

THE CANNONBALL RIVER LIGNITE FIELD, MORTON, ADAMS, AND HETTINGER COUNTIES, NORTH DAKOTA.

By E. RUSSELL LLOYD.

INTRODUCTION.

LOCATION AND EXTENT.

During the summers of 1912 and 1913 the writer undertook to determine as nearly as possible the southeastern limits of the North Dakota lignite region. Previous to that time the presence of lignite in this part of the State was known in only a general way and it was

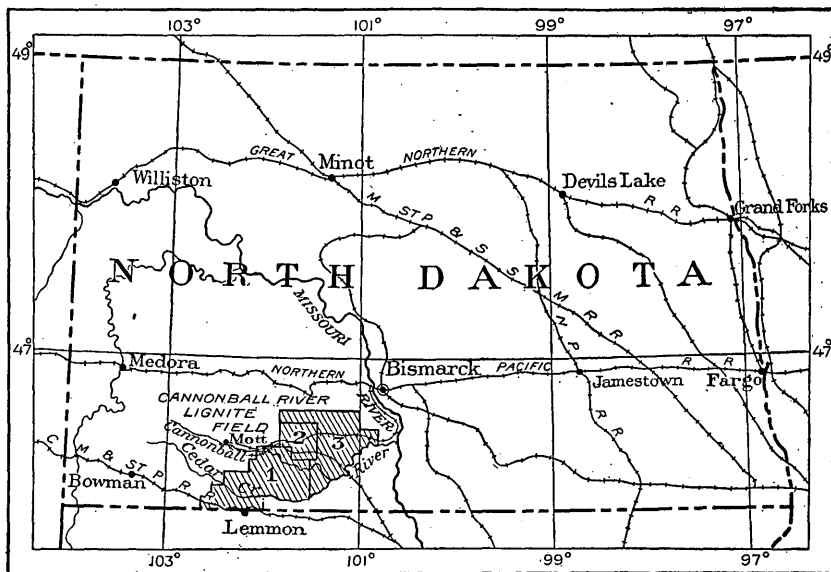


FIGURE 8.—Map of North Dakota, showing location of Cannonball River lignite field. 1, Area shown on Plate XIII; 2, area shown on Plate XIV; 3, area examined but not shown on maps.

necessary to examine a large area wherein lignite occurs only locally and in thin beds. The limits of the region of the more important beds lie partly within the area examined and partly northwest of it, and the term "Cannonball River lignite field" is used to embrace a few small districts wherein lignite is being or may be mined on a large scale and a large area wherein lignite is absent or occurs in beds so thin that it will never be of importance except for local use.

The field has a total area of about 2,170 square miles (fig. 8), of which only about one-fifth, or approximately 420 square miles, is underlain by beds of lignite more than $2\frac{1}{2}$ feet in thickness. A large area in the eastern part of the district examined contains only thin beds of lignite; for that reason it is not included in the area represented on the accompanying maps (Pls. XIII, p. 282, and XIV, p. 290) and will be only briefly described in this report. In another paper the writer proposes to present more fully the scientific data obtained in this and adjoining fields.

The Cannonball River field lies between longitude $100^{\circ} 40'$ and $102^{\circ} 40'$ west (fig. 8). Its southern boundary west of the one hundred and second meridian is the North Dakota-South Dakota State line. East of that meridian it adjoins the old Standing Rock Indian Reservation, the northern boundary of which is formed by Cedar Creek and that part of Cannonball River east of the mouth of this creek. On the northeast the field adjoins the Bismarck quadrangle, which is bounded on the south by latitude $46^{\circ} 30'$ and on the west by longitude 101° . The boundary of the Cannonball River field on the west and north is irregular and was determined by the desirability of immediate classification of this land with regard to its coal or noncoal character and by the time available for examination.

FIELD WORK.

The field examination upon which this report is based was made by parties in charge of the writer during the summers of 1912 and 1913. The writer was assisted in 1912 by B. W. Clark, W. T. Thom, jr., and L. M. Neumann; in 1913 by W. C. Mansfield, A. C. Dennis, and L. M. Neumann. The work was done under the direct supervision of M. R. Campbell and E. G. Woodruff, to both of whom the writer is indebted for many valuable suggestions. The field work was materially assisted by the ever-ready hospitality of residents of the field and by much valuable information contributed by them. It is impracticable to make special mention of these courtesies, and acknowledgments can be made only in this general way.

The area examined in 1912 is shown on the larger map (Pl. XIII) and embraces an area of about 970 square miles. In 1913 an adjoining area of nearly 1,200 square miles was examined in the valleys of Cannonball and Heart rivers, of which eight townships, comprising the more important lignite district, are shown in Plate XIV.

The geologic examination was made primarily for the purpose of classifying the land with regard to the amount of lignite it contains. In conducting such an examination an attempt was made to determine the extent and thickness of the lignite beds from a study of their outcrops, supplemented by such data as could be obtained concerning lignite discovered in wells. Exposures of lignite more than 2 feet thick were carefully measured, and the locations and altitudes

determined with plane table, telescopic alidade, and stadia rod. The outcrops of lignite beds were mapped accurately wherever exposed, and where not exposed they were mapped approximately by reference to adjacent strata or from topographic features alone. Where lignite was not found, the geology and topography were mapped with plane table and alidade.

The Land Office surveys of the region embraced in this report were made between the years 1890 and 1902. The corners are, as a general rule, well marked, and no discrepancy was observed between the position of the stones in the field and that shown on the official plats. Township plats of the General Land Office were used as base maps for the field work and for the construction of Plates XIII and XIV.

PREVIOUS PUBLICATIONS.

The portion of western North Dakota drained by Cannonball River and its tributaries has long been known to be a part of the great lignite area of the Dakotas and eastern Montana. The explorations of the Lewis and Clark expedition, 1804-1806, established the existence of what was supposed to be "stone coal" (lignite) in the Mandan country. Nearly every succeeding expedition added something of interest, but it was not until the exploration of F. V. Hayden, under the direction of Lieut. G. K. Warren, United States Topographical Engineers, that any attempt was made to publish a geologic map of the region.¹ In 1874 an expedition under the command of Gens. Custer and Ludlow, accompanied by N. H. Winchell, as geologist, made a reconnaissance trip to the Black Hills, crossing the Cannonball River field on the way.²

In recent years the Geological Survey of North Dakota has published several articles dealing with the lignite beds of the State, but particular attention was given to the more fully developed territory to the north and west, and the Cannonball River field received scant attention. A. G. Leonard, State geologist, has recently published an article³ in which he records and discusses several sections exposed along Cannonball and Heart rivers in Morton County. Some of these sections have been reexamined by the writer and will be described later.

GEOGRAPHY.

COMMERCIAL RELATIONS.

The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southwestern border of the field in an east-west direction. The Cannonball branch of the same road, which extends from McLaughlin, S. Dak., to New England, N. Dak., crosses the central part of the area

¹ Hayden, F. V., Notes explanatory of a map and section illustrating the geologic structure of the country bordering on the Missouri River from the mouth of the Platte River to Fort Benton: Acad. Nat. Sci. Philadelphia Proc., vol. 9, pp. 109-116, 1858.

² Winchell, N. H., Report of a reconnaissance of the Black Hills of Dakota made in the summer of 1874 by William Ludlow, pp. 22 and following, and map, 1875.

³ Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, pp. 507-547, 1911.

examined in 1913 and the north border of the area examined in 1912. A branch of the Northern Pacific Railway which leaves the main line at Mandan and extends to Mott, N. Dak., also crosses the central part of the area examined in 1913. Wagon roads throughout the field are in general located on section lines, except locally where the land is so rough as to render this impracticable. These roads are numerous and render all parts of the field easily accessible.

The construction of the two branch railway lines has promoted the development of a rich agricultural district. On each line are located a number of towns, all of which have shown a steady growth. Solen, Timmer, Flasher, Lark, Carson, Heil, and Odessa on the Northern Pacific, and Shields, Freda, Raleigh, Brisbane, Leith, and Kaiser on the Cannonball branch of the Chicago, Milwaukee & St. Paul lie within the Cannonball field; Elgin, New Leipzig, and Bentley are only a few miles beyond its limits. Haynes and Petrel lie within the field on the main line of the Chicago, Milwaukee & St. Paul. Lemmon, S. Dak., at the State line, is the center of a large agricultural district and Hettinger, N. Dak., half a mile west of the west boundary of the field, is scarcely less important. The entire region is well settled and is supplied with adequate postal facilities.

TOPOGRAPHY.

The Cannonball River field lies in the Great Plains province, which extends from the Rocky Mountain region eastward and merges gradually with the Glaciated Plains east of Missouri River. The greater part of the field is a rolling prairie, interrupted, however, at many places by high boulder-covered ridges and buttes or by steep-sided valleys. There are also large badland areas in the eastern part of the field. The central and southern parts are drained by Cannonball River and by its principal tributary, Cedar Creek, both of which have wide valleys cut from 200 to 500 feet below the surrounding plateau. Heart River crosses the northern part of the area examined in 1913. The principal smaller tributaries of Cannonball River in the field are Louse Creek with its branches, Chanta Peta and Dogtooth creeks, Three Buttes Creek, Sixmile Creek, and Snake Creek. Crooked, Timber, and Duck creeks flow into Cedar Creek. The only important southern tributary of Heart River is Antelope Creek.

All these streams and many of their smaller tributaries contain either running water or water holes throughout the year. Springs are fairly common throughout the whole area but are most abundant at the outcrops of the principal lignite beds. In most places water can be reached by wells at comparatively shallow depths, and it is from such wells that the principal supply is obtained for domestic use. The water in this area is in general comparatively free from sulphates, calcium, and sodium, the ordinary impurities which render much of the water of the Great Plains region unfit for use.

From a point about a dozen miles above the mouth of Cedar Creek and thence eastward to Missouri River, the valleys of Cannonball River and its principal tributaries are characterized by bad lands which in the eastern part of the field extend locally several miles back from the streams. Within the badland area are wide stretches which appear nearly level but which are cut by numerous small coulees and are only locally sufficiently level for cultivation.

West of the badland areas the valleys of Cannonball River and of Cedar Creek have in general broadly terraced slopes, due chiefly to the erosion of alternating beds of sandstone and shale. The valley of the Cannonball is in general narrower and more rugged than that of Cedar Creek, but both streams have at many places cut steep bluffs in which the strata are well exposed. The general upland part of the field is gently rolling or nearly level, except for numerous high ridges which are practically covered with large quartzitic boulders.

AGRICULTURE.

The Cannonball River field is located in what is known as the semi-arid region of the Great Plains, where the rainfall is only moderate in amount and often comes at seasons when least needed. With the exception of the rocky hills and some rough country along the streams, nearly all of the land can be cultivated, the soil constituents being such that only a small amount of moisture is sufficient to insure good crops. Wheat is by far the most important crop, but flax, oats, rye, barley, potatoes, and other grains and vegetables are raised extensively. Except for a limited growth of small timber along the principal streams and in steep coulees, the region is open prairie, destitute of trees.

GEOLOGY.

STRATIGRAPHY.

GENERAL CHARACTER OF THE ROCKS.

The Fort Union formation, of the lower part of the Tertiary system (Eocene), which contains the greater part of the valuable lignite in the Dakotas and eastern Montana, embraces the surface rocks in the western and northwestern parts of the Cannonball River field. Underneath the Fort Union is a series of beds which are now tentatively classified as probably of early Tertiary age and which have been referred to the Lance formation. The upper 250 or 300 feet of this formation is in the field markedly different in lithologic character from the underlying more typical Lance, and has been found at numerous places to contain the remains of a marine fauna, which has not previously been known in this part of the stratigraphic section. These beds have been mapped separately and are herein designated the Cannonball marine member of the Lance formation.¹ The under-

¹ The Cannonball marine member of the Lance formation is described only briefly in this report. It will be described in detail in a forthcoming paper, which is now in course of preparation.

lying lower part of the Lance is of fresh-water origin and is composed of alternating beds of shale and sandstone which on erosion give rise to the badlands described above. Its thickness is approximately 400 feet. In the extreme eastern part of the field the top of the Fox Hills sandstone, which underlies the Lance formation, is exposed in the bluffs of Cannonball River.

The tops of a few high buttes are capped with sandstone and fresh-water limestone belonging to the White River (Oligocene) formation. Beds of sand and gravel on the tops of some of the higher buttes belong to either the latest Tertiary or to the early part of the Quaternary period, and the Quaternary is also represented by high-terrace river gravel and by glacial boulders.

The general character and relations of the formation exposed in this field are shown in the following table:

Stratigraphy of the Cannonball River lignite field.

System.	Series.	Formation.	Character.	Thickness.
Quaternary.			Glacial boulders and river terrace gravel.	<i>Feet.</i> (a)
Tertiary or Quaternary.			Sand and gravel on tops of high buttes.	(a)
Tertiary.	Oligocene.	White River formation.	Cross-bedded sandstone and fresh-water limestone.	(a)
	Eocene.	Fort Union formation.	Yellow sandstone, shale, clay, and lignite.	300-400
Tertiary (?).	Eocene(?).	Lance formation.	Cannonball marine member (dark sandy shale, dark shaly sandstone and yellow sandstone, containing marine shells).	250-300
			Somber-colored shale, yellow sandstone, and thin lignite beds.	400-450
Cretaceous.	Upper Cretaceous.	Fox Hills sandstone.	Sandstone, yellow or brown, friable.	(a)

a Not determined.

CRETACEOUS SYSTEM.

FOX HILLS SANDSTONE.

The Fox Hills sandstone is exposed in the bluffs of Cannonball River in the extreme eastern part of the area examined in 1913, about 25 miles east of the area shown on the maps accompanying this report. The rock is a fine-grained friable sandstone, yellow or brown in color, and locally contains a rich marine fauna.¹

¹ For more complete description of the Fox Hills sandstone in this region see: Stanton, T. W., Fox Hills sandstone and Lance formation ("Ceratops beds") in South Dakota, North Dakota, and eastern Wyoming: *Am. Jour. Sci.*, 4th ser., vol. 30, pp. 172-188, 1910. Knowlton, F. H., Further data on the stratigraphic position of the Lance formation (Ceratops beds): *Jour. Geology*, vol. 19, pp. 358-376, 1911. Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: *Jour. Geology*, vol. 19, p. 511, 1911; The geological map of North Dakota: *Univ. of North Dakota Quart. Jour.*, vol. 4, No. 1, Oct., 1913. Calvert, W. R., and others, *Geology of the Standing Rock and Cheyenne River Indian reservations, North and South Dakota*: U. S. Geol. Survey Bull. 575, pp. 11-16, 1914.

TERTIARY (?) SYSTEM.

LANCE FORMATION.

Lower part of the Lance formation.—The lower part of the Lance formation outcrops in the valleys of Cannonball River and its tributaries in the eastern part of the field. Within the region shown on the accompanying maps it outcrops only in small areas on Cannonball River and Cedar Creek. This part of the formation consists of alternating beds of shale and sandstone with thin beds of lignite. The total thickness is approximately 400 feet. The shale is predominantly somber in color, commonly gray or black. The sandstone is yellow or buff. Locally, brown carbonaceous layers and lenticular beds of bog iron are present and form conspicuous outcrops. Where the Lance formation is exposed, the surface is characterized by wide and nearly flat valleys bordered by steep and picturesque badland bluffs.

Fossil leaves collected near the top of the lower part of the Lance have been identified by Mr. Knowlton as belonging to the Fort Union flora. Only fragmentary vertebrate remains were found in this portion of the Lance in the Cannonball River field, but in the examination of the Standing Rock Indian Reservation¹ in 1909 abundant remains of dinosaur and turtle bones were found in several places, and a few collections of dinosaur bones have been made near the mouth of Cannonball River.²

The lignite beds of the lower part of the Lance formation have been found nearly everywhere in the Dakotas to be thin and lenticular. The thin beds occurring in this field are no exception to the rule. They are most abundant from 50 to 75 feet below the top of the lower part of the formation and one or more beds are exposed in nearly all parts of the field where that portion of the formation appears at the surface.

*Cannonball marine member.*³—The Cannonball marine member comprises the upper 250 or 300 feet of the Lance formation. It is typically represented in the bluffs of Cannonball River, in Tps. 132 and 133 N., R. 88 W., where the member is well exposed. The following vertical section, measured in this type area, shows the general character of the beds:

Section of Cannonball marine member of Lance formation in river bluff in NW. $\frac{1}{4}$ sec. 11, T. 132 N., R. 88 W.

(Soil.)	Ft.	in.
Sandstone, calcareous.....	6	
Sandstone, gray, partly consolidated, containing numerous layers cemented with iron.....	10	6

¹ Calvert, W. R., and others, *Geology of the Standing Rock and Cheyenne River Indian reservations, North and South Dakota*: U. S. Geol. Survey Bull. 575, pp. 21-22, 1914.

² Stanton, T. W., *Washington Acad. Sci. Proc.*, vol. 11, No. 3, p. 250, 1909. Leonard, A. G., *The Cretaceous and Tertiary formations of western North Dakota and eastern Montana*: Jour. Geology, vol. 19, p. 524, 1911.

³ A more complete description of the Cannonball member is in course of preparation and will soon be published.

	Ft. in.
Sandstone, yellow, consolidated.....	5
Sandstone, red, hard.....	6
Shale, dark gray, with "cannonball" concretions.....	25
Shale, very dark gray, very sandy, with a layer of marine shells 20 feet from base and with "cannonball" concretions.....	103
Base concealed.	
	<hr/> 144 6

The top of the above section lies approximately 50 feet below the top of the member. Although not complete, the section is fairly representative and shows that the Cannonball member in the type locality is composed predominantly of dark sandy shale or shaly sandstone, with a subordinate amount of dark-yellow and gray sandstone commonly occurring in lenticular beds. Similar sections are exposed at other places along Cannonball River and in the bluffs of Cedar Creek and Heart River. Some of the beds of sandstone near the top of the member are very calcareous and contain also a considerable amount of feldspar, biotite, and pyroxene. Over the greater part of the area where the Cannonball member comes near the surface it is concealed by a heavy soil mantle, and in such places the sandstone appears relatively more prominent owing to its greater resistance to erosion.

In the Cannonball River field several collections of marine invertebrate fossils, made from the Cannonball member during the field seasons of 1912 and 1913, have been identified by T. W. Stanton as belonging to a modified Fox Hills fauna.

TERTIARY SYSTEM.

FORT UNION FORMATION.

The Fort Union formation is exposed in the western and north-western parts of the Cannonball River field. The thickness of that part of the formation which outcrops in the field is about 350 feet, but this is only a part of the original thickness of the lignite-bearing rocks of this age which at one time covered the entire region. The lower 100 feet of the formation is made up almost wholly of unconsolidated and partly consolidated yellow and gray sandstone and has previously been included in the Lance formation.¹ The material appears to be of fresh-water origin, however, and for that reason should be included in the Fort Union rather than in the underlying member of the Lance, which is of marine origin.

The higher strata of the Fort Union consist of massive yellow and white sandstone, clay shale, brown and black carbonaceous shale, and lignite. The sandstone is most prominent because of its greater resistance to erosion, but clay shale and carbonaceous shale probably make up more than half of the formation. The sandstone is for the most part unconsolidated, but locally cementation has produced

¹ Leonard, A. G., The Cretaceous formations of western North Dakota and eastern Montana: Jour. Geol.ogy, vol. 19, pp. 507-547, 1911.

resistant ledges which support the flat-topped buttes and plateaus or stand out as rugged hills on an otherwise smooth prairie. In most places the cementation of the sandstone proceeds outward from a center in disklike form with the short axis vertical. Where the process is not far advanced, the individuals appear in a section as lenticular concretions arranged along more or less definite horizons. At a later stage these individuals coalesce to form a ledge of hard sandstone.

A peculiar surface feature of the Fort Union, and to some extent of the underlying Lance formation, is the abundance of angular and wind-worn blocks or boulders of a very hard quartzitic rock. These boulders are in general confined to the higher buttes, over many of which they are strewn so thickly as to make the surface almost impassable for a horse. In general, the boulders on the lower buttes are neither so large nor so numerous, but they are scattered over small hillocks far down in the Lance formation. They are commonly absent over the greater part of the flat prairies and in the valleys. All these boulders are residual remnants from two or more comparatively thin beds in the Fort Union which have been found in place near the tops of several high buttes. The material is very fine grained, composed chiefly of angular or slightly rounded quartz grains, and contains an abundance of silicified plant stems of various sizes, which have in many places weathered out, leaving the rock full of holes.

The age of the Fort Union is attested by three collections of fossil leaves, all of which are typical Fort Union species.

WHITE RIVER FORMATION.

The outcrop of the White River formation in this field is limited to the tops of three high buttes in the northern part of T. 131 N., R. 90 W., and the southern part of T. 132 N., R. 90 W. The formation consists of about 50 feet of calcareous arkosic sandstone overlying a marly limestone, both of which are referred to the formation on faunal and lithologic evidence.

STRUCTURE.

A comparison of the altitudes of the lignite beds at various places, determined during the field work of 1912, shows that the strata have a general but very slight dip to the north or northeast in the northern and western parts of the field and to the north and northwest in the southern and eastern parts. This dip averages about 15 feet to the mile, which is nearly one-sixth of 1°. There is little evidence at hand on which to base a general conclusion concerning the attitude of the beds in the part of the field examined in 1913. In that portion which is shown on Plate XIV (p. 290), the general dip is probably to the north and northwest. The region has apparently not been disturbed by any orogenic movements, with the exception of a probable slight tilting to the northeast and an uplift relative to sea level which has brought it under the influence of erosional rather than of depositional agencies.

THE LIGNITE.

DISTRIBUTION.

The beds of lignite at the top of the lower portion of the Lance formation are so thin that they will probably never be of value except to a slight extent for local use. In the Cannonball River field no lignite beds are known in the Cannonball marine member of the Lance formation. The valuable beds are confined to the upper 250 feet of that part of the Fort Union formation which is exposed in the field. Owing to the heavy mantle of soil which obscures the strata over the greater part of the area, conclusive correlations of the lignite beds exposed at widely separated points can not be made.

After the deposition of the lower sandstone of the Fort Union in this region it seems evident that marsh conditions set in over wide areas, and that in these independent or semi-independent swamps vegetal matter was accumulating throughout the field during approximately the same period of time. This condition led to the formation of lignite on this surface, possibly as one continuous bed throughout the field, but more probably as a series of isolated lenses which are at or very near the same horizon. In the following discussions the lowest important lignite bed in all parts of the field, except in the valley of Cannonball River in T. 133 N., R. 30 W., is called the Haynes lignite bed, although it is possible that beds are thus included under one name which are not continuous with one another or which were not even deposited synchronously. All the evidence in hand, however, indicates that the bed, although varying greatly in thickness, was once practically continuous over at least the greater part of the field. It is therefore believed to be probably present under all the area from which it has not been removed by erosion.

The Haynes lignite bed reaches its greatest known thickness under a range of high buttes north of the town of Haynes in T. 129 N., R. 94 W. In this locality the bed is 11 to 13 feet thick and is being mined extensively for local use. Farther north and east, between Duck and Cedar creeks, in T. 130 N., R. 94 W., the 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 consequently exposures of the bed are practically confined to the places at which it has been mined. The greatest known thickness, 10 feet, in this part of the area is at the Merry mine, in T. 132 N., R. 93 W., half a mile north of the border of the field. From this place 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 on 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. It seems that there are in this locality two beds from 3 to 6 feet thick, the lower of which is 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 thick. 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 adjoining 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 and bone (sections 95, 96, and 97, Pl. XIII, p. 282). 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 (section 98, Pl. XIII). 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 (section 138, Pl. XIII) 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 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.

North of Cannonball River, in the neighborhood of the towns of Leith, Heil, and Kaiser, there are two lignite beds, the lower and more important of which is being mined near Leith in shaft and drift mines and at other places in strip pits. 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. The vertical distance between the beds is approximately 40 feet. In the northwestern part of T. 135 N., R. 88 W., two beds, separated by about 30 feet of shale and sandstone, are being mined in small strip pits. Each bed is about 3 feet thick.

In addition to the lignite beds mentioned above, a few other beds less than 2½ feet thick outcrop in various parts of the field. These will be mentioned in the individual township descriptions given on pages 263-291.

PHYSICAL PROPERTIES.

The lignite of the Cannonball River field is similar in general character to that from other parts of North Dakota. It is very dark brown, almost black, but the powder is brown. Most of the fresh lignite has a dull luster, and much of it a tough woody texture. Detailed examination of the more woody parts shows some variations in texture, color, and luster. Small lenses of bright black lignite, ranging in thickness from a thin film up to an inch or more, alternate with the dark-brown material, which has not nearly so bright a luster. Both these varieties retain in places the fibrous character of the wood from which they were derived. In other varieties the luster is duller, the woody texture is lacking and the lignite contains a large percentage of noncombustible material or ash. Some of the lignite is of a hard black variety with well-developed cleavage similar to the subbituminous coals of eastern Wyoming and Montana.

On exposure to the air lignite loses a considerable part of its moisture, shrinks, and soon falls to pieces, a characteristic which makes shipping in open cars to distant markets almost impossible and which is proving a serious handicap in the development of the mining industry. The breaking up or checking begins almost immediately when fresh lignite is exposed to the air. The cracks on the surface are nearly at right angles, so that the small blocks which scale off are roughly cubical in form. In the best quality of 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. Where the woody texture is not developed much of the lignite weathers into thin laminæ parallel to the bedding plane. The weathering of different varieties of lignite is so characteristic that often an examination of the weathered face of an exposed section will afford a better conception of the variations in character within the bed than will an examination of the fresh material itself.

CHEMICAL COMPOSITION.

In order to ascertain the chemical composition of coal or lignite, it is necessary that samples taken for analysis be as fresh as possible. For this reason the samples from the Cannonball River field were taken only in drift and shaft mines and not from strip pits. Four such samples were collected in accordance with the regulations of the United States Geological Survey, which in brief are as follows: In a clean, fresh face a channel is cut perpendicularly from roof to floor, discarding partings which are thrown out in mining. The material thus obtained is broken to pass through a half-inch screen and the sample is reduced by quartering to about 1 quart, which is placed in a galvanized can, sealed, and sent immediately to the laboratory. The samples were analyzed in the chemical laboratory of the Bureau of Mines at Pittsburgh.

The analyses of these samples are presented in the accompanying table. With them are included for comparison the analyses of three samples collected by A. L. Beekly in 1909 from small strip pits in the valley of Cedar Creek in T. 129 N., R. 88 W., and also the analyses of four representative samples of lignite from producing mines in widely separated parts of North Dakota.

In the table the analyses are given in four forms, marked A, B, C, and D. Analysis A represents the composition of the sample as it comes from the mine. This form of analysis is not well suited for the comparison of one coal with another because the amount of moisture in the sample as it comes from the mine is largely a matter of accident, and consequently analyses of different samples of the same coal expressed in this form may vary widely. Analysis B represents the sample after it has been dried at a temperature a little above the normal until its weight becomes constant. This form of analysis is best adapted to the general purposes of comparisons. Analysis C represents the coal after all the moisture has been eliminated. Analysis D represents the coal after all moisture and ash have been theoretically removed. This is supposed to represent the true coal substance, free from the most significant impurities. Forms C and D are obtained from the others by recalculation.

In the analytical work chemists generally recognize that it is not possible to determine the proximate constituents of coal or lignite with the same degree of accuracy as the ultimate constituents. Therefore, the air-drying loss, moisture, volatile matter, fixed carbon, and ash are given to one decimal place only. In an ultimate analysis the ash, sulphur, hydrogen, carbon, nitrogen, and oxygen are given to two decimal places. It is also understood that calorific determinations to individual units are not reliable; therefore, in the column headed "Calories" the heat values are given to the nearest five units, and in the column headed "British thermal units" they are given to the nearest ten (the value of a British thermal unit being about one-half that of a calorie).

Analyses of lignite samples from the Cannonball River and neighboring fields, North Dakota.

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

Laboratory No.	Name.	Location.				No. on map (Pl. XIII).	Air-drying loss.	Form of analysis.	Proximate.				Ultimate.						Heating value.	
		Quarter.	Sec.	T. N.	R. W.				Moisture.	Volatile matter. ^a	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	Calories.	British thermal units.	
14542	Nipper & Monroe mine, near Haynes, N. Dak.	NW.	16	129	94	4	14.5	A B C D	32.6 21.2	30.6 35.8 45.4 51.8	28.5 33.3 42.3 48.2	8.3 9.7 12.3	1.53 1.79 2.27 2.59	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	4,085 4,780 6,070 6,920	7,360 8,600 10,920 12,460
14544	Pinkham mine, 9 miles north-east of Haynes, N. Dak.	NW.	36	130	94	8	15.3	A B C D	32.4 20.2	30.9 36.5 45.7 52.4	28.1 33.2 41.6 47.6	8.6 10.1 12.7	1.49 1.76 2.21 2.53	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	4,070 4,805 6,025 6,900	7,330 8,650 10,850 12,420
14729	Jones mine, near Leith, N. Dak.	SE.	12	133	88	152	27.1	A B C D	36.2 12.5	29.8 40.8 46.7 54.0	25.3 34.8 39.7 46.0	8.70 11.93 13.63.....	.68 .93 1.07 1.24	6.76 5.15 4.29 4.97	39.45 54.11 61.81 71.56	0.59 .81 .92 1.07	43.82 27.07 18.28 21.16	3,720 5,105 5,830 6,750	6,700 9,190 10,500 12,150
17537F	Kolbank mine, near Leith, N. Dak.	NE.	7	133	87	188	16.6	A B C D	34.7 21.7	29.9 35.8 45.7 54.5	24.9 29.9 38.2 45.5	10.5 12.6 16.1	1.50 1.80 2.30 2.74	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	3,775 4,530 5,785 6,895	6,800 8,150 10,410 12,410
7841	Mine of A. L. McCord, on Cedar Creek, N. Dak.	NE.	5	129	88	139	19.3	A B C D	32.1 15.8	25.6 31.8 37.8 44.8	31.7 39.2 46.6 55.2	10.6 13.2 15.6	1.19 1.48 1.75 2.07	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	3,790 4,695 5,580 6,615	6,820 8,460 10,040 11,910
7839	Surface prospect on Cedar Creek, N. Dak.	SW.	1	129	88	.....	21.1	A B C D	33.1 15.2	25.5 32.4 38.2 41.5	36.1 45.7 53.9 58.5	5.3 6.7 7.9.....	.69 .87 1.03 1.12	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	4,150 5,255 6,200 6,735	7,470 9,460 11,160 12,120
7842	Surface prospect on Cedar Creek, N. Dak.	SE.	4	129	88	.....	23.1	A B C D	32.5 12.2	27.1 35.3 40.1 43.9	34.6 45.0 51.3 56.1	5.8 7.5 8.6.....	.37 .48 .55 .59	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	..... ..... ..... .....	4,030 5,240 5,965 6,525	7,250 9,430 10,740 11,750

1935	Mine of Washburn Lignite Coal Co., Wilton, N. Dak.		1	142	80	32.3	A	40.5	27.1	27.4	5.0	.76					3,690	6,640
							B	12.2	39.9	40.4	7.5	1.12					5,450	9,810
							C		45.5	46.0	8.5	1.28					6,205	11,170
							D		49.7	50.3		1.40					6,780	12,210
1971	Mine of Consolidated Coal Co., Lehigh, N. Dak.		8	139	95	35.6	A	42.1	24.5	25.7	7.7	1.13					3,420	6,160
							B	10.0	38.1	40.0	11.9	1.75					5,310	9,560
							C		42.4	44.4	13.2	1.95					5,905	10,630
							D		48.8	51.2		2.25					6,805	12,250
12533	Mine of United States Reclamation Service, 3 miles north-east of Williston, N. Dak.		7	154	100	33.2	A	43.9	24.9	25.4	5.8	.49					3,300	5,940
							B	16.0	37.2	38.1	8.7	.73					4,940	8,890
							C		44.3	45.3	10.4	.87					5,875	10,580
							D		49.5	50.5		.97					6,555	11,800
14485	Scranton mine of Charles Liddell, Scranton, N. Dak.	SW.	24	131	100	22.5	A	34.8	31.1	26.0	8.1	.66					3,840	6,920
							B	15.9	40.1	33.5	10.5	.85					4,960	8,920
							C		47.7	39.8	12.5	1.01					5,890	10,610
							D		54.5	45.5		1.15					6,730	12,120

* Volatile matter in analyses 14542, 14544, 14729, 17537F, 12533, and 14485 was determined by the modified official method. See Bu. Mines Bull. 22, p. 2, 1913.

Laboratory No. 14542.—Sample from the Haynes lignite bed, Fort Union formation, in the Nipper & Monroe mine, $3\frac{1}{2}$ miles northeast of Haynes, collected in regular manner by E. R. Lloyd on July 30, 1912. Sample taken in entry about 630 feet nearly due east from the mine mouth. The thickness of the bed at this point is about 12 feet, of which the lower 8 feet 3 inches is being mined and was sampled.

Laboratory No. 14544.—Sample from the Haynes lignite bed, Fort Union formation, in mine of William Pinkham, about 9 miles northeast of Haynes, collected in regular manner by E. R. Lloyd on July 30, 1912. Sample taken in main entry about 225 feet south from the mine mouth. The thickness of the bed is about 12 feet, of which the lower 8 feet 10 inches is being mined and was sampled (section 8, Pl. XIII, p. 282.)

Laboratory No. 14729.—Sample from the Haynes (?) lignite bed in the Jones mine of J. T. Dunn, about 2 miles west of Leith, collected in the regular manner by E. R. Lloyd on September 7, 1912. Sample taken in a room about 75 feet southwest from the mine shaft. The thickness of the bed is about 8 feet 6 inches, of which the lower 5 feet 6 inches is being mined and was sampled (section 152, Pl. XIII).

Laboratory No. 17537F.—Sample from the Haynes (?) lignite bed in the Kolbank mine of Simon Pederson, about $1\frac{1}{2}$ miles southwest of Leith, collected in regular manner by E. R. Lloyd on July 10, 1913. Sample taken in room about 70 feet south of the mine mouth. The thickness of the bed at the mouth is 7 feet 9 inches, of which the lower 4 feet 10 inches is being mined and was sampled (section 188, Pl. XIV, p. 290.)

Laboratory No. 7481.—Sample from a bed of lignite in the Lance formation, in the McCord mine (strip pit) on the north side of Cedar Creek, in the NE. $\frac{1}{4}$ sec. 5, T. 129 N., R. 88 W., about 8 miles northeast of Morristown, S. Dak., collected in regular manner by A. L. Beekly in 1909. The bed has a thickness of 2 feet 2 inches, all of which was sampled. The sample was necessarily somewhat weathered, but represents fairly well the character of the lignite.

Laboratory Nos. 7839 and 7842.—Samples collected in regular manner by A. L. Beekly in 1909 from prospect pits on the south side of Cedar Creek, T. 129 N., R. 88 W. They are from the same bed as sample No. 7481 and are also slightly weathered.

Laboratory No. 1935.—Sample from a lignite bed in the Fort Union formation from mine of Washburn Lignite Coal Co., Wilton, McLean County, N. Dak., collected in regular manner by M. R. Campbell on August 3, 1905, at a distance of 1,750 feet from shaft. The thickness of the bed at this point is 9 feet 6 inches, of which the lower 6 feet 6 inches was sampled.

Laboratory No. 1971.—Sample from a lignite bed in Fort Union formation in mine of Consolidated Coal Co., at Lehigh, Stark County, N. Dak., collected in regular manner by M. R. Campbell on August 5, 1905, at a distance of 1,900 feet from the mine mouth. The thickness of the bed at this point is 6 feet 4 inches, of which the lower 5 feet was sampled.

Laboratory No. 12533.—Sample from a lignite bed in Fort Union formation, from mine of United States Reclamation Service, 3 miles northeast of Williston, Williams County, N. Dak., collected in regular manner by F. A. Herald on August 16, 1911, at a distance of 1,225 feet east from the mine mouth. The thickness of the bed at this point is 10 feet 3 inches, of which the lower 8 feet was sampled.

Laboratory No. 14485.—Sample from Harmon (?) lignite bed, Fort Union formation, from the Scranton mine of Charles Liddell, Scranton, Bowman County, N. Dak., collected in regular manner by C. J. Hares on June 30, 1912, from face of east entry 1,000 feet from mine mouth. The total thickness of the bed is 20 feet $3\frac{1}{2}$ inches. The sample represents 6 feet near the middle of the bed.

In a general way the comparative values of the lignite from different mines and different beds can be obtained from the heating values of the air-dried sample (form B of analysis). In the analyses from

the Cannonball River field, however, this criterion is at fault. In three of these analyses, the first, second, and fourth given in the above table, the air-drying loss is comparatively small, which is probably due to the slightly weathered condition of the lignite sampled. As a result, the other sample—the third in the table—gave a much higher heating value in the air-dried form of analysis, although it has a lower heating value in all the other forms. The results of the three analyses of lignite beds in the Lance formation must be considered as of comparatively little value on account of the weathered condition of the samples. They suggest, however, that the Lance lignite is probably of a little higher grade than that from the Fort Union.

In all lignites the percentage of moisture is very high. On exposure to air a considerable part of this moisture is evaporated and a resultant shrinkage takes place, causing the lignite to check or break up into small pieces. The percentage of sulphur represented in the analyses is higher than in the lignites of some portions of the plains basins, but it is not so high as in other regions. It occurs in the form of nodules or balls of pyrite or marcasite distributed along both joint and bedding planes.

In the analyses of samples from the Cannonball River field, and in some of the others given in the above table, the volatile matter was determined by a new or modified method. This method involved a preliminary heating of the lignite before subjecting it to a temperature high enough to drive off the volatile matter. In the standard method the higher heat is applied at once, a process which when applied to lignite is apt to cause sputtering with attendant mechanical loss of particles of the sample. This loss affects chiefly the fixed carbon, so that when the modified method is used the determined percentage of that constituent is generally higher, in some analyses as much as 20 per cent.

In addition to the careful analyses made by the Bureau of Mines a number of supplementary chemical tests were made with a small portable outfit during the progress of field work. These tests were made in order to determine in a number of samples the percentage of moisture set free on air drying and the percentage of noncombustible material or ash. This work was done by C. E. Leshner, of the United States Geological Survey, in September, 1912. The samples were all taken in the west-central part of the field. The most important results of these tests are presented in tabular form on page 260:

Tests on lignite samples from the Cannonball River lignite field.

[Made by C. E. Leshner, September, 1912.]

No.	Name.	Location.			Location on map (Pl. XIII).	Air-drying loss.	Form of analysis. ^a	Proximate.				Color of ash.	Luster, weathering, and other characters.
		Sec.	T. N.	R. W.				Moisture.	Volatile matter.	Fixed carbon.	Ash.		
1	Kelch's strip pit.....	4	132	91	93	21	B	10	.34	40	16	.....	Total thickness of bed, 64 inches. Lignite, partly weathered.
2	Compton's strip pit.....	10	133	90	111	.....	A	.....	.....	.....	16.5	Yellow....	Dull, platy, from fresh surface 18 inches back from face.
3	do.....	10	133	90	111	.....	A	.....	.....	.....	10	Red.....	Dull, platy, from weathered surface.
4	do.....	10	133	90	111	.....	A	.....	.....	.....	4.5	Yellow....	Bright, massive, conchoidal, from fresh surface 18 inches back from face.
5	do.....	10	133	90	111	.....	A	.....	.....	.....	5	White.....	Bright, massive, conchoidal, from weathered surface.
6	do.....	10	133	90	111	.....	B	.....	.....	.....	12	.....	Hard to burn off. Mineral charcoal.
7	Delebar's strip pit.....	15	133	90	107	.....	A	.....	.....	.....	3	White.....	Woody, fibrous material.
8	do.....	15	133	90	107	.....	A	.....	.....	.....	23.5	.....	Dirty parting, dull, dry.
9	do.....	15	133	90	107	33	B	.....	.....	.....	14	Gray.....	Soft black material, weathered.
10	Well.....	32	133	90	99	29	B	3.5	46	36	14	.....	From well under water.
11	Coffin Butte strip pit...	34	132	90	98	21	B	.....	.....	.....	7.5	.....	Upper bench of bed. Good lignite.
12	do.....	34	132	90	98	21	B	.....	.....	.....	14	.....	Lower bench of bed. Lignite 2 feet 3 inches, shale 1 inch.
13	do.....	34	132	90	98	32	B	.....	.....	.....	2.5	Red.....	Good lignite.
14	do.....	34	132	90	98	11	B	.....	.....	.....	54.5	.....	Parting, sandy.
15	Strip pit.....	26	133	90	104	32	B	.....	.....	.....	6	.....	Weathered top of bed appears very dirty.
16	do.....	26	132	91	65	38	B	.....	.....	.....	23	.....	Carbonaceous material with thin streaks of good lignite, weathered.
17	do.....	27	132	90	97	44	B	.....	.....	.....	23	Red.....	Very soft, weathered at top of bed.
18	do.....	33	132	91	55	15	B	.....	.....	.....	50	White....	Parting, bone.
19	Jones mine.....	12	133	88	152	11	B	.....	.....	.....	33	.....	Bone.
20	do.....	12	133	88	152	23	B	.....	.....	.....	32.5	.....	Lignite (?).
21	do.....	12	133	88	152	33	B	.....	.....	.....	13	.....	Standard sample. Chemical Laboratory No. 14729.

^a A indicates sample as taken from mine; B indicates air-dried sample.

The results of these tests, which were purposely made on material of all grades of purity, are particularly important for reference during the course of field work, as the most variable element in the North Dakota lignites is the amount of ash. For purposes of land classification it is assumed arbitrarily that lignite or coal does not contain over 33 per cent ash. If the percentage is higher and the material otherwise similar, it is called bone. The work carried on by Mr. Leshar was particularly efficacious in determining the character of material which lies near this border line. For example, Nos. 8, 9, 16, and 17 represent finely divided material the value of which could not be told owing to the much weathered state in which it was found. The tests, however, showed that the ash content of all four samples is below 33 per cent and that in one, No. 9, it is sufficiently low to class the material as high-grade lignite. Nos. 19 and 20 represent a parting which in the mine examination was classed as bone. The analyses showed it to be at the dividing line. Two samples, Nos. 7 and 13, were selected fragments of the best quality of lignite and show that the minimum amount of ash in lignite is about 2.5 per cent.

MINING DEVELOPMENT.

At the times of the examination (1912 and 1913) there were only two important mining districts in the Cannonball field, one in T. 129 N., R. 94 W., north of Haynes, and the other in T. 133 N., Rs. 87 and 88 W. Strip pits have also been opened and lignite taken out for local use in nearly all parts of the field. In the Haynes district, T. 129 N., R. 94 W., the lignite underlies a high narrow ridge and is 11 to 13 feet thick. Five drift mines have been opened and supply the local trade for 15 or 20 miles to the east and south. A small quantity of lignite is hauled in wagons to Haynes and shipped on the railroad. The two largest mines are the Nipper & Monroe mine in sec. 16 and the Brown mine of the Haynes Coal & Mining Co. in sec. 8, both of which are shipping mines. Two other mines, the Stephenson & Gunderson, in sec. 15, and the mine of the Claremont Coal Co., in sec. 16, depend chiefly on the local demand. At the Farmers mine of the Haynes Coal Association, in sec. 9, mining has been done both by stripping and by drifting, but the mine was not in operation at the time of examination in August, 1912. In the vicinity of Leith there are two important mines, one a drift mine, in sec. 7, T. 133 N., R. 87 W., which is owned by Simon Pederson, and the other a shaft mine, in sec. 12, T. 133 N., R. 88 W., owned by John T. Dunn. Although neither of these is a shipping mine, they supply a large local demand. The main lignite bed in this locality varies considerably in thickness, reaching a maximum of about 8 feet 6 inches.

In sec. 36, T. 130 N., R. 94 W., a small drift mine, operated by William Pinkham, supplies the local demand. All these mines, except that of Simon Pederson, are dry, but the lignite on analysis

shows the characteristically high moisture content. At all of these places only the lower part of the bed is mined, as the shale or clay shale overlying the lignite is too weak to serve as a roof, and 2 or 2½ feet of lignite must be left for that purpose.

The lignite in nearly all the mines is shot from the solid, a very wasteful method, in which nearly a third of the lignite is broken in small fragments and left in the mine. This method of mining is particularly inexcusable in the Haynes district, where the supply of lignite is very limited. The writer estimated that over one-half of the bed was being wasted or rendered useless by this practice.

In all parts of the field lignite is obtained for local use by stripping off the surface material near the outcrop. Although the labor involved in this process is comparatively great it seems to be at present the most economical method of supplying the local demand, except where the bed is 6 or 7 feet thick. The bottoms of most of these strip pits are filled with water, which is one of the most serious obstacles to this method of mining.

The most extensive stripping examined is the Merry mine in sec. 34, T. 132 N., R. 93 W., half a mile north of the boundary of the field. Here the lignite bed has a thickness of 10 feet, and the pit is easily drained. Mining at this point, however, could be carried on more profitably by a drift.

Some of the difficulties affecting mining have already been mentioned. Many of the lignite beds, which are commonly inclosed by beds of relatively impervious shale, form channels for underground water, which issue at the outcrop as springs. It will in general, therefore, be necessary that drift mines be opened on north or northeast slopes so that the entries follow the slight but general rise of the beds, which is to the southwest, and which it is believed will be sufficient to furnish natural drainage.

The most serious drawback to mining in this field is the character of the overlying shale or clay shale, which is so weak that it can not be used as a roof, so that part of the top of the bed must be left for this purpose. For this reason only the thicker beds can at present be mined, except by surface stripping.

The lignite is at present used generally for domestic purposes and to some extent for steaming. The low grade of the fuel and its extremely poor stocking qualities render it unfit for shipping in open cars, so that development for some years at least will be governed by the local demand. Experiments made by the Bureau of Mines at Pittsburgh¹ and by the experiment station of the North Dakota School of Mines² have proved that the North Dakota lignites can be

¹ Wright, C. L., Briquetting tests of lignite at Pittsburgh, Pa., 1908-9, Bu. Mines Bull. 14, 1911.

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

made into briquets at a cost which would place them on the market in favorable competition with high-grade coals.

DESCRIPTION BY TOWNSHIPS.

The following description of the Cannonball lignite field deals with township units, beginning with T. 129 N., R. 95 W. The ranges are described in order from west to east and in each range the townships are considered from south to north. The townships shown on Plate XIII (p. 282) are described first.

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

T. 129 N., R. 95 W.

The surface of T. 129 N., R. 95 W., is a broad rolling prairie interrupted by a few prominent sandstone-capped buttes. Flat Creek flows eastward across the central part of the township and drains the greater part of its area. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the central part of the township in an east-west direction. Hettinger is situated on that road in sec. 13 of the township adjoining on the west. All the rocks exposed in the township belong to the Fort Union formation. The highest land is in the northeastern part, in secs. 1 and 2, where a high rounded ridge strewn with quartzitic boulders extends westward from T. 129 N., R. 94 W.

The principal lignite bed of the region, to which the name Haynes lignite bed is applied, underlies the ridge in secs. 1 and 2, its presence being shown at a few points by mounds of red clinker and by black dust or "blossom" at the surface. Otherwise it is concealed, and no measurement of its thickness could be made nearer than the mine of the Haynes Coal Co., in sec. 8, T. 129 N., R. 94 W., where it is 13 feet thick. A thin bed of lignite at a lower horizon underlies some of the buttes in the southern part of the township and was measured at locations 1 and 2 in secs. 25 and 28, where thicknesses of 1 foot 7 inches and 1 foot 4 inches, respectively, were found.

T. 129 N., R. 94 W.

The most prominent topographic feature of T. 129 N., R. 94 W., is a high rounded ridge extending from sec. 6 southeast into sec. 22. The surface slopes gradually away from this divide to the valleys of Duck Creek on the north and Flat Creek on the south. South of Flat Creek, along the southern border of the township, there is a

series of prominent buttes capped with 30 to 40 feet of resistant sandstone. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southern part of the township in a southeast-northwest direction. The town of Haynes is located on that road in sec. 29.

The rocks that outcrop in the township belong to the Fort Union formation except in a part of the valley of Flat Creek, where the upper part of the Cannonball marine member of the Lance formation appears at the surface.

The most important bed of lignite in the Cannonball River field, the Haynes bed, underlies the high ridge in the northwest-central part of the township. It is being mined in four drift mines in secs. 8 (location 3), 15 (location 6), and 16 (locations 4 and 5). A fifth mine in sec. 9 (location 7) was not in operation in the summer of 1912. Except for a few small mounds of reddened clinker there is no surface indication of this bed, and it was first found in a well in the SW. $\frac{1}{4}$ sec. 9. All five of the mines lie within a radius of less than a mile and show little variation in the character of the lignite or the thickness of the bed, which ranges from 10 feet in the Stephenson & Gunderson mine (location 6, Pl. XIII, p. 282) to 13 feet in the Brown mine (location 3). The tops of the hills south of the village of Haynes are at about the altitude of this bed, but owing to the dip of the strata are stratigraphically lower, and the bed is therefore not present in that locality. A sample for chemical analysis was obtained from the Nipper & Monroe mine (location 4), the results of which are shown in the table on page 16. Sections measured in two of the mines are shown in Plate XIII (locations 5 and 6).

T. 130 N., R. 94 W.

The surface of T. 130 N., R. 94 W., is for the most part rolling prairie, interrupted by a number of prominent buttes in the eastern and central parts of the township. All the outcropping strata belong to the lower 200 feet of the Fort Union formation. The high buttes are underlain by the Haynes lignite bed, but the lignite has been burned extensively and much of the neighboring surface is strewn with blocks of reddened clinker or with small mounds of the same material. In only a few of the larger buttes is the lignite preserved unburned.

Two mines are in operation in the township, one a strip pit in sec. 3 (section 9, Pl. XIII), now partly filled with water, and the other a drift mine operated by William Pinkham, in the NW. $\frac{1}{4}$ sec. 36 (section 8, Pl. XIII). The lower part of the bed in the strip pit at location 9 could not be examined, but the thickness is reported to be 13 feet; it is separated by 2 feet 4 inches of shale from a 2-foot bed of impure lignite above. At location 8 the main bed is reported to be 12 feet thick and the upper bed 1 foot 6 inches thick. A sample of the

lower 8 feet 10 inches of the bed was obtained from this mine, the analysis of which is given in the table on page 256.

T. 129 N., R. 93 W.

The greater part of T. 129 N., R. 93 W., is drained by Duck Creek, which flows eastward across the north-central part. The rolling prairie, which is characteristic of most of the township, is interrupted by numerous prominent buttes, many of which are capped by a resistant sandstone. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southern part of the township in an east-west direction. The town of Petrel lies in sec. 35, and White Butte post office, S. Dak., is a few hundred feet south of the south line of sec. 31. The rocks belong to the lower 200 feet of the Fort Union formation and to the upper part of the Cannonball marine member of the Lance formation. The tops of the highest buttes in secs. 4 and 25 are capped with reddened clinker, showing the former presence of a bed of lignite, which is now entirely burned out. This bed was presumably the Haynes lignite bed.

T. 130 N., R. 93 W.

Cedar Creek flows southeast across the central part of T. 130 N., R. 93 W., and drains the entire area of the township. All the rocks belong to the Fort Union formation except those in a small area in the creek valley in the southeastern part of the township, where the upper beds of the Cannonball marine member of the Lance formation are exposed.

The Haynes lignite bed outcrops near the tops of a few high rocky buttes in secs. 30, 31, and 32. In this locality it has been extensively burned, however, and probably only a very small quantity of lignite remains. A bed of lignite, presumably also the Haynes, underlies the low hills in the northeastern corner of the township. It is for the most part concealed at the outcrop, and surface indications were found at only two places. At the Maire mine, in the SE. $\frac{1}{4}$ sec. 1 (location 11), some lignite has been removed by stripping the overlying surface material. The bed at this place has a thickness of about 7 feet, part of which is under water. At the other locality, in the SE. $\frac{1}{4}$ sec. 2 (location 10), only some weathered lignite and ashes are exposed on the surface.

T. 131 N., R. 93 W.

A series of high rocky buttes, the divide between Cedar Creek and Timber Creek, extends across T. 131 N., R. 93 W., in a general north-west-southeast direction. On either side of this divide the surface slopes gently downward toward the valleys of the two streams. The higher buttes are strewn with large quartzitic boulders, and practi-

cally the whole area is grass covered. All the rocks belong to the Fort Union formation, but exposures are in general poor.

At least one bed of lignite underlies the central part of the township and is correlated with the Haynes bed. Its outcrop, as shown on the map (Pl. XIII), is located as accurately as the available data would permit. Farther east, in T. 131 N., R. 92 W., two other beds have been found, one about 50 feet and the other nearly 150 feet higher in the section. As the hills in T. 131 N., R. 93 W., rise nearly 200 feet above the level of the Haynes coal, it is probable that one or both of these higher beds are present in the township but are concealed.

The Haynes bed was examined at a few places in this township and surface indications were found at several other places. In the SW. $\frac{1}{4}$ sec. 5 (location 12) a strong spring issues from a bed of lignite, which is probably the Haynes bed. No measurement, however, was made and no evidence was obtained with regard to the bed from that place to the southeast as far as sec. 28, where, on the west side of the hill, there is a small but prominent mound of clinker. At the south end of the same hill a section was measured (location 13), but only 1 foot 4 inches of weathered lignite and ash was found. Two other sections were measured south of the ridge, one in the SW. $\frac{1}{4}$ sec. 27 (location 14) and the other near the west quarter corner of sec. 35 (section 15, Pl. XIII, p. 282). The thicknesses measured at these places were 5 feet 6 inches and 5 feet 5 inches, respectively, but at both places the top of the bed was slightly burned. Small mounds of clinker at a few places in sec. 34 show where the bed has been burned at the outcrop. North of the divide, in the SE. $\frac{1}{4}$ sec. 12 (location 16) weathered lignite was reported in a well, and on a small stream near the center of sec. 13 (location 17) 1 foot 2 inches of the base of the bed was found, but the upper part had been eroded away. At Olsen's mine, in the SW. $\frac{1}{4}$ sec. 11 (location 18), the greater part of the bed is under water. Mr. Olsen reports that there is 3 feet of good lignite, and the writer has estimated that the weathered and burned material above represents at least 2 feet more. The bed was found in a well in the NW. $\frac{1}{4}$ sec. 2 (location 19), but the thickness is not known. Half a mile north of the township line, at Merry's mine, in sec. 34, T. 132 N., R. 93 W. (section 20, Pl. XIII), the bed has a thickness of 10 feet, all of which is good lignite. A considerable amount of lignite has been removed for local use.

T. 129 N., R. 92 W.

The most prominent topographic feature in T. 129 N., R. 92 W., is a series of high rocky buttes in the east-central part of the area, which were known to the early explorers in the region as Les Belles Pierres Hills from the abundance of colored pebbles scattered over their tops. North of the hills the slope is steep, but to the south it is comparatively gradual down to the rolling prairie country around

Lemmon, S. Dak. The drainage is to the north toward Cedar Creek. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southern part of the township in an east-west direction. Lemmon is located on that road at the State line south of sec. 35.

The rocks that outcrop in most of this township belong to the Fort Union formation, but in the valleys of Duck Creek and a small creek in sec. 2 the upper part of the Cannonball marine member of the Lance formation is exposed.

The horizon of the Haynes lignite bed lies from 75 to 100 feet below the tops of the higher hills, but no evidence of any bed of lignite more than a few inches in thickness could be found in the township.

T. 130 N., R. 92 W.

Cedar Creek flows eastward across the southern part of T. 130 N., R. 92 W., and drains its entire area. South of the stream the surface rises steeply toward Les Belles Pierres Hills, but to the north the slope is much more gradual. The rocks belong to the upper part of the Cannonball marine member of the Lance formation and to the Fort Union formation, the former outcropping only in the valley of Cedar Creek. The Cannonball member is well exposed in the bluffs of the creek, but the Fort Union is for the most part concealed by a heavy mantle of soil. The high hills along the north border of the township are almost covered with large residual blocks of quartzitic material, a bed of which, apparently in place, forms the top of Spring Butte in sec. 4.

A lignite bed, which is believed to be the Haynes bed, underlies the higher land in the northern part of the township, but its outcrop is for the most part concealed. On the southwest side of Spring Butte, in sec. 4 (location 21), the bed has been mined to some extent for local use, but the bottom of the pit is now under water. At this place 4 feet 5 inches of lignite is exposed. On the other side of Spring Butte, also in sec. 4, is the Spring Butte strip pit (location 22) in which 4 feet of lignite is exposed above the water in the bottom of the pit. The measurements obtained in strip pits in T. 131 N., R. 92 W., indicate that the bed is thinner toward the east.

Near the top of Spring Butte, in sec. 4 (location 23), a bed of lignite about 2 feet thick is exposed about 150 feet above the Haynes bed. A bed of lignite less than 2 feet thick was found at a corresponding altitude on a high butte near the north line of sec. 1.

T. 131 N., R. 92 W.

T. 131 N., R. 92 W., is an area of very broad fertile valleys separated by high rocky ridges. The greater part of the township is drained by small streams flowing toward the north and east into Timber Creek, which crosses its northeastern corner. The main divide extends across the southern part of the township, but two high

spurs extend into the northwest and east-central parts. All the rocks belong to the Fort Union formation, but there are very few natural exposures.

At least two lignite beds outcrop in the township, but the data are so meager that correlations of the various exposures and well records are not invariably certain. The lower bed, which is supposed to be the same as the Haynes lignite bed, underlies the greater part of the township, except in parts of the valleys to the northeast and east. The upper bed is about 50 feet higher and underlies only the buttes. The outcrops of the beds as shown on the map were sketched largely from the topography and are only approximately correct.

On the south side of the divide between Cedar and Timber creeks the lower bed has been mined at two places, at Rogers's strip pit in the SE. $\frac{1}{4}$ sec. 31 (location 24) and at Cooper's strip pit near the west line of sec. 35 (section 25, Pl. XIII). The Rogers mine is not operated at present and is partly filled with water. The lignite exposed above water level has a thickness of 5 feet 8 inches. At Cooper's mine, however, where a considerable amount of lignite is being removed for local use, the total thickness of the bed is only 3 feet 8 inches. North of the main ridge, at Hubbard's mine, in the SE. $\frac{1}{4}$ sec. 25 (section 26, Pl. XIII), the bed is only 1 foot 2 inches thick. A bed of lignite, doubtfully correlated with the Haynes bed, outcrops in a steep bluff in the SE. $\frac{1}{4}$ sec. 24 (location 27), where it has a thickness of only 1 foot. At Sheep Creek mine, in sec. 23 (location 28), the bottom of the bed is covered with water, but 3 feet 2 inches of lignite is exposed above water level. The five localities mentioned above are the only places in the township where the bed could be examined. At a number of places, however, in the western part of the township, lignite at about the horizon of the Haynes bed is reported in wells. These reported sections are as follows:

Lignite sections, probably on Haynes bed, reported in T. 131 N., R. 92 W.

[In addition to sections described in text and shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
		<i>Ft. in.</i>			<i>Feet.</i>
29	NW. $\frac{1}{4}$ sec. 10...	Lignite in well..... 2 6	35	SW. $\frac{1}{4}$ sec. 29...	Lignite in spring... (a)
30	SE. $\frac{1}{4}$ sec. 20...	Lignite in well..... 3	36	SE. $\frac{1}{4}$ sec. 30...	Lignite in well..... (a)
31	NW. $\frac{1}{4}$ sec. 28...	Lignite in well..... 2	37	SE. $\frac{1}{4}$ sec. 18...	Lignite in well..... 2+
32	SE. $\frac{1}{4}$ sec. 28...	Lignite in well..... (a)	38	SE. $\frac{1}{4}$ sec. 4...	Lignite in well..... (a)
33	SW. $\frac{1}{4}$ sec. 27...	Lignite in well..... 7	39	NE. $\frac{1}{4}$ sec. 4...	Lignite in well..... (a)
34	SW. $\frac{1}{4}$ sec. 28...	Lignite in well..... 6	40	SW. $\frac{1}{4}$ sec. 5...	Lignite in well..... 3

a Unknown.

The upper bed is exposed at only one place in the township, a prospect in the SE. $\frac{1}{4}$ sec. 11 (section 44, Pl. XIII, p. 282). At this place it has a thickness of 5 feet 5 inches. Lignite at about this horizon was reported to have been found in several wells in the town-

ship, indicating that the bed probably has a thickness of 3 to 6 feet, at least in the eastern part of the township.

Lignite sections reported on bed about 50 feet above Haynes lignite bed in T. 131 N., R. 92 W.

[In addition to section shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
41	SW. $\frac{1}{4}$ sec. 26.	Lignite in well..... <i>Ft. in.</i> (a)	45	NW. $\frac{1}{4}$ sec. 22.	Lignite in well..... <i>Feet.</i> 2
42	NW. $\frac{1}{4}$ sec. 26.	Lignite in well..... (a)	46	NE. $\frac{1}{4}$ sec. 8.	Lignite dust brought up by prairie dogs.
43	SE. $\frac{1}{4}$ sec. 14.	Lignite in well..... 1 6			

^a Unknown.

T. 129 N., R. 91 W.

Les Belles Pierres Hills extend from the west more than halfway across the north-central part of T. 129 N., R. 91 W. The northern slope of the hills is broken into a series of steep bluffs separated by wide benches. South of the hills is a smooth, gently rolling prairie. The drainage of the entire township is to the north toward Cedar Creek. The main line of the Chicago, Milwaukee & St. Paul Railway crosses the southern part of the township in an east-west direction. The Cannonball marine member of the Lance formation is exposed in the valleys of Plum Creek and other northward-flowing streams. Fort Union strata underlie all the higher portion of the township. Beds of resistant sandstone belonging to this formation form prominent escarpments on the sides of the higher hills, but over the greater part of the township rock exposures are very few. No lignite was found or reported within the township.

T. 130 N., R. 91 W.

Cedar Creek flows eastward across the southern part of T. 130 N., R. 91 W., and with its principal tributary, Timber Creek, drains the entire area. South of the creek the bluffs rise somewhat abruptly toward Les Belles Pierres Hills, but to the north there is a more gradual slope. Rocks belonging to the Cannonball marine member of the Lance formation outcrop in the valleys of Cedar and Timber creeks in the northeastern corner of the township. These rocks are well exposed in the creek bluff about a mile east of Stowers post office and at a few other points along the creek. They are overlain by the lower part of the Fort Union formation, which occupies only a small part of the area.

A lignite bed which is correlated with the Haynes bed underlies a high butte along the north line of secs. 5 and 6. No exposure of the bed was found in this township, but in a well in the NE. $\frac{1}{4}$ sec. 6 (location 48) 2 feet of weathered lignite was reported at a depth of 26 feet. No evidence of the higher beds was found in this township.

T. 131 N., R. 91 W.

Timber Creek flows southeastward across the central part of T. 131 N., R. 91 W., and drains the entire area. The surface is for the most part a rolling prairie, rising to a series of rough buttes in the northern part of the township, and to a high ridge in the southwestern corner. The outcropping rocks belong to the Fort Union formation except in the low, flat area along Timber Creek and its tributaries in the southeastern corner of the township, where the upper part of the Cannonball marine member of the Lance formation appears at the surface.

There is evidence that three beds of lignite outcrop within the township, but exposures are so few that correlations are very unsatisfactory. The lowest bed outcrops in the steep bluffs of a branch of Timber Creek in sec. 9 (location 49), where it has a thickness of 1 foot 9 inches. Lignite at about the same horizon was reported in two wells, one in the SW. $\frac{1}{4}$ sec. 10 (location 50), where the thickness is unknown, and the other in the NW. $\frac{1}{4}$ sec. 14 (location 51), where the thickness is 2 feet. The next higher bed of lignite, which is correlated with the Haynes bed, is not exposed within the township, but a well in the SE. $\frac{1}{4}$ sec. 2 (location 52) reached the top of a bed of lignite which is at about the horizon of that bed. Just north of the township line, in the SE. $\frac{1}{4}$ sec. 33, T. 132 N., R. 91 W. (section 55, Pl. XIII, p. 282), the bed has a thickness of 6 feet 6 inches.

In the SE. $\frac{1}{4}$ sec. 31 (section 53, Pl. XIII) a bed of lignite 4 feet 10 inches thick is exposed in an abandoned strip pit. This bed is about 50 feet above the Haynes bed. It is not exposed in the northern part of the township, but its horizon is indicated by mounds of clinker at a number of places.

T. 132 N., R. 91 W.

A high, irregular upland area extends across the central part of T. 132 N., R. 91 W., forming the divide between Cannonball River and Cedar Creek. The whole township is characterized by nearly flat-topped hills with moderately steep slopes. The rocks all belong to the Fort Union formation and, as in other parts of the field, are covered with a heavy mantle of soil.

Two beds of lignite outcrop within the township, the lower of which is doubtfully correlated with the Haynes bed. In the southern part of the township this bed has been mined by stripping at two places, in the NW. $\frac{1}{4}$ sec. 31 (location 54) and in the SE. $\frac{1}{4}$ sec. 33 (section 55, Pl. XIII). At location 54 the pit is partly filled with water, and only 2 feet 2 inches of lignite was exposed. At location 55 the bed is 6 feet 6 inches in thickness, but contains three thin partings of shale and bone. Half a mile west of the township line, in sec. 36, T. 132 N., R. 92 W. (location 47), there is a strip pit in which

the bed is at least 6 feet 4 inches thick, the base being concealed by water in the bottom of the pit. In the northern part of the township a bed, which is probably the Haynes, is exposed in three strip pits, and was reported to be present in several wells. At Kelch's mine, in sec. 4 (section 63, Pl. XIII), the bed is 5 feet 4 inches thick, but there is a considerable diminution in thickness toward the east. The lignite sections on this bed in the northern part of the township are as follows:

Lignite sections probably on the Haynes bed in the northern part of T. 132 N., R. 91 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
56	NE. $\frac{1}{4}$ sec. 12.	Lignite in well.... <i>Ft. in.</i> 1	60	SE. $\frac{1}{4}$ sec. 10 (strip pit).	Shale, gray. <i>Ft. in.</i> Lignite..... 1 10 Bone..... 4 Lignite..... 2+ Base of bed below water. Total lignite. 3 10+
57	SE. $\frac{1}{4}$ sec. 12.	Lignite in abandoned prospect full of water.... 2½-3			
58	SW. $\frac{1}{4}$ sec. 12.	Lignite in well... (a)			
59	NW. $\frac{1}{4}$ sec. 12.	Lignite in well... (a)	62	SE. $\frac{1}{4}$ sec. 9.	Lignite in well... 5

a Unknown.

About 50 feet above the Haynes bed is a lignite bed which outcrops at the base of a flat-topped hill in the southeastern part of the township. This bed is mined by stripping at two places in sec. 26 (locations 65 and 66) and was reported in wells in sec. 28 (location 64) and sec. 26 (location 67). The section measured at location 66 is shown graphically on Plate XIII (p. 282). Both pits were partly filled with water and only the approximate thickness could be ascertained. The bed is probably 5 feet or more in thickness in the southern part of the township. The partial sections obtained are as follows:

Lignite sections on bed 50 feet above the Haynes lignite bed in T. 132 N., R. 91 W.

[In addition to section shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.
64	NE. $\frac{1}{4}$ sec. 28.....	Lignite in well..... <i>Ft. in.</i> (a)
65	SW. $\frac{1}{4}$ sec. 26 (strip pit).....	Shale..... Lignite..... 2 Shale..... 3 Lignite..... 5 Base of bed below water.
67	NW. $\frac{1}{4}$ sec. 26.....	Lignite in well..... (a)

a Unknown

T. 130 N., R. 90 W.

Cedar Creek flows eastward in a wide valley through the southern portion of T. 130 N., R. 90 W., and is joined in the southeastern part by Timber Creek, its largest tributary. These valleys are separated from the general upland level by a series of steep scarps and wide benches. That part of the township lying south of Cedar Creek was examined¹ in 1909 and is not included in the Cannonball River field. The greater part of the township, with the exception of the bluffs of Cedar and Timber creeks, is grass covered and rock exposures are few. The rocks in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. Only the lower part of the Fort Union is exposed in the township and these strata are for the most part yellow sandstone. No lignite was found or reported within the township.

T. 131 N., R. 90 W.

The principal topographic feature in T. 131 N., R. 90 W., is a group of high rugged buttes in its northern and central parts. Elsewhere in the township the country is rolling prairie, covered with a heavy mantle of soil, and rock exposures are few. The rocks in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union and White River formations with surficial deposits of late Tertiary or Quaternary river gravels. The top of the Cannonball member appears in the valleys of two small streams in the southern part of the township. Fort Union rocks outcrop throughout the remainder of the area, except on the tops of the highest buttes, which are capped by white marly limestone and sandstone of White River age. The deposits of river sand and gravel are very conspicuous on the tops of some of the buttes which are a little lower than the base of the White River.

The lignite beds are not so well exposed in this township as in areas to the north and west. The lowest bed is thin, and its presence is shown only by a small mound of clinker in the SE. $\frac{1}{4}$ sec. 14 and by about a foot of lignite in two wells in the western part of the same section (locations 68 and 69).

The next higher bed, which is doubtfully correlated with the Haynes lignite bed, is reported to have a thickness of about 6 feet in an old well in sec. 8 (location 70). In sec. 22 (location 71), at about the same horizon, some lignite dust has been brought to the surface by badgers. In the NE. $\frac{1}{4}$ sec. 23 (location 72) 2 feet 9 inches of lignite is exposed, but the top of the bed is eroded away. The same bed was reached by a well in sec. 12 (location 73) and by two wells in sec. 4 (locations 74

¹ Calvert, W. R., and others, *Geology of the Standing Rock and Cheyenne River Indian reservations*, North and South Dakota: U. S. Geol. Survey Bull. 575, p. 43, 1914.

and 75). These data are insufficient for definite conclusions, but it seems probable that the bed has a thickness of 3 to 7 feet under all the high land in the northern part of the township.

A higher bed of lignite was found in a well in sec. 10 (location 76), where it was reported to have a thickness of 3 feet. In sec. 2 (location 78), however, the following section was measured:

Section at location 78, in the SE. $\frac{1}{4}$ SW. $\frac{1}{4}$ sec. 2, T. 131 N., R. 90 W.

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

At several places in secs. 10 and 15, high up on the sides of the buttes, a considerable amount of reddened clinker shows where this lignite bed has been burned. The thickness of the bed in this part of the township could not be determined. At a horizon possibly somewhat lower, in the SW. $\frac{1}{4}$ sec. 12 (location 77), some prospecting has been done, but the bed examined was only a few inches thick.

T. 132 N., R. 90 W.

The surface in T. 132 N., R. 90 W., is for the most part smoothly rolling prairie interrupted by a few high rounded hills. Sheep Creek, which flows northeast toward Cannonball River, drains the greater part of the township. The rocks are all Fort Union (Eocene) in age with the exception of 20 or 30 feet of fine-grained marly limestone of White River age (Oligocene) on the top of Coffin Butte in sec. 34. The beds dip to the northeast at about the same angle as the slope of the valley of Sheep Creek.

The lowest bed of lignite in the township, which is doubtfully correlated with the Haynes bed, outcrops in the valley of Sheep Creek not far above the water level. In the central and eastern parts of the township the bed has been mined by stripping at a number of places and is also reported to have been found in several wells. In a number of the strip pits the bottom of the bed is concealed by water, so that in only a few places could the complete thickness be measured. The minimum thickness is probably in sec. 1, where the bed contains over 4 feet of lignite (section 81, Pl. XIII). The thickness increases to the south and southwest. In the SE. $\frac{1}{4}$ sec. 16 (location 90) the thickness is over 5 feet. Thicknesses of 6 feet or more were reported at three places. All the data obtained concerning the bed in this township are given in Plate XIII (p. 282) or in the following table:

Lignite sections on Haynes (?) bed in T. 132 N., R. 90 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
		<i>Ft. in.</i>			<i>Ft. in.</i>
79	NE. $\frac{1}{2}$ sec. 13..	Shale..... Sandstone..... 3 6 Lignite..... 2+ Base of bed below water. Reported thickness..... 6 6	87	Center sec. 26..	Lignite in well... (a)
			89	NE. $\frac{1}{2}$ sec. 21..	Lignite in spring. (a)
			90	SE. $\frac{1}{2}$ sec. 16 (strip pit).	Shale, gray..... 3+ Clay, black..... 8 Lignite..... 5 2+ Base of bed under water.
80	SE. $\frac{1}{2}$ sec. 12..	Lignite in well... (Horizon doubtful.) 8			
82	NE. $\frac{1}{2}$ sec. 14..	Weathered lignite on surface.	91	SW. $\frac{1}{2}$ sec. 10 (in well).	Lignite..... 4 Shale..... 2 Lignite..... 4 6±
83	SW. $\frac{1}{2}$ sec. 14 (strip pit).	Clay, bluish gray. Lignite..... 3 9+ Base of bed under water.	92	SW. $\frac{1}{2}$ sec. 14..	Lignite in well... (a)
			93	NE. $\frac{1}{2}$ sec. 11 (prospect pit).	Lignite..... 1 6+ Base of bed below water.
84	NE. $\frac{1}{2}$ sec. 26..	Lignite in well.. (a)	94	SE. $\frac{1}{2}$ sec. 2....	Shale, sandy..... 7+ Lignite..... 2 10+ Base of bed below water. Reported thickness..... 6
85	NE. $\frac{1}{2}$ sec. 26..	Lignite in well... 2+			
86	SE. $\frac{1}{2}$ sec. 26..	Lignite in well... (a)			

a Unknown.

About 50 feet above the Haynes lignite bed is another important bed which has been mined by stripping at three places in secs. 35 and 27 but which was not found elsewhere in the township. In each of these mines the thickness of the bed is over 6 feet, but a number of partings of shale and bone reduce the value to some extent. The three sections measured (sections 95, 96, and 97) are shown in Plate XIII.

A bed of lignite about 100 feet higher stratigraphically is exposed in an abandoned strip pit (section 98, Pl. XIII) on the north slope of Coffin Butte in sec. 34. The total thickness is 4 feet 7 inches, but a parting of shale 1 foot 11 inches thick makes the bed of little value.

T. 133 N., R. 90 W.

Cannonball River flows eastward across the northern part of T. 133 N., R. 90 W., in a comparatively narrow valley, which is separated from the upland by a series of steep bluffs and wide terraces. Branch lines of the Northern Pacific and the Chicago, Milwaukee & St. Paul railways cross the northwestern part of the township. Odessa, in sec. 5, is located on the Northern Pacific, and New Leipzig, in sec. 35 of the township to the north, is a connecting point for the two roads. The strata throughout the township belong to the Fort Union formation, the lower sandstones of which are well exposed in

the bluffs of Cannonball River and of a creek which flows northward in the eastern part of the township. Back from these streams, however, exposures are poor and the correlation of beds is difficult. The general dip of the strata to the northeast is a little more pronounced in this township than in areas to the south and west.

The lowest bed of lignite outcrops in the river bluffs in the eastern part of the township but is of little importance. It was measured at locations 101 and 100, in secs. 12 and 14, respectively, and is 1 foot 8 inches in thickness at both places. Another bed of lignite 1 foot 4 inches in thickness is exposed in a shallow well in the NE. $\frac{1}{4}$ sec. 32 (location 99).

About 30 feet above the bed at locations 100 and 101 is an important bed of lignite, which has been mined by stripping at several places in the river bluffs, in secs. 9, 10, and 13, where the thickness ranges from 3 feet 9 inches to 7 feet 6 inches. (See sections 107, 108, 109, and 111, Pl. XIII, p. 282.) The section at location 110 is as follows:

Section of lignite bed at location 110, in the SE. $\frac{1}{4}$ sec. 10, T. 133 N., R. 90 W.

	Ft.	in.
Shale, sandy.....	10	
Lignite.....	3	6
Bone.....		$\frac{1}{2}$
Lignite.....		8
Bone.....		1
Lignite.....	1	5
Shale.....	6	
	21	8 $\frac{1}{2}$

Farther east, in sec. 11, the bed is much thinner. (See sections 106 and 112, Pl. XIII.) This bed is probably at a somewhat lower horizon than the Haynes lignite bed. In the bluffs of a small steep-sided valley in the southeastern part of the township a lignite bed, probably the Haynes bed, is well exposed and is from 3 feet 10 inches to 4 feet 9 inches thick. (See sections 102, 103, 104, and 105, p. 36.) In sec. 22, however, two wells, one in the SE. $\frac{1}{4}$ and the other in the SW. $\frac{1}{4}$ (location 113), pass through the horizon of this bed, but are reported to have passed through no lignite. In a well in sec. 28 (location 114) a thickness of 2 feet was reported.

A bed exposed at a small strip pit in sec. 32 (location 115) is at least 3 feet 9 inches thick, but the base of the bed is concealed by water in the bottom of the pit. This bed is correlated with the bed described above because of the accordance in altitude, but this evidence is not at all conclusive.

Lignite sections on Haynes (?) lignite bed in T. 133 N., R. 90 W.

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
102	NW. $\frac{1}{4}$ sec. 25 (strip pit).	Shale..... Ft. in. Lignite..... 5+ Bone..... 10 Lignite..... 1 Base of bed concealed below water. 3 6+	105	SW. $\frac{1}{4}$ sec. 26.	Lignite in well.. Ft. in. 3 6
103	SE. $\frac{1}{4}$ sec. 23..	Shale, sandy.... 10+ Shale, carbonaceous..... 1 4 Lignite..... 3 5 Shale..... 1 Lignite..... 1 Shale..... 4	113	SW. $\frac{1}{4}$ sec. 22..	Well passing through lignite horizon. Bed reported to be absent.
104	SE. $\frac{1}{4}$ sec. 26 (strip pit).	Shale, brown. Lignite..... 4 9+ Base of bed below water.	114	SW. $\frac{1}{4}$ sec. 28..	Lignite in well.. 2
			115	SW. $\frac{1}{4}$ sec. 32 (strip pit).	Shale. Lignite..... 3 9+ Base of bed below water.

About 100 feet higher than the Haynes(?) bed is another bed of lignite which outcrops near the tops of the high buttes in sec. 21 (location 116) and in sec. 36, where it has been burned extensively. No exposures of the bed, however, could be found in this township. The horizon of the bed is below the tops of the group of high buttes in secs. 22 and 27, but as no evidence of the bed could be found there the conclusion was reached that it is either very thin or absent.

T. 130 N., R. 89 W.

Cedar Creek flows eastward across the southern part of T. 130 N., R. 89 W., and forms the southern boundary of the Cannonball River field. The valley is generally wide and open and is bordered in only a few places by vertical bluffs. North of the stream the surface rises gradually to the moderately rolling prairie land characteristic of the northern part of the township. The rocks that outcrop in the township belong to the lower part of the Lance formation, the Cannonball marine member of the Lance, and to the Fort Union formation. The Lance formation outcrops in the valley of Cedar Creek, where it is fairly well exposed in a few of the steeper bluffs. The Fort Union underlies the northern portion of the township, but is for the most part concealed by a heavy mantle of soil. With the exception of a thin bed near the top of the lower part of the Lance, no lignite was found or reported within the township.

T. 131 N., R. 89 W.

The surface of T. 131 N., R. 89 W., is for the most part rolling upland prairie, interrupted by numerous small rounded buttes and

a few high rocky buttes. The most conspicuous feature is Pretty Rock Butte, which is a prominent landmark for all the surrounding region. The rocks belong to the Fort Union formation, with the exception of two small areas in the southwestern part of the township, where the streams have cut through to the top of the Cannonball marine member of the Lance formation. The rocks are for the most part concealed by the heavy mantle of soil, but the upper beds are well exposed on the south face of Pretty Rock Butte. The general dip of the strata in this part of the field is toward the northwest.

Two beds of lignite outcrop on the sides of Pretty Rock Butte, the lower of which is probably the Haynes bed. This bed also underlies a number of low hills to the north and northwest. It has a thickness of 4 feet 2 inches on the south side of Pretty Rock Butte (section 120, Pl. XIII), and is probably over 2½ feet thick throughout the township. The upper bed was examined at only one place in the NW. ¼ sec. 34 (section 122, Pl. XIII), where it is 2 feet 5 inches thick.

Lignite sections on the Haynes (?) lignite bed in T. 131 N., R. 89 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
117	SW. ¼ sec. 6....	Lignite in well..... <i>Ft. in.</i> 1 6	121	NW. ¼ sec. 34..	Shale. <i>Ft. in.</i> Lignite, much weathered 1 10 Shale.
118	SW. ¼ sec. 6....	Lignite in well..... 5			

T. 132 N., R. 89 W.

The surface of T. 132 N., R. 89 W. is for the most part rolling upland prairie which is dissected by a few steep-sided valleys and is surmounted in the northwestern part by a group of rocky hills. The rocks in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The sandy shale of the Cannonball member outcrops in the narrow valleys in the eastern part of the township, but the Fort Union rocks are largely concealed by the heavy mantle of soil.

A bed of lignite, correlated with the Haynes bed, underlies the high buttes in the northwestern part of the township and has been mined or prospected at several places. The greatest known thickness in the township, 4 feet 7 inches, is found in a strip pit in sec. 19 (section 123, Pl. XIII). Evidence as to the thickness of this bed in other parts of the township is very unsatisfactory, but indicates that there is little variation. Two of the sections measured in the township (sections 123 and 128) are shown graphically in Plate XIII. The other data concerning the bed are as follows:

Lignite sections on Haynes (?) lignite bed in T. 132 N., R. 89 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
124	NW. $\frac{1}{4}$ sec. 20.	Lignite in well..... <i>Ft. tn.</i> 3 6	129	SW. $\frac{1}{4}$ sec. 4....	Lignite in well..... <i>Ft.</i> 3±
125	SE. $\frac{1}{4}$ sec. 18...	Lignite in well..... (a)	130	SW. $\frac{1}{4}$ sec. 4	Lignite under water (a)
126	NW. $\frac{1}{4}$ sec. 10 (prospect pit).	Lignite (reported).... 3±		(prospect pit).	

a Unknown.

At the north end of the ridge, about 100 feet north of the township line, in the SE. $\frac{1}{4}$ sec. 36, T. 133 N., R. 89 W. (location 127), is a prospect pit in which 1 foot 8 inches of weathered lignite and ash is exposed. This may also be the Haynes bed, but the section is probably not complete.

T. 133 N., R. 89 W.

Cannonball River flows eastward across the northern part of T. 133 N., R. 89 W., in a comparatively narrow valley which is separated from the upland prairie on either side by a series of steep bluffs and wide terraces. Except near the river valley, the surface is moderately rolling prairie interrupted by a few rocky buttes. In the southwestern part of the township is an especially prominent group of high hills. The rocks that outcrop in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The sandy shale of the upper part of the Cannonball member and the yellow and white sandstone of the lower part of the Fort Union formation are well exposed along the bluffs of Cannonball River and Sheep Creek, but in other parts of the township the exposures are few. A good section of the Fort Union strata exposed in sec. 5 (location 136) has been examined and described by A. G. Leonard.¹ The section exposed at this place is as follows:

Section of Fort Union formation in the NE. $\frac{1}{4}$ sec. 5, T. 133 N., R. 89 W.

[See also section 136 on Pl. XIII.]

	<i>Ft.</i>	<i>in.</i>
Shale, gray, yellow, and brown.....	40	
Lignite (Haynes bed).....	3	10
Shale, gray.....	4	4
Lignite.....		11
Shale, gray.....	18	6
Lignite.....	1	11
Shale.....	1	2
Lignite.....	2	3
Shale, light gray, sandy.....	8	7
Lignite.....	1	6
Sandstone, light gray and yellow.....	75	
Water level.		

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¹ Leonard, A. G., The Cretaceous and Tertiary formations of western North Dakota and eastern Montana: Jour. Geology, vol. 19, p. 519, 1911.

The lowest bed of lignite in the above section corresponds with the lowest bed exposed in the river bluff in the SW. $\frac{1}{4}$ sec. 7 (location 131), where the section is as follows:

Section of Fort Union formation in SW. $\frac{1}{4}$ sec. 7, T. 133 N., R. 89 W.

	Ft.	in.
Sandstone, gray, unconsolidated.....	5+	
Bone.....		4
Shale, brown.....		4
Lignite.....		4
Shale, brown.....		2
Lignite.....		2
Shale, gray to light brown.....	1	2
Lignite.....		2
Shale, gray, sandy.....	4	6
Lignite.....	1	2
Sandstone, gray, unconsolidated.....	5+	
	18	4

The uppermost bed of lignite in the first section above is correlated with the Haynes bed and with the bed which is being mined at two places in sec. 6 (sections 134 and 135, Pl. XIII). The same bed was examined in the NW. $\frac{1}{4}$ sec. 8 (section 133, Pl. XIII) and in lot 2, sec. 1 (section 137, Pl. XIII). The average thickness in this part of the township is about 4 feet. On the south side of the river this bed is very poorly exposed, but in an abandoned mine in sec. 20 (section 132, Pl. XIII) it has a thickness of 6 feet 7 inches.

Another bed outcrops high up on the sides of the hills in the southwestern part of the township, where it has been extensively burned. A single measurement was obtained on this bed in section 32 (section 138, Pl. XIII), where it has a total thickness of 7 feet 8 inches with an 8-inch parting of sandstone 2 feet from the top.

T. 129 N., R. 88 W.

Only the small part of T. 129 N., R. 88 W., which lies north of Cedar Creek, is included in this field. The rocks that outcrop in this part of the township belong to the lower part of the Lance formation and are fairly well exposed in the creek bluffs and in a few steep slopes.

A group of thin beds of lignite outcrops in the bluffs of the creek and the smaller tributary streams. Two measurements of the thickest bed have been made in this township on the north side of Cedar Creek, one at the McCord mine in sec. 5 (location 139), where the thickness is 2 feet 2 inches, and the other in sec. 3 (section 140, Pl. XIII), where the thickness is 2 feet 10 $\frac{1}{2}$ inches with a half-inch parting of shale 1 foot from the top. Measurements made south of Cedar Creek show that the bed is very lenticular in character. Chemical analyses were made of three samples obtained by A. L. Beekly in 1909 from the McCord mine and from two strippings on the south side of Cedar Creek. The results of these analyses are given on page 256.

T. 130 N., R. 88 W.

The surface in T. 130 N., R. 88 W., is irregularly broken, rising from the level of Cedar Creek on the south to the upland prairie in the north-western part. The rocks in the township belong to the lower part of the Lance formation, to the Cannonball member of the Lance, and to the Fort Union formation. The Lance formation is fairly well exposed in the bluffs of Cedar Creek and some of its large tributaries, but elsewhere in the township exposures are few. A group of thin beds of lignite occurs near the top of the lower part of the Lance, the thickest of which has been mined by stripping at several localities in sec. 35. At all of the places examined the bed is less than 2½ feet in thickness. Two of the sections measured (sections 142 and 143) are shown graphically on Plate XIII (p. 282). The third, at location 141, is as follows:

Section of lignite bed in the lower part of the Lance formation at location 141, NW. ¼ sec. 30, T. 130 N., R. 88 W.

	Ft.	in.
Shale.		
Lignite.....	1	6
Shale.....		1
Lignite.....		9
Shale, brown.		
	2	4

T. 131 N., R. 88 W.

The surface of T. 131 N., R. 88 W., is a rolling upland interrupted by the steep-sided valleys of Snake Creek and its tributaries. The rocks belong to the Cannonball marine member of the Lance formation and to the lower part of the Fort Union formation, but the surface is covered with a heavy mantle of soil and exposures are very few. No lignite was found in this township nor does lignite appear anywhere in the Cannonball River field in this part of the stratigraphic section.

T. 132 N., R. 88 W.

Cannonball River flows eastward across the northern part of T. 132 N., R. 88 W. The valley is bordered on the north and south by a series of steep slopes separated by wide benches. The rocks belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. Almost the whole thickness of the Cannonball member is exposed within the township, and these strata are typically shown in the steep bluffs along the river. Elsewhere in the township, however, exposures are few. No lignite was found within the township nor is any known at this part of the stratigraphic section in the Cannonball River field.

T. 133 N., R. 88 W.

Cannonball River flows southeastward across the southern part of T. 133 N., R. 88 W., in a comparatively narrow valley. The slopes on the south side of the valley are much more abrupt than those on the

north, the northern part of the township being a rolling upland. The Cannonball branch of the Chicago, Milwaukee & St. Paul Railway crosses the northeastern part of the township. The rocks belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The Cannonball member is well exposed in the bluffs of Cannonball River, but the Fort Union strata which underlie the upland areas are very poorly exposed.

About 100 feet above the base of the Fort Union is a bed of lignite, believed to be the Haynes bed, which is mined in a shaft mine in section 12 and in several strip pits in other parts of the township. The bed ranges in thickness from 2 feet in sec. 6 (location 145) to 8 feet 6 inches in sec. 12 (section 152, Pl. XIII). It is possible, however, that the measurement at location 145 is of another bed, as near-by measurements in section 6 (locations 144 and 146) show thicknesses of 3 feet 9 inches and 3 feet 7 inches, respectively.

The presence of a second bed of lignite somewhat higher in the section is indicated by weathered lignite (bloom) in the soil at location 157 in the SE. $\frac{1}{4}$ sec. 11.

A chemical analysis was made of a sample collected from the Jones mine in sec. 12 (location 152), the results of which are given on page 256. The data concerning the Haynes (?) lignite bed, in addition to the graphic sections given on Plate XIII, are as follows:

Lignite sections on Haynes (?) lignite bed in T. 133 N., R. 88 W.

[In addition to sections shown on Pl. XIII.]

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
145	NW. $\frac{1}{4}$ sec. 6..	Shale. <i>Fl. in.</i> Lignite, much 2 weathered. Clay, sandy.	149	NW. $\frac{1}{4}$ sec. 9..	Lignite in well... <i>Fl. in.</i> 2±
146	NW. $\frac{1}{4}$ sec. 6...	Shale, gray..... 8+ Shale, carbon- 2 aceous. Lignite..... 3 7½ Shale, brown, sandy.	153	NE. $\frac{1}{4}$ sec. 1 (prospect pit).	Lignite reported.. 7
147	NW. $\frac{1}{4}$ sec. 5..	Lignite in well.... (a)	154	SW. $\frac{1}{4}$ sec. 2 (strip pit).	Clay, gray. Lignite..... 4+ Base of bed below water.
148	SW. $\frac{1}{4}$ sec. 5...	Lignite in well.... (a)	155	NW. $\frac{1}{4}$ sec. 2..	Lignite in well.... 1 6±
			156	Lot 2, sec. 4...	Lignite in well.... 8 6±

a Unknown.

T. 130 N., R. 87 W.

The surface of T. 130 N., R. 87 W., slopes gradually but irregularly from the upland prairie in the north to the valley of Cedar Creek, which flows eastward near the south township line. The rocks in the township belong to the lower part of the Lance formation and to the Cannonball marine member of the Lance. The brown shale and dark

sandstone at the top of the lower part of the Lance are exposed in local badlands in the southern portion of the township, but the greater part of the area is covered with a heavy mantle of soil, and exposures are scarce.

A few thin lenticular beds of lignite appear near the top of the lower part of the Lance, the most important of which is 2 feet 8 inches thick in sec. 13 (section 160, Pl. XIII). At this place a considerable amount of lignite has been mined by stripping. Measurements of a bed which is presumably the same were made at two other places in the township. The sections obtained at these places are as follows:

Lignite sections in lower part of Lance formation, T. 130 N., R. 87 W.

[In addition to sections shown on Pl. XIII.]

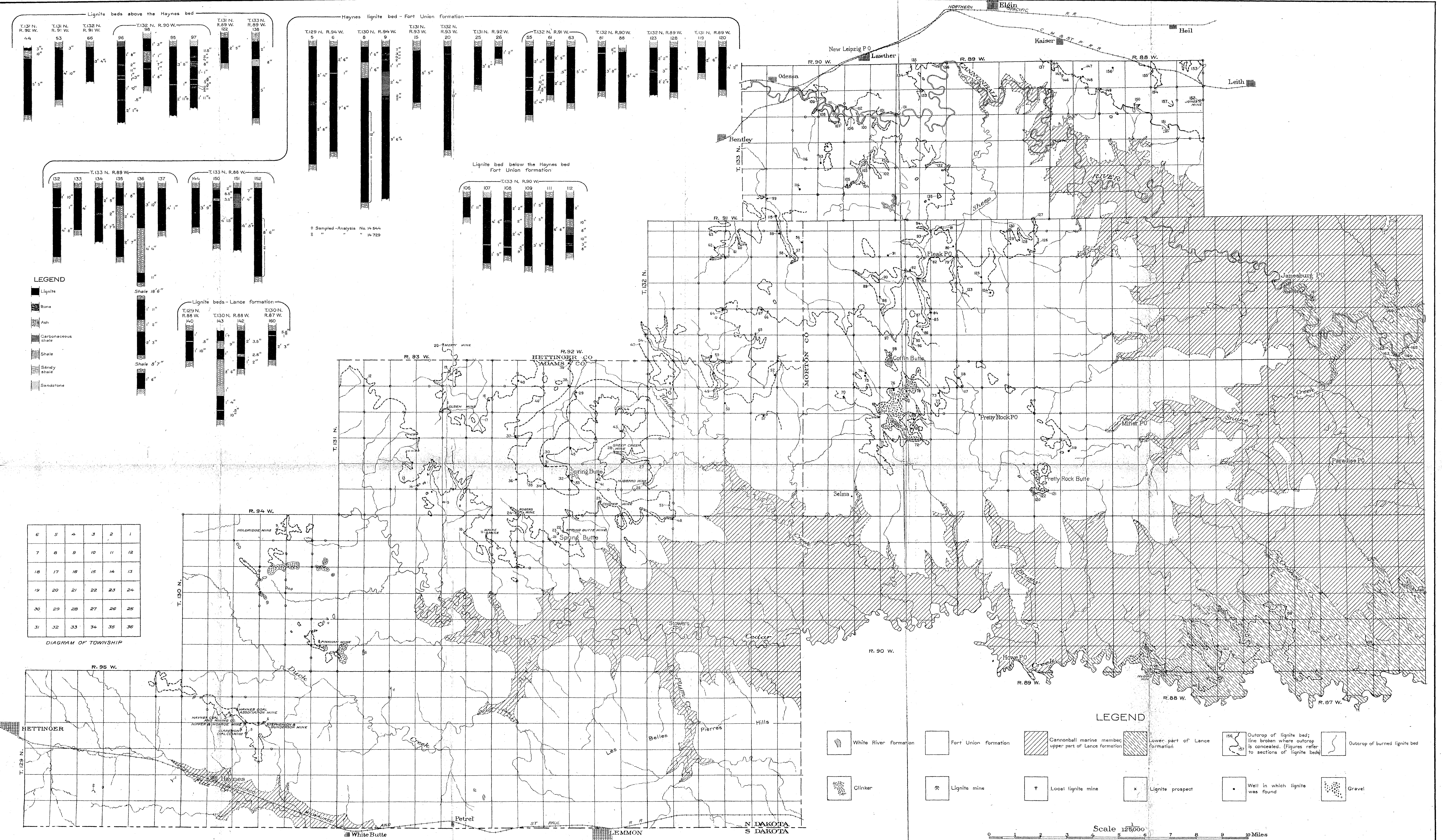
No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
158	SE. $\frac{1}{4}$ sec. 19...	Sandstone, yellow <i>Ft. in.</i> to brown..... 3 10 Lignite..... 10 Shale, brown..... 6 6 Sandstone, gray..... 1 6 Lignite..... 7 Shale, brown..... 6 Sandstone, gray, shaly..... 4 Lignite..... 6 Sandstone and shale 12	159	NE. $\frac{1}{4}$ sec. 34..	Shale, gray. <i>Ft. in.</i> Lignite..... 1 10 Bone..... 8 Shale, gray.

T. 131 N., R. 87 W.

The surface of T. 131 N., R. 87 W., is a gently rolling upland prairie which has been deeply dissected by Snake Creek and other streams. The outcropping rocks belong to the lower part of the Lance formation, the Cannonball marine member of the Lance, and the Fort Union formation, but the strata are not well exposed on account of the heavy mantle of soil. No lignite has been found within the township.

T. 132 N., R. 87 W.

Cannonball River flows southeast across the southern part of T. 132 N., R. 87 W., in a comparatively steep-sided valley. The bluffs of the river are higher and the strata better exposed in this township than in any other part of the field. The comparatively small area which lies south of the river is deeply dissected by small coulees, but in the northern part of the township are considerable areas of land sufficiently level to be cultivated. In the north-central part is a high level-topped mesa with deeply dissected borders, an outlying remnant of the extensive uplands which extend from the north into secs. 2, 3, and 11.



GEOLOGIC MAP OF WESTERN PART OF CANNONBALL RIVER LIGNITE FIELD, NORTH DAKOTA

The rocks that outcrop in the township belong to the lower part of the Lance formation, the Cannonball marine member of the Lance, and the Fort Union formation. The upper beds of the lower part of the Lance are well exposed in the river bluffs in the southeastern part of the township. They disappear below the river bed less than a mile east of Janesburg post office, which is located in sec. 18. No definite line, however, can be drawn between these beds and those of the Cannonball marine member which overlies them. The Cannonball member outcrops over the greater part of the township and is overlain in turn by the lower sandstone of the Fort Union, which caps the high upland areas in the northeastern and southwestern parts of the township.

Lignite within the township occurs only in beds less than 2 feet 6 inches thick in the lower part of the Lance. It is mined, however, by stripping at a number of places for local use. The following table includes all the measurements that have been made within the township:

Sections of lignite beds in lower part of Lance formation in T. 132 N., R. 87 W.

No. on map (Pl. XIII).	Location.	Section.	No. on map (Pl. XIII).	Location.	Section.
161	SE. $\frac{1}{4}$ sec. 20 (prospect in river bluff).	Shale. <i>Ft. in.</i> Lignite..... 1 6 Shale.	164	SW. $\frac{1}{4}$ sec. 36 (outcrop in river bluff).	Sandstone, gray. <i>Ft. in.</i> Lignite..... 1 4 Shale, brown.
162	SE. $\frac{1}{4}$ sec. 35 (outcrop in river bluff).	Shale, gray. Lignite..... 1 9 Shale, brown..... 2 Shale, gray. <u>1 11</u>	165	SW. $\frac{1}{4}$ sec. 36 (prospect in river bluff).	Shale, gray. Lignite..... 2 1 Shale, brown..... 2 Shale, gray. <u>2 3</u>
163	SE. $\frac{1}{4}$ sec. 35 (prospect in river bluff).	Shale, bluish gray. Shale, blue, fissile. 5 Lignite..... 2 2 Shale, brown. <u>2 7</u>	166	NW. $\frac{1}{4}$ sec. 25 (prospect).	Shale, gray. Lignite..... 1 3 Shale, brown..... 3 Shale, gray. <u>1 6</u>

T. 134 N., R. 88 W.

The surface of T. 134 N., R. 88 W., is chiefly of the rolling-prairie type of topography characteristic of a large part of the Cannonball River field. The relief is most pronounced in the southeastern part, where there are a number of moderately high elongated buttes. The western part of the township is also higher and somewhat more broken than the central and northeastern parts. In the northern portion the surface slopes gently toward Antelope Creek, which flows eastward, meandering within a stream flat which is from one-fourth to one-half mile wide and is bordered by low bluffs. Probably nine-tenths of the land in the township could be cultivated. The township is crossed by branches of the Northern Pacific and the Chicago, Milwaukee & St. Paul railways.

All the rocks that outcrop in the township belong to the Fort Union formation. The strata, however, are for the most part concealed by a heavy mantle of soil.

Lignite has been found at a number of places, both at the outcrop and in wells. In several places the lignite is mined from strip pits for local use. Correlations on the basis of the carefully determined elevations of all exposures indicate that there are three beds of lignite. Of these the lowest is the thinnest and least important, although it is being mined at two places, one on Antelope Creek in sec. 5 (location 169) and the other on a branch of that stream in sec. 9 (location 167). The sections exposed at these places are as follows:

Lignite sections on lowest coal bed in T. 134 N., R. 88 W.

No. on map (Pl. XIV).	Location.	Section.	No. on map (Pl. XIV).	Location.	Section.
167	SW. $\frac{1}{4}$ sec. 9 (small strip pit).	Shale, light brown at top, more car- bonaceous and darker below, <i>Ft. in.</i> fossiliferous..... 4 6 Bone..... 1 Lignite, bony..... 2 Lignite, brown, with bright black streaks, good..... 1 2 Shale, carbonaceous..... 1 Shale, sandy..... 2 2 Total lignite... 1 4	169	SE. $\frac{1}{4}$ sec. 5 (small strip pit).	Shale, dark blue, carbonaceous at base, fossilifer- <i>Ft. in.</i> ous..... 6 6 Shale, sandy..... 1 Lignite, good, woody texture... 2 3 Clay shale..... Total lignite. 2 3

The bed is also reported to have been found in a well in the SE. $\frac{1}{4}$ sec. 8 (location 168), where it has a thickness of 2 feet.

The second or middle of the three lignite beds is the most important and is probably the Haynes lignite bed. Locally it has been burned at the outcrop, causing a baking and reddening of the overlying shale, as, for example, near the center of sec. 36, where there is a small knoll of brick-red clinker. At three places in the township the bed is mined for local use; in the NW. $\frac{1}{4}$ sec. 34 (location 171); on a branch of Antelope Creek in the NE. $\frac{1}{4}$ sec. 19 (section 176, Pl. XIV, p. 290); and in the SW. $\frac{1}{4}$ sec. 8 (section 178, Pl. XIV). The bed is also exposed in several wells. In the southeastern corner of the township the bed is 7 or 8 feet thick. Farther northwest it is thinner, being only 2 feet 6 inches at location 176 in sec. 19. Still farther north it becomes thicker and averages between 4 $\frac{1}{2}$ and 5 feet in the northwest corner of the township. All the evidence regarding the thickness of the bed is shown on Plate XIV or in the following table:

Lignite sections on Haynes (?) lignite bed in T. 134 N., R. 88 W.

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

No. on map (Pl. XIV).	Location.	Section.	No. on map (Pl. XIV).	Location.	Section.
170	SE. $\frac{1}{4}$ sec. 26...	Lignite in cistern... <i>Ft. in.</i> 5	173	NE. $\frac{1}{4}$ sec. 15...	Lignite, weathered in side of butte... (a)
171	NW. $\frac{1}{4}$ sec. 34 (strip pit).	Sandstone, yellow, friable... 8 Lignite, bony... 5 Lignite, weathered... 3 5 Shale... 1 Lignite, good... 3 5+ Base of bed below water.	174	SE. $\frac{1}{4}$ sec. 20...	Lignite in well (reported)..... 3
		Total lignite. 7 3+	175	NW. $\frac{1}{4}$ sec. 20.	Section in well (reported): Lignite..... 1 Parting..... 1 Lignite..... 3 Total lignite.. 4
172	SE. $\frac{1}{4}$ sec. 21...	Lignite in well, reported 12	177	NE. $\frac{1}{4}$ sec. 18 (prospect).	Lignite, concealed by water in prospect. (a)

(a) Thickness and relations not determined.

This bed is being successfully mined in the Jones mine in sec. 12, T. 133 N., R. 88 W., and in the Kolbank mine in sec. 7, T. 133 N., R. 87 W.

The uppermost lignite bed is stratigraphically about 50 feet higher than the preceding. It is exposed on the ridge south of Heil in the NE. $\frac{1}{4}$ sec. 35 (section 179, Pl. XIV), where the total thickness is 4 feet 10 inches including a 1-inch parting of bone. Half a mile southwest on the next ridge (location 180) there is evidence of weathered lignite or "blossom" in the soil at about the same stratigraphic horizon. The bed is apparently entirely concealed from this point northwestward to the SW. $\frac{1}{4}$ sec. 20 (location 181) where there is a large mound of reddened clinker formed by the burning of the bed. Near a branch of Antelope Creek in sec. 19 (location 182) the total thickness of the bed, inclusive of two partings, is 4 feet 11 inches. The section of the bed exposed at this place is shown graphically on Plate XIV (p. 290).

T. 135 N., R. 88 W.

The surface of T. 135 N., R. 88 W., is a smoothly rolling prairie, broken here and there by rocky buttes which are capped with resistant sandstone. A high rounded ridge extends into the western part of the township and from it the surface slopes gradually downward to the northeast and to the south. The area is drained by small streams, some of which flow north to Heart River and others east or south to Antelope Creek, which crosses the southwestern corner of the township.

All strata that outcrop in the township belong to the Fort Union formation. The surface mantle of soil is so nearly continuous, however, that the underlying rocks are exposed only locally in the more prominent buttes and in the deeply cut stream channels.

Lignite is being mined at the two Tipke mines in sec. 7 (locations 184 and 185), but elsewhere in the township, with the exception of a small mound of clinker in the NW. $\frac{1}{4}$ sec. 32, surface indications of lignite seem to be entirely lacking. In sec. 36, T. 135 N., R. 89 W., several small strip pits have been opened on the banks of Antelope Creek, at one of which (location 183) a section was measured and is shown graphically on Plate XIV. The total amount of coal is 4 feet 8 inches, but a parting of shale 1 foot 1 inch in thickness separates the bed into two parts. The clinker in sec. 32, T. 135 N., R. 88 W., is probably caused by the burning of this bed.

The two mines in sec. 7 are located on two beds which are separated by a stratigraphic interval of about 30 feet. The lower bed is exposed in the northern mine (location 184), where the thickness is approximately 3 feet, but the bottom of the pit was filled with water and an accurate measurement could not be obtained. In the southern mine (location 185) the bed is nearly 3 feet thick, including a 1-inch parting, and is overlain by a number of thin beds of lignite separated by shale partings. The complete detailed section is shown on Plate XIV.

The bed which is being mined in sec. 36, T. 135 N., R. 89 W., is probably one of the two beds described above.

T. 133 N., R. 87 W.

The northern part of T. 133 N., R. 87 W., lies on the divide between Heart and Cannonball rivers and is a region of broad open prairies interrupted locally by low buttes capped with resistant ledges of sandstone. The land in the southern part of the township is equally smooth and slopes gradually southward toward the valley of Cannonball River. The Cannonball branch of the Chicago, Milwaukee & St. Paul Railway crosses the northern part of the township and the town of Leith is located on that road in sec. 5.

The rocks that outcrop in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The rocks, however, are for the most part concealed by a heavy mantle of soil, so that exposures are rare. The contact between the two formations was sketched from topography alone.

Two beds of lignite outcrop on the sides of a group of high hills which extend into the northwestern part of the township. The lower of these is the more important and is being mined for local use in a drift mine in sec. 7 (location 188). The shaft mine, Jones mine, in sec. 12, T. 133 N., R. 88 W., is on the same bed. The Kolbank mine in sec. 7, owned and operated by Simon Pederson, was a strip

pit until the summer of 1913, when an entry was made. The graphic section shown on Plate XIV was measured at the entry. Although the total thickness of the bed is 7 feet 9 inches, only the lower part of the bed is being mined, because the upper part must be left for a roof. A sample for chemical analysis was collected in this mine, the analysis of which is shown on page 256. The thickness of the part mined where the sample was collected was 4 feet 10 inches.

South of the divide in the NE. $\frac{1}{4}$ sec. 18 (location 186) and in the NW. $\frac{1}{4}$ sec. 17 (location 187) the same bed was found in a weathered condition near the surface. At location 186, in an old prospect, 2 feet 3 inches of ash and weathered lignite is exposed. At location 187 a few inches of much-weathered lignite outcrops on the side of a low hill. These exposures, however, show only the remnants of the bed, which may confidently be expected to prove much thicker when exposed under a sufficient amount of cover to protect it from weathering. Mounds of clinker at several places within the township show where the bed has been burned at the outcrop. This clinker is especially prominent at the south end of a long ridge in sec. 19 and on the east side of Spring Butte in sec. 17. The same coal bed is exposed in a small strip pit on top of a rounded hill in sec. 10 (location 189), where the thickness of the bed is 4 feet. The lignite at this place, however, is much weathered and therefore of little value.

The upper bed was formerly mined by Mr. Pederson in sec. 7, about 1,000 feet southwest from the mine described above. The outcrop is now concealed, but the average thickness as reported by Mr. Pederson is about 4 feet. This bed is stratigraphically about 40 feet above the lower bed.

T. 134 N., R. 87 W.

T. 134 N., R. 87 W., lies on the northern side of the broad divide which separates the drainage systems of Heart and Cannonball rivers. The general slope of the surface is to the northwest toward Antelope Creek, which flows northeast across secs. 7, 6, and 5. The surface is for the most part well adapted to dry farming, but locally the rolling prairie is interrupted by steep-sided rocky buttes. A branch of the Northern Pacific Railway crosses the township centrally in an east-west direction. The town of Carson on that road is located in sec. 13. The outcropping rocks belong to the Fort Union formation, with the exception of a small area in the valley of Antelope Creek, in secs. 5 and 6; where the Cannonball marine member of the Lance formation is exposed. Practically the only natural exposures of the rocks within the township are in the valley of Antelope Creek and high up on the sides of some of the more rugged buttes.

Groups of rocky hills both north and south of Carson are underlain by the same bed of lignite which is mined at the Kolbank mine near Leith in T. 133 N., R. 87 W. The surface, however, is covered with

so heavy a mantle of soil that the lignite bed appears at the surface only at a few places. At the old Carter ranch in the SW. $\frac{1}{4}$ sec. 24 (location 190) is a drift mine now abandoned and largely caved. The following section was measured at the mouth of the mine:

Section in Carter lignite mine, SW. $\frac{1}{4}$ sec. 24, T. 134 N., R. 87 W., location 190.

	Ft.	in.
Shale, gray.....	10	
Shale, light brown.....		5
Lignite, good quality.....	2	3
Bone.....		3
Lignite, good quality.....	2	11+
Base, concealed by water.		

North of the town of Carson, in a group of three small but prominent hills, a considerable amount of prospecting for lignite has been done. Two drift mines have been opened on the south slope of the central hill in the NW. $\frac{1}{4}$ sec. 13 (location 192), but both have been abandoned. The following section was measured at the mouth of the west entry:

Section at mouth of abandoned lignite mine in NW. $\frac{1}{4}$ sec. 13, T. 134 N., R. 87 W.

	Ft.	in.
Shale, gray, sandy.....	10	
Shale, brown, carbonaceous at base.....		8
Lignite, bony.....		9
Bone.....		1
Lignite, fair quality.....		5
Bone.....		1
Lignite, good quality.....	1	3
Clay shale.		

The owner reported that there is considerable variation in thickness of the bed and that it locally reaches a thickness of 3 feet or more. The above, however, is probably a representative section.

A lower coal bed was reported to have been found at a depth of 40 feet in a well close to the railway track near Carson station (location 191); the driller reported that the well was sunk 2 feet into a bed of lignite and stopped. No other evidence could be obtained with regard to this lower bed.

T. 133 N., R. 86 W.

The northern part of T. 133 N., R. 86 W., lies on the divide between Cannonball River and Louse Creek, a region of wide rolling prairies interrupted by a few high rocky buttes. On the south this upland area is terminated by a moderately steep scarp beyond which is a region of smoothly rounded hills separated by steep-sided valleys. The Cannonball branch of the Chicago, Milwaukee & St. Paul Railway crosses the northern part of the township in an east-west direction. The town of Brisbane in sec. 9 is located on that road.

The rocks outcropping in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union for-

mation. The area is largely grass covered and exposures are few. The general character of the Cannonball member is shown by a few exposures along the larger streams in the southern part of the township; practically the only part of the Fort Union exposed is a heavy cross-bedded sandstone which outcrops in the higher buttes in the northeastern part of the township.

The coal bed which is mined at the Kolbank mine near Leith, in T. 133 N., R. 87 W., underlies a group of rounded hills in the northwestern part of the township. The only exposure found, however, was in a railway cut in sec. 7 (location 193), where the thickness of the bed is only 1 foot 6 inches.

T. 134 N., R. 86 W.

The topography in T. 134 N., R. 86 W., is somewhat diversified. Although the general character of the surface is that of a rolling upland prairie, in the southern part of the township a number of prominent rocky buttes rise above this general upland level which in the central and eastern parts is depressed by the wide valley of Louse Creek. The uplands are in most places separated from this valley by an escarpment which is particularly prominent in the north-central part of the township. In the northern part there are local areas of sand dunes. The whole of the township is drained by Louse Creek, one of the principal tributaries of Cannonball River. A branch of the Northern Pacific Railway crosses the central part of the township following the valley of Louse Creek for most of the distance.

The strata that outcrop in the township belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The rocks of the Cannonball member are exposed in the valley of Louse Creek, and those of the Fort Union formation underlie the upland area.

The lignite bed which is mined at the Kolbank mine near Leith, in T. 133 N., R. 87 W., underlies Circle Butte in sec. 31 and a few other high buttes in the southern part of the township. At the north end of Circle Butte some mining and prospecting have been done, but the openings are now largely fallen in and the lignite concealed. The lignite section at location 194, shown graphically on Plate XIV, was measured near the mouth of one of the old drift mines. Local reports indicate that the lignite in other openings is of better quality than that at the point examined and that the bed ranges in thickness from 4 to 6 feet. In a small prospect on an isolated butte in sec. 32 (location 195) the bed is only 1 foot 11½ inches thick and contains a parting of 1½ inches of shale 5 inches from the base. In sec. 26 (location 196), in another small butte, the bed was reported to have a thickness of only 1 foot.

T. 135 N., RS. 86 AND 87 W.

T. 135 N., Rs. 86 and 87 W., lies on the northern border of the broad upland separating the valleys of Heart and Cannonball rivers. The upland surface is a smoothly rolling prairie, above which rise a few rocky buttes capped by sandstone. The northward-flowing streams have cut deep canyon-like gorges through these uplands. The most prominent stream is Antelope Creek which flows northward through the western part of T. 135 N., R. 87 W.

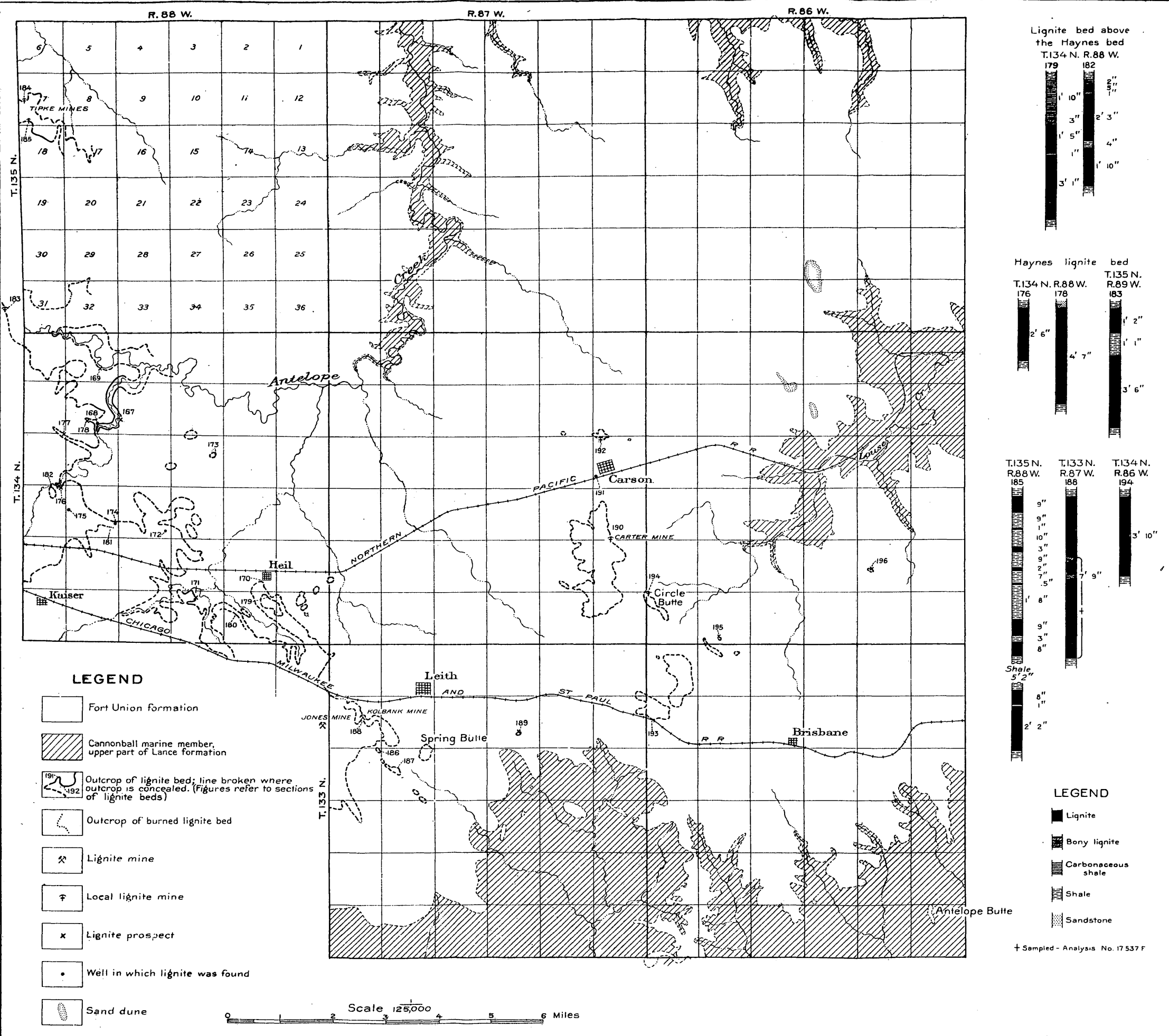
The greater part of the upland surface is sufficiently level for cultivation, but the sandy character of the soil makes large areas almost valueless except for grazing. In the southwestern part of T. 135 N., R. 86 W., is a considerable area of so-called lake beds. These lake beds or playas are dry, except after heavy rainfalls, and are almost surrounded by small areas of sand dunes.

The rocks that outcrop within the two townships belong to the Cannonball marine member of the Lance formation and to the Fort Union formation. The upper beds of the Cannonball member are well exposed in the steep stream bluffs, but the Fort Union strata are almost invariably concealed except for beds of resistant sandstone which form the capping of prominent buttes. No lignite bed of any value outcrops in either of the two townships.

EASTERN PART OF CANNONBALL RIVER FIELD.

A brief mention should be made of the thin beds of lignite in the large area examined in 1913 which is not included in the accompanying maps. A map and a more detailed description of this part of the field will be published later.

The majority of the lignite beds in the eastern part of the field belong to the lower part of the Lance formation. This series of strata, about 400 feet in thickness, is separated from the Fort Union formation, in which lie the important lignite beds described in the foregoing pages, by about 300 feet of the shales and sandstones of the Cannonball marine member of the Lance. This latter series contains no lignite and might properly be designated as "barren measures." The lower part of the Lance outcrops in the valleys of Cannonball River and its tributaries. It extends up Cedar Creek nearly to Howe post office, up Cannonball River almost to Janesburg, up Dogtooth Creek to Raleigh, and up Louse Creek several miles above Flasher. This is a region of wide flats bordered by steep badland bluffs in which the strata are well exposed. Numerous examinations were made of the lignite beds exposed in these bluffs and in the strip pits from which the local supply of fuel is obtained. So far as known the maximum thickness of any of the lignite beds in the Lance is in a local mine in sec. 10, T. 134 N., R. 84 W., a few miles south of Flasher, where the following section is exposed:



GEOLOGIC MAP OF CENTRAL PART OF CANNONBALL RIVER LIGNITE FIELD, MORTON COUNTY, NORTH DAKOTA

Lignite section in strip pit in sec. 10, T. 134 N., R. 84 W.

	Ft.	in.
Shale.....	12	
Lignite, good.....	2	3½
Shale, brown, carbonaceous.....	1	2
Lignite, good.....	1	1
Lignite, bony.....		9
Bone.....		2
Shale.....		

Half a mile south of this point, in Copenhagen's mine in the NE. ¼ sec. 15 of the same township, the bed is somewhat thinner, but similar with regard to the character and thickness of the partings. At this place about 4,000 tons of lignite has been mined by drifting, but the shale roof proved too weak and the drift was abandoned in favor of the more laborious method of stripping. In the northern part of T. 132 N., R. 84 W., and the southern part of T. 133 N., R. 84 W., strip pits have been opened up at a number of places and considerable amounts of lignite removed. The lignite in these pits ranges in thickness from 10 inches to 2 feet. Similarly thin beds of lignite have been mined in the badland areas west of Wade in Tps. 130 and 131 N., R. 86 W., and in the extensive badland bluffs northwest of Solen in Tps. 134 and 135 N., Rs. 81 and 82 W.

There are a few thin beds of lignite in the lower part of the Fort Union formation near the north border of the field. These beds were examined at several places in T. 136 N., Rs. 82, 83, 84, 86, 87, and 88 W. No bed, however, was found to be more than 2½ feet thick. At an abandoned mine in sec. 1, T. 136 N., R. 84 W., Mr. Woll, the owner, reported that the total thickness is about 3 feet but that there is a considerable amount of shale or bone.

Farther north, in T. 137 N., R. 89 W., a considerable amount of lignite is mined for local use. No examination, however, was made in this township.

