F.	2130

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent
Moisture	0.00
Volatile Matter	4.16
Fixed Carbon	81.52
Ash	14.32
Sulphur	.80
British Thermal Units per lb. (B. T. U.)	12240

The lignite, with moisture as received, yielded 9480 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	5.2
Illuminants	.4
Oxygen	1.2
Carbon Monoxide	14.2
Methane	3.1
Hydrogen	58.7
Nitrogen	17.2
Heating value, British Thermal Units per cubic foot, unpurified, gross	275

Laboratory No. 5520
Description: Sec. 3, T. 162, R. 95, S.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	35.19
Volatile Matter	25.81
Fixed Carbon	30.83
Ash	8.17
Sulphur	.56
British Thermal Units per lb. (B. T. U.)	6825

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	36.20
Alumina (Al_2O_3)	17.90
Iron Oxide (Fe_2O_3)	8.60
Calcium Oxide (CaO)	16.34
Magnesium Oxide (MgO)	5.45
Sodium and Potassium Oxides (computed as chlorides)	15.28
Other constituents and variations in combinations	.23
Fusion Temperature of the ash, degrees F.	2085

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	5.54
Fixed Carbon	73.61
Ash	20.85
Sulphur	1.29
British Thermal Units per lb. (B. T. U.)	11340

The lignite, with moisture as received, yielded 8860 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.0
Illuminants	3.2
Oxygen	2.5
Carbon Monoxide	18.9
Methane	15.3
Hydrogen	26.2
Nitrogen	14.9

Heating value, British Thermal Units per cubic foot, unpurified, gross 353

Laboratory No. 5521
Description: Sec. 10, T. 162, R. 95, N.E. ¼ and N.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	35.86
Volatile Matter	25.19
Fixed Carbon	33.15
Ash	5.80
Sulphur	.48
British Thermal Units per lb. (B. T. U.)	6933

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	26.64
Alumina (Al_2O_3)	14.29
Iron Oxide (Fe_2O_3)	6.31
Calcium Oxide (CaO)	24.44
Magnesium Oxide (MgO)	4.84
Sodium and Potassium Oxides (computed as chlorides)	21.77
Other constituents and variations in combinations	1.71
Fusion Temperature of the ash, degrees F.	2105

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.49
Fixed Carbon	80.00
Ash	15.51
Sulphur	.96
British Thermal Units per lb. (B. T. U.)	12070

The lignite, with moisture as received, yielded 9880 cu. ft. of of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	17.8
Illuminants	2.4
Oxygen	1.7
Carbon Monoxide	22.7
Methane	8.1
Hydrogen	39.2
Nitrogen	8.1

Heating value, British Thermal Units per cubic foot, unpurified, gross 321

Laboratory No. 5522
Description: Sec. 9, T. 162, R. 95, E. ½

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	36.50
Volatile Matter	26.14
Fixed Carbon	32.02
Ash	5.34
Sulphur	.52
British Thermal Units per lb. (B. T. U.)	6945

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	22.92
Alumina (Al_2O_3)	18.18
Iron Oxide (Fe_2O_3)	7.54
Calcium Oxide (CaO)	19.96
Magnesium Oxide (MgO)	5.28
Sodium and Potassium Oxides (computed as chlorides)	22.70
Other constituents and variations in combinations	3.42
Fusion Temperature of the ash, degrees F.	2082

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.59
Fixed Carbon	80.61
Ash	15.80
Sulphur	1.12
British Thermal Units per lb. (B. T. U.)	12308

The lignite, with moisture as received, yielded 8880 cu. ft. of of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	4.4
Illuminants	.6
Oxygen	1.2
Carbon Monoxide	12.2
Methane	4.5
Hydrogen	63.5
Nitrogen	13.6
Heating value, British Thermal Units per cubic foot, unpurified, gross	301

Laboratory No. 5523
Description: Sec. 17, T. 162, R. 94

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	32.64
Volatile Matter	26.82
Fixed Carbon	32.82
Ash	7.72
Sulphur	.35
British Thermal Units per lb. (B. T. U.)	6785

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	36.54
Alumina (Al_2O_3)	21.54
Iron Oxide (Fe_2O_3)	5.08
Calcium Oxide (CaO)	18.48
Magnesium Oxide (MgO)	4.27
Sodium and Potassium Oxides (computed as chlorides)	8.32
Other constituents and variations in combinations	5.77
Fusion Temperature of the ash, degrees F.	2112

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	5.84
Fixed Carbon	74.80
Ash	19.36
Sulphur	1.07
British Thermal Units per lb. (B. T. U.)	11700

The lignite, with moisture as received, yielded 8390 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	23.8
Illuminants	1.2
Oxygen	2.4
Carbon Monoxide	16.5
Methane	12.5
Hydrogen	33.7
Nitrogen	9.9
Heating value, British Thermal Units per cubic foot, unpurified, gross	309

Laboratory No. 5524
Description: Sec. 24, T. 162, R. 93, N. ½

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	32.24
Volatile Matter	26.45
Fixed Carbon	34.11
Ash	7.20
Sulphur	.30
British Thermal Units per lb. (B. T. U.)	6745

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	34.28
Alumina (Al_2O_3)	20.30
Iron Oxide (Fe_2O_3)	6.31
Calcium Oxide (CaO)	17.72
Magnesium Oxide (MgO)	4.30
Sodium and Potassium Oxides (computed as chlorides)	24.00
Other constituents and variations in combinations	—6.91
Fusion Temperature of the ash, degrees F.	2100

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.10
Fixed Carbon	77.60
Ash	19.30
Sulphur	.78
British Thermal Units per lb. (B. T. U.)	11646

The lignite, with moisture as received, yielded 10710 cu. ft. unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.6
Illuminants	2.0
Oxygen	1.6
Carbon Monoxide	22.0
Methane	7.3
Hydrogen	42.5
Nitrogen	6.0
Heating value, British Thermal Units per cubic foot, unpurified, gross	315

Laboratory No. 5525
Description: Sec. 27, T. 145, R. 93

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	37.43
Volatile Matter	27.16
Fixed Carbon	27.40
Ash	8.01
Sulphur	.99
British Thermal Units per lb. (B. T. U.)	6092

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	23.62
Alumina (Al_2O_3)	12.40
Iron Oxide (Fe_2O_3)	10.32
Calcium Oxide (CaO)	22.48
Magnesium Oxide (MgO)	6.78
Sodium and Potassium Oxides (computed as chlorides)	10.16
Other constituents and variations in combinations	14.24
Fusion Temperature of the ash, degrees F.	2265

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.93
Fixed Carbon	75.66
Ash	20.41
Sulphur	2.15
British Thermal Units per lb. (B. T. U.)	11935

The lignite, with moisture as received, yielded 8810 cu. ft. unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.8
Illuminants	1.9
Oxygen	1.4
Carbon Monoxide	21.7
Methane	8.5
Hydrogen	38.3
Nitrogen	8.4
Heating value, British Thermal Units per cubic foot, unpurified, gross	311

Laboratory No. 5526
Description: Sec. 4, T. 132, R. 91

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	33.38
Volatile Matter	25.50
Fixed Carbon	26.35
Ash	14.77
Sulphur	2.57
British Thermal Units per lb. (B. T. U.)	6400

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	30.38
Alumina (Al_2O_3)	17.74
Iron Oxide (Fe_2O_3)	27.56
Calcium Oxide (CaO)	12.26
Magnesium Oxide (MgO)	7.40
Sodium and Potassium Oxides (computed as chlorides)	5.25
Other constituents and variations in combinations	— .59
Fusion Temperature of the ash, degrees F.	2050

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.20
Fixed Carbon	62.40
Ash	34.40
Sulphur	4.42
British Thermal Units per lb. (B. T. U.)	9807

The lignite, with moisture as received, yielded 7840 cu. ft. unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	17.0
Illuminants	2.4
Oxygen	1.8
Carbon Monoxide	20.2
Methane	9.2
Hydrogen	40.4
Nitrogen	9.0
Heating value, British Thermal Units per cubic foot, unpurified, gross	328

Laboratory No. 5527
Description: Sec. 5, T. 134, R. 95, S.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	40.98
Volatile Matter	25.28
Fixed Carbon	28.68
Ash	5.06
Sulphur	.88
British Thermal Units per lb. (B. T. U.)	6247

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	11.04
Alumina (Al_2O_3)	12.00
Iron Oxide (Fe_2O_3)	10.80
Calcium Oxide (CaO)	30.08
Magnesium Oxide (MgO)	8.71
Sodium and Potassium Oxides (computed as chlorides)	12.46
Other constituents and variations in combinations	14.91
Fusion Temperature of the ash, degrees F.	2305

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.61
Fixed Carbon	81.04
Ash	15.35
Sulphur	1.73
British Thermal Units per lb. (B. T. U.)	12500

The lignite, with moisture as received, yielded 8810 cu. ft. unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.7
Illuminants	1.6
Oxygen	1.6
Carbon Monoxide	19.4
Methane	7.2
Hydrogen	37.7
Nitrogen	12.8
Heating value, British Thermal Units per cubic foot, unpurified, gross	284

Laboratory No. 5528
Description: Sec. 5, T. 134, R. 95, N.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	39.66
Volatile Matter	26.80
Fixed Carbon	27.42
Ash	6.12
Sulphur	2.06
British Thermal Units per lb. (B. T. U.)	6280

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	9.54
Alumina (Al_2O_3)	10.68
Iron Oxide (Fe_2O_3)	26.06
Calcium Oxide (CaO)	22.00
Magnesium Oxide (MgO)	5.88
Sodium and Potassium Oxides (computed as chlorides)	9.00
Other constituents and variations in combinations	16.84
Fusion Temperature of the ash, degrees F.	2246

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	5.46
Fixed Carbon	79.07
Ash	15.47
Sulphur	3.62
British Thermal Units per lb. (B. T. U.)	12430

The lignite, with moisture as received, yielded 6870 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	22.6
Illuminants	2.8
Oxygen	2.0
Carbon Monoxide	17.4
Methane	10.3
Hydrogen	31.0
Nitrogen	13.9
Heating value, British Thermal Units per cubic foot, unpurified, gross	306

Laboratory No. 5529
Description: Sec. 6, T. 134, R. 95, S.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	41.00
Volatile Matter	25.97
Fixed Carbon	28.61
Ash	4.42
Sulphur	.65
British Thermal Units per lb. (B. T. U.)	6285

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	23.91
Alumina (Al_2O_3)	12.12
Iron Oxide (Fe_2O_3)	4.08
Calcium Oxide (CaO)	32.22
Magnesium Oxide (MgO)	8.21
Sodium and Potassium Oxides (computed as chlorides)	8.14
Other constituents and variations in combinations	11.32
Fusion Temperature of the ash, degrees F.	2390

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.20
Fixed Carbon	79.32
Ash	16.48
Sulphur	1.77
British Thermal Units per lb. (B. T. U.)	12366

The lignite, with moisture as received, yielded 8460 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.2
Illuminants	2.0
Oxygen	1.4
Carbon Monoxide	20.2
Methane	7.6
Hydrogen	34.9
Nitrogen	14.7
Heating value, British Thermal Units per cubic foot, unpurified, gross	288

Laboratory No. 5530
Description: Sec. 2, T. 134, R. 96, N.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	43.47
Volatile Matter	23.82
Fixed Carbon	24.89
Ash	7.82
Sulphur	1.67
British Thermal Units per lb. (B. T. U.)	5720

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	24.40
Alumina (Al_2O_3)	27.46
Iron Oxide (Fe_2O_3)	4.02
Calcium Oxide (CaO)	17.82
Magnesium Oxide (MgO)	3.58
Sodium and Potassium Oxides (computed as chlorides)	5.03
Other constituents and variations in combinations	17.69
Fusion Temperature of the ash, degrees F.	2088

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.86
Fixed Carbon	74.60
Ash	21.54
Sulphur	2.89
British Thermal Units per lb. (B. T. U.)	11590

The lignite, with moisture as received, yielded 9415 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.4
Illuminants	2.8
Oxygen	2.0
Carbon Monoxide	18.0
Methane	7.4
Hydrogen	39.6
Nitrogen	11.8
Heating value, British Thermal Units per cubic foot, unpurified, gross	307

Laboratory No. 5531
Description: Sec. 2, T. 134, R. 96, N.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	39.53
Volatile Matter	27.26
Fixed Carbon	27.71
Ash	5.50
Sulphur	.55
British Thermal Units per lb. (B. T. U.)	6262

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	18.06
Alumina (Al_2O_3)	9.64
Iron Oxide (Fe_2O_3)	6.00
Calcium Oxide (CaO)	31.12
Magnesium Oxide (MgO)	8.91
Sodium and Potassium Oxides (computed as chlorides)	2.32
Other constituents and variations in combinations	23.95
Fusion Temperature of the ash, degrees F.	2361

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	8.71
Fixed Carbon	77.56
Ash	13.73
Sulphur	.82
British Thermal Units per lb. (B. T. U.)	12020

The lignite, with moisture as received, yielded 10440 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	21.8
Illuminants	2.2
Oxygen	2.3
Carbon Monoxide	17.4
Methane	12.4
Hydrogen	30.0
Nitrogen	13.9
Heating value, British Thermal Units per cubic foot, unpurified, gross	315

Laboratory No. 5532
Description: Sec. 8, T. 142, R. 79, S.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	38.99
Volatile Matter	25.56
Fixed Carbon	28.06
Ash	7.39
Sulphur	.52
British Thermal Units per lb. (B. T. U.)	6245

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	7.70
Alumina (Al_2O_3)	11.71
Iron Oxide (Fe_2O_3)	5.41
Calcium Oxide (CaO)	47.21
Magnesium Oxide (MgO)	19.04
Sodium and Potassium Oxides (computed as chlorides)	4.30
Other constituents and variations in combinations	4.63
Fusion Temperature of the ash, degrees F.	2102

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.51
Fixed Carbon	75.14
Ash	21.35
Sulphur	1.20
British Thermal Units per lb. (B. T. U.)	11603

The lignite, with moisture as received, yielded 9220 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	4.6
Illuminants	.4
Oxygen	1.6
Carbon Monoxide	15.7
Methane	3.2
Hydrogen	57.5
Nitrogen	17.0
Heating value, British Thermal Units per cubic foot, unpurified, gross	277

Laboratory No. 5533
Description: Sec. 17, T. 148, R. 84, N.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	41.36
Volatile Matter	25.52
Fixed Carbon	28.73
Ash	4.39
Sulphur	.25
British Thermal Units per lb. (B. T. U.)	6165

ANALYSIS OF THE ASH

	Per cent
Silica (SiO_2)	21.82
Alumina (Al_2O_3)	8.20
Iron Oxide (Fe_2O_3)	6.56
Calcium Oxide (CaO)	31.22
Magnesium Oxide (MgO)	11.60
Sodium and Potassium Oxides (computed as chlorides)	19.14
Other constituents and variations in combinations	1.46
Fusion Temperature of the ash, degrees F.	2365

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent
Moisture	0.00
Volatile Matter	4.20
Fixed Carbon	81.33
Ash	14.47
Sulphur	.68
British Thermal Units per lb. (B. T. U.)	12244

The lignite, with moisture as received, yielded 10750 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.0
Illuminants	2.4
Oxygen	1.2
Carbon Monoxide	21.6
Methane	6.2
Hydrogen	36.0
Nitrogen	14.6
Heating value, British Thermal Units per cubic foot, unpurified, gross	288

Laboratory No. 5534
Description: Sec. 32, T. 149, R. 80

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	39.76
Volatile Matter	26.40
Fixed Carbon	27.55
Ash	6.29
Sulphur	.45
British Thermal Units per lb. (B. T. U.)	5988

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	25.24
Alumina (Al_2O_3)	15.96
Iron Oxide (Fe_2O_3)	9.59
Calcium Oxide (CaO)	29.40
Magnesium Oxide (MgO)	7.34
Sodium and Potassium Oxides (computed as chlorides)	4.59
Other constituents and variations in combinations	7.88
Fusion Temperature of the ash, degrees F.	2320

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.82
Fixed Carbon	75.68
Ash	19.50
Sulphur	1.20
British Thermal Units per lb. (B. T. U.)	11818

The lignite, with moisture as received, yielded 9650 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.2
Illuminants	2.0
Oxygen	1.8
Carbon Monoxide	19.6
Methane	7.7
Hydrogen	39.5
Nitrogen	10.2
Heating value, British Thermal Units per cubic foot, unpurified, gross	302

Laboratory No. 5535
Description: Sec. 2, T. 150, R. 79

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	39.34
Volatile Matter	25.12
Fixed Carbon	30.26
Ash	5.28
Sulphur	.32
British Thermal Units per lb. (B. T. U.)	6305

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	21.40
Alumina (Al_2O_3)	8.50
Iron Oxide (Fe_2O_3)	6.56
Calcium Oxide (CaO)	34.84
Magnesium Oxide (MgO)	7.44
Sodium and Potassium Oxides (computed as chlorides)	5.28
Other constituents and variations in combinations	15.98
Fusion Temperature of the ash, degrees F.	2378

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	5.94
Fixed Carbon	77.04
Ash	17.02
Sulphur	1.25
British Thermal Units per lb. (B. T. U.)	11780

The lignite, with moisture as received, yielded 9990 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	20.5
Illuminants	1.7
Oxygen	2.2
Carbon Monoxide	22.2
Methane	8.0
Hydrogen	35.3
Nitrogen	10.1
Heating value, British Thermal Units per cubic foot, unpurified, gross	295

Laboratory No. 5536
Description: Sec. 6, T. 139, R. 98, S.W. ¼; Sec. 1, T. 139, R. 99, S.E.¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	40.95
Volatile Matter	24.30
Fixed Carbon	27.05
Ash	7.70
Sulphur	1.35
British Thermal Units per lb. (B. T. U.)	5926

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	18.88
Alumina (Al_2O_3)	13.72
Iron Oxide (Fe_2O_3)	22.00
Calcium Oxide (CaO)	13.47
Magnesium Oxide (MgO)	5.70
Sodium and Potassium Oxides (computed as chlorides)	21.05
Other constituents and variations in combinations	5.18
Fusion Temperature of the ash, degrees F.	2030

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.80
Fixed Carbon	77.10
Ash	19.10
Sulphur	1.97
British Thermal Units per lb. (B. T. U.)	11770

The lignite, with moisture as received, yielded 8530 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	17.6
Illuminants	1.9
Oxygen	1.3
Carbon Monoxide	21.8
Methane	7.1
Hydrogen	40.3
Nitrogen	10.0
Heating value, British Thermal Units per cubic foot, unpurified, gross	304

Laboratory No. 5537
Description: Sec. 6, T. 139, R. 98

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	40.86
Volatile Matter	25.01
Fixed Carbon	29.14
Ash	4.99
Sulphur	.60
British Thermal Units per lb. (B. T. U.)	6120

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	23.10
Alumina (Al_2O_3)	19.12
Iron Oxide (Fe_2O_3)	2.38
Calcium Oxide (CaO)	18.90
Magnesium Oxide (MgO)	8.13
Sodium and Potassium Oxides (computed as chlorides)	21.70
Other constituents and variations in combinations	6.67
Fusion Temperature of the ash, degrees F.	2105

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	7.04
Fixed Carbon	78.11
Ash	14.85
Sulphur	1.15
British Thermal Units per lb. (B. T. U.)	12550

The lignite, with moisture as received, yielded 9060 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	24.3
Illuminants	2.1
Oxygen	1.9
Carbon Monoxide	17.2
Methane	11.3
Hydrogen	31.5
Nitrogen	11.7
Heating value, British Thermal Units per cubic foot, unpurified, gross	306

Laboratory No. 5538
Description: Sec. 28, T. 140, R. 99

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	42.91
Volatile Matter	24.12
Fixed Carbon	26.24
Ash	6.73
Sulphur	1.01
British Thermal Units per lb. (B. T. U.)	5458

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	24.80
Alumina (Al_2O_3)	15.91
Iron Oxide (Fe_2O_3)	9.43
Calcium Oxide (CaO)	15.04
Magnesium Oxide (MgO)	6.66
Sodium and Potassium Oxides (computed as chlorides)	26.52
Other constituents and variations in combinations	1.64
Fusion Temperature of the ash, degrees F.	2052

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	6.38
Fixed Carbon	73.77
Ash	19.85
Sulphur	1.89
British Thermal Units per lb. (B. T. U.)	11350

The lignite, with moisture as received, yielded 7960 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.2
Illuminants	2.2
Oxygen	2.7
Carbon Monoxide	18.7
Methane	11.9
Hydrogen	30.0
Nitrogen	15.3
Heating value, British Thermal Units per cubic foot, unpurified, gross	314

Laboratory No. 5539
Description: Sec. 8, T. 139, R. 95

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	38.72
Volatile Matter	25.55
Fixed Carbon	29.14
Ash	6.59
Sulphur	1.10
British Thermal Units per lb. (B. T. U.)	6240

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	21.48
Alumina (Al_2O_3)	11.38
Iron Oxide (Fe_2O_3)	14.40
Calcium Oxide (CaO)	19.06
Magnesium Oxide (MgO)	7.26
Sodium and Potassium Oxides (computed as chlorides)	18.17
Other constituents and variations in combinations	8.25
Fusion Temperature of the ash, degrees F.	2095

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	5.48
Fixed Carbon	73.90
Ash	20.62
Sulphur	2.66
British Thermal Units per lb. (B. T. U.)	11800

The lignite, with moisture as received, yielded 9330 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	17.6
Illuminants	1.6
Oxygen	3.2
Carbon Monoxide	15.6
Methane	6.9
Hydrogen	32.5
Nitrogen	22.6
Heating value, British Thermal Units per cubic foot, unpurified, gross	252

Laboratory No. 5540
Description: Sec. 7, T. 139, R. 95

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	40.34
Volatile Matter	24.76
Fixed Carbon	29.42
Ash	5.48
Sulphur	.55
British Thermal Units per lb. (B. T. U.)	6005

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	24.42
Alumina (Al_2O_3)	13.59
Iron Oxide (Fe_2O_3)	1.97
Calcium Oxide (CaO)	27.32
Magnesium Oxide (MgO)	9.91
Sodium and Potassium Oxides (computed as chlorides)	11.26
Other constituents and variations in combinations	11.53
Fusion Temperature of the ash, degrees F.	2325

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	6.52
Fixed Carbon	77.64
Ash	15.84
Sulphur	.99
British Thermal Units per lb. (B. T. U.)	11920

The lignite, with moisture as received, yielded 10000 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.1
Illuminants	1.9
Oxygen	2.2
Carbon Monoxide	19.7
Methane	9.5
Hydrogen	36.6
Nitrogen	11.0
Heating value, British Thermal Units per cubic foot, unpurified, gross	310

Laboratory No. 5541
Description: Sec. 1, T. 151, R. 81, E. ½

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	38.43
Volatile Matter	28.62
Fixed Carbon	29.98
Ash	2.97
Sulphur	.29
British Thermal Units per lb. (B. T. U.)	6949

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	2.47
Alumina (Al_2O_3)	12.36
Iron Oxide (Fe_2O_3)	5.58
Calcium Oxide (CaO)	43.45
Magnesium Oxide (MgO)	13.71
Sodium and Potassium Oxides (computed as chlorides)	6.17
Other constituents and variations in combinations	16.26
Fusion Temperature of the ash, degrees F.	2405

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.25
Fixed Carbon	84.10
Ash	11.65
Sulphur	1.28
British Thermal Units per lb. (B. T. U.)	12771

The lignite, with moisture as received, yielded 10900 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	16.7
Illuminants	1.8
Oxygen	1.4
Carbon Monoxide	22.2
Methane	8.3
Hydrogen	41.5
Nitrogen	8.1
Heating value, British Thermal Units per cubic foot, unpurified, gross	320

Laboratory No. 5542
Description: Sec. 1, T. 151, R. 81, N.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	38.29
Volatile Matter	27.73
Fixed Carbon	29.45
Ash	4.53
Sulphur	.28
British Thermal Units per lb. (B. T. U.)	6659

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	15.24
Alumina (Al_2O_3)	16.16
Iron Oxide (Fe_2O_3)	5.74
Calcium Oxide (CaO)	35.20
Magnesium Oxide (MgO)	9.84
Sodium and Potassium Oxides (computed as chlorides)	5.92
Other constituents and variations in combinations	11.90
Fusion Temperature of the ash, degrees F.	2391

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	2.60
Fixed Carbon	83.70
Ash	13.70
Sulphur	.91
British Thermal Units per lb. (B. T. U.)	12460

The lignite, with moisture as received, yielded 9680 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.8
Illuminants	2.0
Oxygen	1.4
Carbon Monoxide	20.0
Methane	8.3
Hydrogen	42.4
Nitrogen	7.1
Heating value, British Thermal Units per cubic foot, unpurified, gross	319

Laboratory No. 5543
Description: Sec. 35, T. 152, R. 81, S. ½ of N.W. ¼ and N. ½ of S.W. ¼ (Top 4 feet)

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	42.70
Volatile Matter	25.20
Fixed Carbon	28.98
Ash	3.12
Sulphur	.11
British Thermal Units per lb. (B. T. U.)	6407

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	47.20
Alumina (Al_2O_3)	20.03
Iron Oxide (Fe_2O_3)	3.77
Calcium Oxide (CaO)	15.88
Magnesium Oxide (MgO)	5.30
Sodium and Potassium Oxides (computed as chlorides)	4.90
Other constituents and variations in combinations	2.92
Fusion Temperature of the ash, degrees F.	2364

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.45
Fixed Carbon	85.00
Ash	10.55
Sulphur	.41
British Thermal Units per lb. (B. T. U.)	12552

The lignite, with moisture as received, yielded 10240 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.8
Illuminants	1.8
Oxygen	1.2
Carbon Monoxide	21.6
Methane	7.0
Hydrogen	40.4
Nitrogen	9.2
Heating value, British Thermal Units per cubic foot, unpurified, gross	301

Laboratory No. 5544

Description: Sec. 35, T. 152, R. 81, S. ½ of N.W. ¼ and N. ½ of S.W. ¼ (Lower 3 feet)

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	40.93
Volatile Matter	23.84
Fixed Carbon	25.41
Ash	9.82
Sulphur	.43
British Thermal Units per lb. (B. T. U.)	5516

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	34.40
Alumina (Al_2O_3)	16.13
Iron Oxide (Fe_2O_3)	7.87
Calcium Oxide (CaO)	23.20
Magnesium Oxide (MgO)	6.60
Sodium and Potassium Oxides (computed as chlorides)	5.00
Other constituents and variations in combinations	6.80
Fusion Temperature of the ash, degrees F.	2214

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.43
Fixed Carbon	68.00
Ash	28.57
Sulphur	.98
British Thermal Units per lb. (B. T. U.)	10400

The lignite, with moisture as received, yielded 8550 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.6
Illuminants	1.6
Oxygen	1.4
Carbon Monoxide	19.4
Methane	7.1
Hydrogen	39.6
Nitrogen	11.3
Heating value, British Thermal Units per cubic foot, unpurified, gross	289

Laboratory No. 5545

Description: Sec. 27, T. 152, R. 81, S.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	36.81
Volatile Matter	30.34
Fixed Carbon	29.31
Ash	3.54
Sulphur	.30
British Thermal Units per lb. (B. T. U.)	6717

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	6.82
Alumina (Al_2O_3)	6.62
Iron Oxide (Fe_2O_3)	7.04
Calcium Oxide (CaO)	42.84
Magnesium Oxide (MgO)	1.38
Sodium and Potassium Oxides (computed as chlorides)	12.43
Other constituents and variations in combinations	22.87
Fusion Temperature of the ash, degrees F.	2365

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	6.35
Fixed Carbon	81.20
Ash	12.45
Sulphur	1.20
British Thermal Units per lb. (B. T. U.)	12667

The lignite, with moisture as received, yielded 9160 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.6
Illuminants	2.4
Oxygen	.8
Carbon Monoxide	2[illegible].2
Methane	6.8
Hydrogen	32.8
Nitrogen	16.[illegible]
Heating value, British Thermal Units per cubic foot, unpurified, gross	282

Laboratory No. 5546
Description: Sec. 27, T. 152, R. 81, N.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	37.44
Volatile Matter	26.62
Fixed Carbon	32.12
Ash	3.82
Sulphur	.29
British Thermal Units per lb. (B. T. U.)	6859

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	15.06
Alumina (Al_2O_3)	12.14
Iron Oxide (Fe_2O_3)	5.32
Calcium Oxide (CaO)	37.00
Magnesium Oxide (MgO)	8.80
Sodium and Potassium Oxides (computed as chlorides)	10.62
Other constituents and variations in combinations	11.06
Fusion Temperature of the ash, degrees F.	2366

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	6.14
Fixed Carbon	82.26
Ash	11.60
Sulphur	.88
British Thermal Units per lb. (B. T. U.)	12560

The lignite, with moisture as received, yielded 9310 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.8
Illuminants	1.8
Oxygen	2.4
Carbon Monoxide	20.2
Methane	11.5
Hydrogen	34.0
Nitrogen	10.3
Heating value, British Thermal Units per cubic foot, unpurified, gross	321

Laboratory No. 5547
Description: Sec. 19, T. 152, R. 81, N.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	39.10
Volatile Matter	26.41
Fixed Carbon	31.22
Ash	3.27
Sulphur	.28
British Thermal Units per lb. (B. T. U.)	7130

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	11.00
Alumina (Al_2O_3)	10.75
Iron Oxide (Fe_2O_3)	8.77
Calcium Oxide (CaO)	36.66
Magnesium Oxide (MgO)	8.20
Sodium and Potassium Oxides (computed as chlorides)	14.80
Other constituents and variations in combinations	9.82
Fusion Temperature of the ash, degrees F.	2350

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	8.10
Fixed Carbon	81.66
Ash	10.24
Sulphur	.60
British Thermal Units per lb. (B. T. U.)	12730

The lignite, with moisture as received, yielded 10180 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	17.1
Illuminants	2.0
Oxygen	2.3
Carbon Monoxide	18.4
Methane	10.6
Hydrogen	40.1
Nitrogen	9.5
Heating value, British Thermal Units per cubic foot, unpurified, gross	330

Laboratory No. 5548
Description: Sec. 19, T. 152, R. 81, N.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	38.35
Volatile Matter	27.83
Fixed Carbon	30.87
Ash	2.95
Sulphur	.09
British Thermal Units per lb. (B. T. U.)	6796

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	0.00
Alumina (Al_2O_3)	14.90
Iron Oxide (Fe_2O_3)	6.66
Calcium Oxide (CaO)	60.00
Magnesium Oxide (MgO)	13.40
Sodium and Potassium Oxides (computed as chlorides)	4.60
Other constituents and variations in combinations	.44
Fusion Temperature of the ash, degrees F.	2385

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	5.66
Fixed Carbon	83.87
Ash	10.47
Sulphur	1.06
British Thermal Units per lb. (B. T. U.)	12900

The lignite, with moisture as received, yielded 7525 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	24.4
Illuminants	1.6
Oxygen	2.4
Carbon Monoxide	16.8
Methane	16.3
Hydrogen	26.4
Nitrogen	12.1
Heating value, British Thermal Units per cubic foot, unpurified, gross	331

Laboratory No. 5549
Description: Sec. 30, T. 152, R. 81, N.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	42.05
Volatile Matter	25.99
Fixed Carbon	29.06
Ash	2.90
Sulphur	.12
British Thermal Units per lb. (B. T. U.)	6141

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	0.00
Alumina (Al_2O_3)	15.38
Iron Oxide (Fe_2O_3)	7.94
Calcium Oxide (CaO)	52.00
Magnesium Oxide (MgO)	14.25
Sodium and Potassium Oxides (computed as chlorides)	10.15
Other constituents and variations in combinations	.28
Fusion Temperature of the ash, degrees F.	2356

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.38
Fixed Carbon	85.60
Ash	10.02
Sulphur	.40
British Thermal Units per lb. (B. T. U.)	12657

The lignite, with moisture as received, yielded 9110 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.6
Illuminants	1.8
Oxygen	1.1
Carbon Monoxide	20.3
Methane	6.3
Hydrogen	38.0
Nitrogen	12.9
Heating value, British Thermal Units per cubic foot, unpurified, gross	281

Laboratory No. 5550
Description: Sec. 27, T. 153, R. 82, S.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	40.40
Volatile Matter	28.19
Fixed Carbon	28.02
Ash	3.39
Sulphur	.21
British Thermal Units per lb. (B. T. U.)	6790

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	14.62
Alumina (Al_2O_3)	11.58
Iron Oxide (Fe_2O_3)	4.00
Calcium Oxide (CaO)	46.82
Magnesium Oxide (MgO)	10.32
Sodium and Potassium Oxides (computed as chlorides)	4.56
Other constituents and variations in combinations	8.10
Fusion Temperature of the ash, degrees F.	2440

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	6.64
Fixed Carbon	81.90
Ash	11.46
Sulphur	.74
British Thermal Units per lb. (B. T. U.)	12650

The lignite, with moisture as received, yielded 10310 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.3
Illuminants	1.8
Oxygen	2.0
Carbon Monoxide	19.7
Methane	15.5
Hydrogen	28.9
Nitrogen	13.8
Heating value, British Thermal Units per cubic foot, unpurified, gross	344

Laboratory No. 5551
Description: Sec. 13, T. 159, R. 102, S.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	38.92
Volatile Matter	27.11
Fixed Carbon	27.95
Ash	6.02
Sulphur	.65
British Thermal Units per lb. (B. T. U.)	6240

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	15.64
Alumina (Al_2O_3)	26.77
Iron Oxide (Fe_2O_3)	5.31
Calcium Oxide (CaO)	22.10
Magnesium Oxide (MgO)	1.70
Sodium and Potassium Oxides (computed as chlorides)	10.61
Other constituents and variations in combinations	17.87
Fusion Temperature of the ash, degrees F.	2215

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.47
Fixed Carbon	75.82
Ash	20.71
Sulphur	1.75
British Thermal Units per lb. (B. T. U.)	11860

The lignite, with moisture as received, yielded 9750 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent
Carbon Dioxide	19.0
Illuminants	2.4
Oxygen	1.6
Carbon Monoxide	22.4
Methane	7.0
Hydrogen	37.4
Nitrogen	10.2
Heating value, British Thermal Units per cubic foot, unpurified, gross	303

Laboratory No. 5552
Description: Sec. 9, T. 158, R. 101, S.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	35.94
Volatile Matter	27.87
Fixed Carbon	30.18
Ash	6.01
Sulphur	.36
British Thermal Units per lb. (B. T. U.)	6500

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	20.64
Alumina (Al_2O_3)	11.66
Iron Oxide (Fe_2O_3)	9.60
Calcium Oxide (CaO)	36.45
Magnesium Oxide (MgO)	10.90
Sodium and Potassium Oxides (computed as chlorides)	5.50
Other constituents and variations in combinations	5.25
Fusion Temperature of the ash, degrees F.	2350

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	6.06
Fixed Carbon	75.92
Ash	18.02
Sulphur	1.56
British Thermal Units per lb. (B. T, U.)	12022

The lignite, with moisture as received, yielded 12900 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	17.8
Illuminants	1.8
Oxygen	1.8
Carbon Monoxide	23.0
Methane	6.8
Hydrogen	40.8
Nitrogen	8.0
Heating value, British Thermal Units per cubic foot, unpurified, gross	305

Laboratory No. 5553
Description: Sec. 9, T. 156, R. 94, S.E.¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	35.50
Volatile Matter	26.35
Fixed Carbon	24.66
Ash	13.49
Sulphur	2.55
British Thermal Units per lb. (B. T. U.)	5820

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	18.44
Alumina (Al_2O_3)	8.18
Iron Oxide (Fe_2O_3)	26.88
Calcium Oxide (CaO)	10.50
Magnesium Oxide (MgO)	1.92
Sodium and Potassium Oxides (computed as chlorides)	21.54
Other constituents and variations in combinations	12.54
Fusion Temperature of the ash, degrees F.	1930

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	7.21
Fixed Carbon	63.15
Ash	29.64
Sulphur	5.53
British Thermal Units per lb. (B. T. U.)	10650

The lignite, with moisture as received, yielded 8550 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	23.4
Illuminants	1.3
Oxygen	2.6
Carbon Monoxide	18.3
Methane	10.3
Hydrogen	33.2
Nitrogen	10.9
Heating value, British Thermal Units per cubic foot, unpurified, gross	293

Laboratory No. 5554
Description: Sec. 19, T. 154, R. 94

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	42.13
Volatile Matter	24.74
Fixed Carbon	28.57
Ash	4.56
Sulphur	.28
British Thermal Units per lb. (B. T. U.)	5865

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	7.60
Alumina (Al_2O_3)	4.75
Iron Oxide (Fe_2O_3)	8.48
Calcium Oxide (CaO)	29.00
Magnesium Oxide (MgO)	1.70
Sodium and Potassium Oxides (computed as chlorides)	43.95
Other constituents and variations in combinations	4.52
Fusion Temperature of the ash, degrees F.	2240

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.60
Volatile Matter	5.50
Fixed Carbon	80.90
Ash	13.60
Sulphur	.74
British Thermal Units per lb. (B. T. U.)	12280

The lignite, with moisture as received, yielded 9830 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.3
Illuminants	1.4
Oxygen	2.2
Carbon Monoxide	20.6
Methane	6.4
Hydrogen	40.0
Nitrogen	11.1
Heating value, British Thermal Units per cubic foot, unpurified, gross	284

Laboratory No. 5555
Description: Sec. 33, T. 159, R. 100, S.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	37.64
Volatile Matter	25.93
Fixed Carbon	31.94
Ash	4.49
Sulphur	.47
British Thermal Units per lb. (B. T. U.)	6510

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	9.39
Alumina (Al_2O_3)	9.45
Iron Oxide (Fe_2O_3)	5.00
Calcium Oxide (CaO)	25.82
Magnesium Oxide (MgO)	9.33
Sodium and Potassium Oxides (computed as chlorides)	39.76
Other constituents and variations in combinations	1.25
Fusion Temperature of the ash, degrees F.	2190

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.77
Fixed Carbon	83.10
Ash	12.13
Sulphur	1.33
British Thermal Units per lb. (B. T. U.)	12650

The lignite, with moisture as received, yielded 9140 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.4
Illuminants	2.2
Oxygen	1.6
Carbon Monoxide	18.8
Methane	9.0
Hydrogen	39.1
Nitrogen	9.9
Heating value, British Thermal Units per cubic foot, unpurified, gross	314

Laboratory No. 5556
Description: Sec. 28, T. 154, R. 100, N.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	36.35
Volatile Matter	25.41
Fixed Carbon	29.95
Ash	8.29
Sulphur	.62
British Thermal Units per lb. (B. T. U.)	6345

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	36.24
Alumina (Al_2O_3)	16.26
Iron Oxide (Fe_2O_3)	4.92
Calcium Oxide (CaO)	15.44
Magnesium Oxide (MgO)	6.00
Sodium and Potassium Oxides (computed as chlorides)	22.00
Other constituents and variations in combinations	—.86
Fusion Temperature of the ash, degrees F.	2070

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.71
Fixed Carbon	79.53
Ash	15.76
Sulphur	1.13
British Thermal Units per lb. (B. T. U.)	12190

The lignite, with moisture as received, yielded 8560 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.2
Illuminants	3.2
Oxygen	1.4
Carbon Monoxide	20.2
Methane	9.4
Hydrogen	35.4
Nitrogen	11.2
Heating value, British Thermal Units per cubic foot, unpurified, gross	327

Laboratory No. 5557
Description: Sec. 21, T. 154, R. 100, N.E. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	36.54
Volatile Matter	27.06
Fixed Carbon	28.76
Ash	7.64
Sulphur	.92
British Thermal Units per lb. (B. T. U.)	6213

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	28.30
Alumina (Al_2O_3)	10.72
Iron Oxide (Fe_2O_3)	8.36
Calcium Oxide (CaO)	18.66
Magnesium Oxide (MgO)	7.95
Sodium and Potassium Oxides (computed as chlorides)	19.10
Other constituents and variations in combinations	6.91
Fusion Temperature of the ash, degrees F.	2105

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.08
Fixed Carbon	76.74
Ash	19.18
Sulphur	1.39
British Thermal Units per lb. (B. T. U.)	11882

The lignite, with moisture as received, yielded 10590 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.0
Illuminants	2.4
Oxygen	1.2
Carbon Monoxide	20.5
Methane	7.9
Hydrogen	41.8
Nitrogen	7.2
Heating value, British Thermal Units per cubic foot, unpurified, gross	321

Laboratory No. 5558
Description: Sec. 17, T. 154, R. 100, S.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	36.53
Volatile Matter	27.81
Fixed Carbon	30.21
Ash	5.45
Sulphur	.83
British Thermal Units per lb. (B. T. U.)	6595

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	16.74
Alumina (Al_2O_3)	10.34
Iron Oxide (Fe_2O_3)	14.20
Calcium Oxide (CaO)	20.72
Magnesium Oxide (MgO)	6.28
Sodium and Potassium Oxides (computed as chlorides)	24.84
Other constituents and variations in combinations	6.88
Fusion Temperature of the ash, degrees F	2208

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.39
Fixed Carbon	81.74
Ash	14.87
Sulphur	1.93
British Thermal Units per lb. (B. T. U.)	12570

The lignite, with moisture as received, yielded 9360 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.4
Illuminants	1.7
Oxygen	1.7
Carbon Monoxide	19.8
Methane	7.6
Hydrogen	40.2
Nitrogen	9.6
Heating value, British Thermal Units per cubic foot, unpurified, gross	299

Laboratory No. 5559
Description: Sec. 10, T. 154, R. 100, N. ½

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	42.03
Volatile Matter	22.97
Fixed Carbon	28.44
Ash	6.56
Sulphur	.58
British Thermal Units per lb. (B. T. U.)	5845

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	34.72
Alumina (Al_2O_3)	14.10
Iron Oxide (Fe_2O_3)	7.72
Calcium Oxide (CaO)	14.00
Magnesium Oxide (MgO)	5.56
Sodium and Potassium Oxides (computed as chlorides)	23.60
Other constituents and variations in combinations	.30
Fusion Temperature of the ash, degrees F	2075

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	2.96
Fixed Carbon	77.40
Ash	19.64
Sulphur	1.41
British Thermal Units per lb. (B. T. U.)	11580

The lignite, with moisture as received, yielded 10820 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	16.6
Illuminants	1.8
Oxygen	3.0
Carbon Monoxide	18.0
Methane	6.1
Hydrogen	38.1
Nitrogen	16.4
Heating value, British Thermal Units per cubic foot, unpurified, gross	273

Laboratory No. 5560
Description: Sec. 24, T. 152, R. 82, N.W.¼
(Bottom 7 feet)

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	37.24
Volatile Matter	27.50
Fixed Carbon	30.65
Ash	4.61
Sulphur	.21
British Thermal Units per lb. (B. T. U.)	6797

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	26.81
Alumina (Al_2O_3)	7.84
Iron Oxide (Fe_2O_3)	6.00
Calcium Oxide (CaO)	36.38
Magnesium Oxide (MgO)	8.35
Sodium and Potassium Oxides (computed as chlorides)	8.71
Other constituents and variations in combinations	5.91
Fusion Temperature of the ash, degrees F.	2347

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	4.08
Fixed Carbon	81.97
Ash	13.95
Sulphur	.83
British Thermal Units per lb. (B. T. U.)	12380

The lignite, with moisture as received, yielded 11200 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.8
Illuminants	2.0
Oxygen	1.4
Carbon Monoxide	21.2
Methane	8.8
Hydrogen	40.9
Nitrogen	6.9
Heating value, British Thermal Units per cubic foot, unpurified, gross	326

Laboratory No. 5561
Description: Sec. 24, T. 152, R. 82, N.W. ¼ (Top 2½ feet)

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	37.36
Volatile Matter	24.62
Fixed Carbon	33.83
Ash	4.19
Sulphur	.18
British Thermal Units per lb. (B. T. U.)	6664

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	13.20
Alumina (Al_2O_3)	5.54
Iron Oxide (Fe_2O_3)	7.90
Calcium Oxide (CaO)	44.94
Magnesium Oxide (MgO)	5.20
Sodium and Potassium Oxides (computed as chlorides)	9.24
Other constituents and variations in combinations	13.98
Fusion Temperature of the ash, degrees F.	2390

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	6.42
Fixed Carbon	80.93
Ash	12.65
Sulphur	.79
British Thermal Units per lb. (B. T. U.)	12450

The lignite, with moisture as received, yielded 9660 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	19.1
Illuminants	1.2
Oxygen	2.6
Carbon Monoxide	22.6
Methane	9.2
Hydrogen	35.5
Nitrogen	9.8
Heating value, British Thermal Units per cubic foot, unpurified, gross	301

Laboratory No. 5562
Description: Sec. 29, T. 154, R. 97, S.W. ¼

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent.
Moisture	38.30
Volatile Matter	25.74
Fixed Carbon	29.04
Ash	6.92
Sulphur	.81
British Thermal Units per lb. (B. T. U.)	6153

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	16.15
Alumina (Al_2O_3)	10.43
Iron Oxide (Fe_2O_3)	17.55
Calcium Oxide (CaO)	23.72
Magnesium Oxide (MgO)	7.41
Sodium and Potassium Oxides (computed as chlorides)	6.95
Other constituents and variations in combinations	17.79
Fusion Temperature of the ash, degrees F.	2290

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	3.72
Fixed Carbon	74.30
Ash	21.98
Sulphur	2.75
British Thermal Units per lb. (B. T. U.)	11830

The lignite, with moisture as received, yielded 10620 cu. ft. of unpurified gas per ton, corrected.

ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	18.4
Illuminants	1.4
Oxygen	1.3
Carbon Monoxide	24.1
Methane	5.5
Hydrogen	39.2
Nitrogen	10.1
Heating value, British Thermal Units per cubic foot, unpurified, gross	284

Laboratory No. 5563
Description: Sec. 18, T. 144, R. 87, N.½ of N.½

ANALYSIS OF LIGNITE WITH MOISTURE AS RECEIVED

	Per cent
Moisture	34.33
Volatile Matter	28.17
Fixed Carbon	32.97
Ash	4.53
Sulphur	1.00
British Thermal Units per lb. (B. T. U.)	7040

ANALYSIS OF THE ASH

	Per cent.
Silica (SiO_2)	13.60
Alumina (Al_2O_3)	14.75
Iron Oxide (Fe_2O_3)	2.79
Calcium Oxide (CaO)	26.24
Magnesium Oxide (MgO)	9.18
Sodium and Potassium Oxides (computed as chlorides)	14.40
Other constituents and variations in combinations	19.04
Fusion Temperature of the ash, degrees F.	2393

CHAR AND GAS TESTS

ANALYSIS OF CHAR

	Per cent.
Moisture	0.00
Volatile Matter	5.12
Fixed Carbon	82.71
Ash	12.17
Sulphur	1.70
British Thermal Units per lb. (B. T. U.)	12720

The lignite, with moisture as received, yielded 11270 cu. ft. of unpurified gas per ton, corrected.

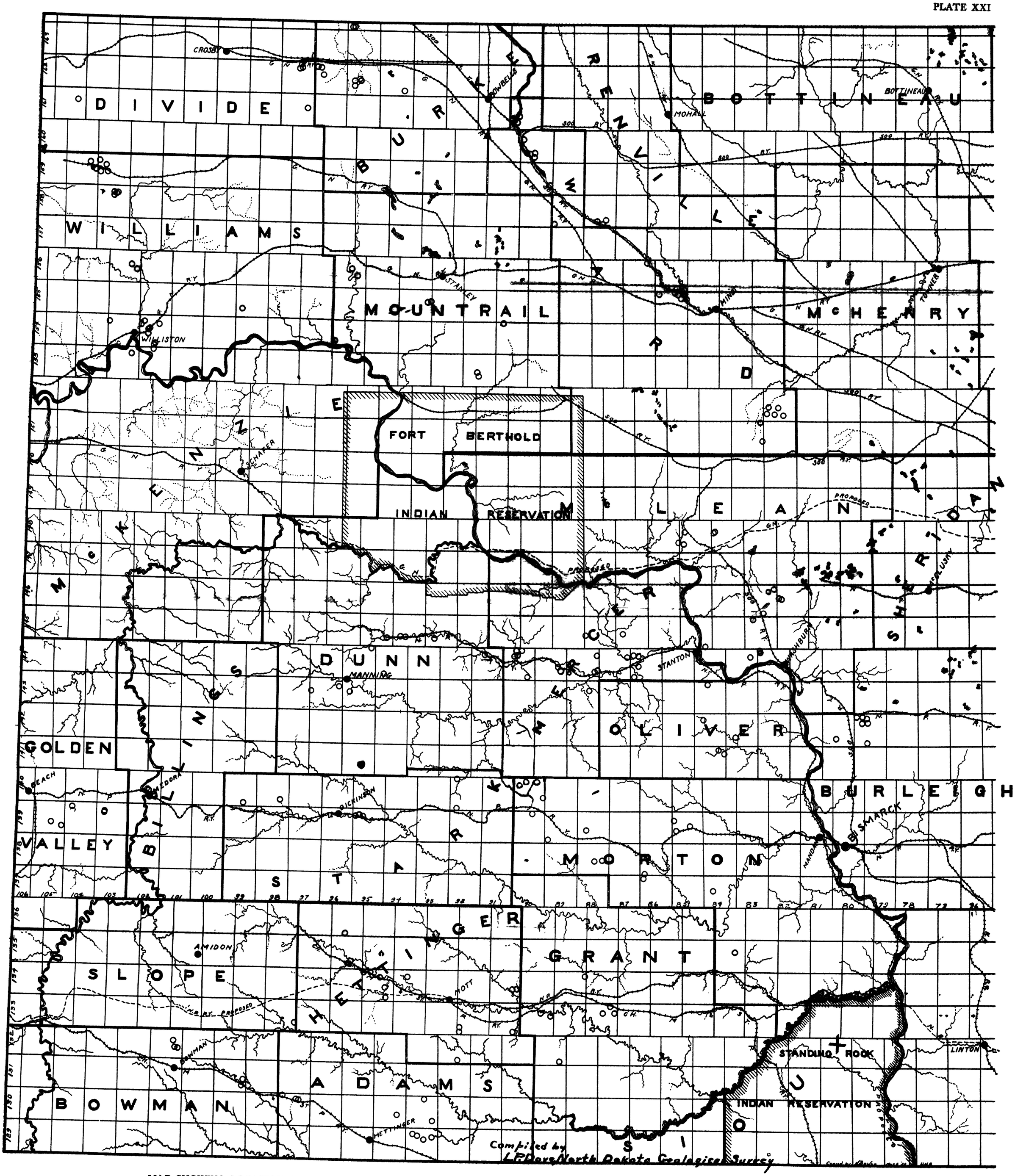
ANALYSIS OF THE GAS

	Per cent.
Carbon Dioxide	15.9
Illuminants	1.3
Oxygen	2.1
Carbon Monoxide	21.8
Methane	8.2
Hydrogen	39.2
Nitrogen	11.5
Heating value, British Thermal Units per cubic foot, unpurified, gross	302

NOTE: It must be remembered that the analyses given in this report are not intended to cover the entire lignite area, or all the mines, but rather the localities and mines referred to specially in this report. The analyses from many other deposits and mines have been covered by previous work and reports of the School of Mines.

The high ash and comparatively low grade of some of the samples may be due, in a few cases, to the taking of the particular sample from an outcrop or imperfectly developed deposit.

A proper interpretation of these analyses and tests, and what they signify, can best be obtained by referring to the discussion of the character and composition of lignite in this chapter, pages 171, 172 and 177.



MAP SHOWING LOCATION OF THE MORE IMPORTANT COAL MINES OF NORTH DAKOTA. MINES ARE REPRESENTED BY OPEN CIRCLES

LIST OF LIGNITE MINES

The following list of mines is taken from the Sixth Annual Report of the State Mine Inspector for the year ending October 31, 1924. This list of 253 mines does not include many small "mines" which are located at a distance from the railroad. For example, coal is dug for local use in many places in Slope and McKenzie counties, but no mines are given as being found in these counties.

Then, too, the number of mines changes from year to year, some mines being closed down or abandoned, while new ones are being opened from time to time.

ADAMS COUNTY

Name of Mine	Address
S. D. Coal Mining Co.	Haynes
Stevenson & Schmickrath	Haynes
Becher Coal Mine	Haynes
Leroy Smith Mine	Haynes
Taylor & Bingham Mine	Haynes
Pearl Butte Mine	Haynes
Leff Coal Mine	Reeder
Minnehaha Coal Co.	Reeder
Reeder Coal Co.	Reeder
Powell Coal Mine	Reeder
Hagen Mine	Reeder
Wothe Mine	Reeder
Rocky Ridge Coal Co.	Hettinger
Nels Hanson Mine	Hettinger
Haynes Independent Coal Co.	Haynes

BILLINGS COUNTY

High Grade Coal Co.	Medora
Red Trail Coal Co.	Medora
Demores Coal Mine	Medora

BOWMAN COUNTY

The Johnson Fuel Co.	Scranton
Scranton Lignite Coal Co.	Scranton
Fischbein Coal Co.	Scranton
Hardy Mine & Sales Co.	Scranton
Halleck Coal Co.	Bowman
Touhey Mine	Bowman

BURKE COUNTY

Truax Coal Co.	Columbus
Whittier-Crockett Co.	Columbus
Bosness Coal Mine	Columbus
Henrickson Bros. Co.	Columbus
Post Coal Mine	Columbus
Larson Coal Co.	Cloumbus
Fenster Coal Co.	Larson
Domrese Coal Co.	Larson
Kielhock & Wixon	Columbus

BURLEIGH COUNTY

Name of Mine	Address
Washburn Lignite Coal Co.	Wilton
Ecklund Mine	Wilton
Lind Bros. Mine	Wilton
Berger Mine	Baldwin
Peterson Fuel Co.	Wilton
Backman Mine	Wilton
Asplund Mine	Wilton
Casino Coal Co.	Wilton
Anderson Mine	Wilton
Engstrom Mine	Wilton
Fosberg Mine	Wilton

DIVIDE COUNTY

Hought Coal Co.	Noonan
Kimball Coal Co.	Noonan
Light Bros. Coal Co.	Noonan
Logelin Coal Co.	Noonan
Hagen Bros. Mine	Noonan
Johnson Mine	Zahl
Larson & Anderson	Noonan
Stanislowsky Mine	Atcoal

DUNN COUNTY

Dunn Center Coal Co.	Dunn Center
Hy-Grade Coal Co.	Dunn Center
Dodge Coal Co.	Dodge
Regeth Mine	Manning
Millestead Mine	Killdeer
Yarder Bros. Mine	Werner

GOLDEN VALLEY COUNTY

Sentinel Butte Co.	Sentinel Butte
Grimm Coal Co.	Sentinel Butte
Runion Coal Mine	Sentinel Butte

GRANT COUNTY

Utter Coal Mine	New Leipzig
Circle Butte Coal Co.	Carson
Kolbank Coal Co.	Leith
Cain Coal Co.	New Leipzig
Gottlieb Roth Mine	Odessa
Lemke Coal Co.	Burt
Kranich Coal Mine	Elgin
Wutzke Coal Mine	Elgin
Roger Coal Mine	New Leipzig
Boyer Bros. Co.	Fleak
Weltz Mine	Burt
Wolforth Coal Mine	Elgin
Knapp Mine	New Leipzig
Spring Butte Coal Co.	New Leipzig
Buchanan Mine	New Leipzig
Raattamas Mine	New Leipzig
Nord Coal Mine	New Leipzig
W. W. Wolden	New Leipzig

HETTINGER COUNTY

Name of Mine	Address
Loe Coal Mine	Mott
Kelsch Coal Mine	Bently
Weinandy Coal Mine	Havelock
Watson Coal Mine	Mott
Albrecht Coal Mine	New England
Havelock Quality Coal	Havelock
Watrous O. K. Lignite Co.	Bently
Reiss Coal Mine	New England
Coalbank Mining Co.	Coalbank
Jackson & Blank	Havelock
Indian Creek Coal Co.	Regent
Havelock Coal Co.	Havelock
Aaby Light & Power Co.	New England
Arnold Mine	Regent

McLEAN COUNTY

Kunkel Coal Co.	Garrison
Stevens Bros.	Garrison
Braasch Bros. Mine	Roseglen
Frederich Coal Mine	Underwood
Payne Coal Mine	Underwood
Isaacson Mine	Underwood
Pfister Mine	Washburn
Beerle Mine	Garrison
Quality Coal Co.	Garrison
Crescent Lignite Coal Co.	Washburn
Wagner Coal Mine	Underwood
Bartley Coal Co.	Underwood
Rupp Coal Mine	Garrison
Johnson Coal Co.	Coleharbor
Bitumina Coal Mine	Washburn
Malloy & Crumb Coal Co.	Underwood
Zook Coal Co.	Garrison
Minter Mine	Douglas
Roseglen City Mine	Roseglen

MERCER COUNTY

Lucky Strike Coal Co.	Zap
Zap Colliery Co.	Zap
Knife River Mining Co.	Beulah
Zap Coal Co.	Zap
Hazen Coal Co.	Hazen
Schmidt Coal Mine	Beulah
Dry Flint Coal Co.	Zap
Spring Creek Coal Co.	Zap
Kessler Mine	Beulah
Sailer Bros. Mine	Beulah
Kerner & Kerner	Beulah
Serr Coal Mine	Stanton
Johnson Mine	Beulah

MORTON COUNTY

Name of Mine	Address
McCormick Coal Mine	New Salem
Hebron Brick Co.	Hebron
North Star Coal Co.	Hebron
Thor Coal Mine	Almont
Reichel Coal Mine	Almont
Glen Ullin Coal Co.	Glen Ullin
Kokkler Mine	Glen Ullin
Pleasant Ridge Coal Co.	Glen Ullin
Harnish Coal Co.	Hebron
Wadeson Coal Mine	Hebron
Kramer Coal Mine	New Salem
P. H. Hooveatol	Almont
Bison Lignite Co.	Glen Ullin
Campbell Mine	Mandan
Teppo Mine	Mandan
Kopenen Mine,	Mandan
Pitzer Mine	Mandan
Little Heart Mine	Mandan

MOUNTRAIL COUNTY

Shell Creek Coal Co.	Plaza
Westermark & Warren	Parshall
Palda Coal Co.	Palermo
Williams Coal Mine	White Earth
Carkuff Coal Mine	Stanley
Parshall Coal Co.	Parshall
Deep Vein Coal Co.	Palermo
Lofgren Coal Co.	Parshall
Dockter Coal Co.	Parshall
Kale Coal Co.	Stanley
Tom Olson Mine	White Earth
Chas. Carkuff Mine	Stanley
Frank Ferris Coal Mine	Parshall
Jack Panchel	Van Hook
William Cousin	Van Hook
Evenson & Anderson	Van Hook
Jess Stringer	Sanish
Thomas Moore	White Earth
Ed Gathaman	White Earth
Chas. Leaf	White Earth
John Garber	White Earth
Henry Charles	White Earth
Nels Blicker	White Earth
John Altenthaler	White Earth
George Porger	White Earth

OLIVER COUNTY

Pleasant Valley Coal Co.	Center
M. N. Tripp Coal Mine	Center
Spring Valley Coal Co.	Center
Bertram Mine	Center

STARK COUNTY

Pittsburgh Coal Mine	Dickinson
Benek Coal Mine	Dickinson
Perzinski Mine	So. Heart

Name of Mine	Address
Zenith Coal Co.	Zenith
North Star Mine	Richardton
Leigh Mining Co.	Dickinson
Lerfald Lignite Mine	Belfield
Kubischta Mine	So. Heart
Ridl Coal Mine	Dickinson
Frank Marsh	So. Heart
S. S. Sutherland	So. Heart

WARD COUNTY

Midway Coal Co.	Burlington
Union Mine	Burlington
Bartoshevich Coal Co.	Sawyer
Wilson Coal Mine	Kenmare
Hunnewell Coal Co.	Burlington
Reed Coal Mine	Sawyer
Fasmark Coal Mine	Kenmare
Murray Coal Mine	Kenmare
Bechtold Coal Mine	Sawyer
Coffin Coal Mine	Velva
Jensen Bros. Mine	Carpio
Cherry Vale Coal Co.	Burlington
Burlington City Mine	Burlington
Colton Coal Co.	Burlington
Leeson West Coal Co.	Sawyer
Perlichek Coal Co.	Burlington
Mellon Coal Mine	Kenmare
O'Neil Coal Mine	Kenmare
Smith Coal Mine	Kenmare
United Light & Power Co.	Kenmare
Clemench & Larson	Burlington
Kandoff Mine	Burlington
Schultz Bros. Mine	Kenmare
Kemp Coal Mine	Kenmare
Lytle Coal Mine	Donnybrook
Miller Mine	Donnybrook
Walters Mine	Donnybrook
Johnson Mine	Donnybrook
Jensen Bros. Mine	Carpio
Tehalka Mine	Carpio
Foxholm Coal Mine	Foxholm
White Ash Coal Co.	Foxholm
Larson Coal Co.	Burlington
Hard Luck Coal Co.	Burlington
Shopp Coal Co.	Sawyer
Vix Coal Co.	Sawyer
Tree Coal Co.	Sawyer
Jonas Johnson	Kenmare
Black Hawk	Kenmare

WILLIAMS COUNTY

Williston Coal & Ice Co.	Williston
U. S. Reclamation Mine	Williston
Square Deal Coal Co.	Williston
Avoca Coal Co.	Williston
Farmers & Merchants Co.	Williston
Carbon Coal Co.	Williston

Name of Mine	Address
Hanks Coal Co.	Hanks
Beaver Creek Coal Mine	Tioga
Falks Coal Mine	Hanks
Peterson Coal Mine	Williston
Ray Coal Mine	Williston
Miller Coal Mine	Williston
B'ue Flame Coal Mine	Williston
Johnson Coal Mine	Zahl
Vizina Coal Co.	Williston
Moorman Coal Co.	Wheelock
Nordlein Coal Co.	Zahl
Cow Creek Coal Co.	Bonetrail
Breen Coal Co.	Williston
Folvog Coal Mine	Grenora
Black Diamond	Williston
Black Beauty	Hanks
Frants Franson	Tioga
Hans Granley	Huffland
Barney Hall	Wheelock
Hoving Coal Mine	Wheelock
Thompson Coal Mine	Williston
Todd Coal Mine	Williston
N. T. Narverson	Zahl
Black Bear	Williston

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