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GEOLOGY AND LIGNITE RESOURCES OF THE MARMARTH FIELD, SOUTHWESTERN NORTH DAKOTA

BY

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GEOLOGY AND LIGNITE RESOURCES OF THE MARMARTH FIELD, SOUTHWESTERN NORTH DAKOTA

By C. J. HARES

INTRODUCTION

SCOPE OF REPORT

It is generally recognized that the part of North Dakota lying west of Missouri River is richly endowed with beds of lignite, which though of low rank and small present value compared with other coals of the country, constitute a tremendous reserve supply of fuel that sooner or later will be called upon to supply light, heat, and power to the inhabitants of this and surrounding regions. Although the period of extensive utilization of such fuel may not yet be at hand, the United States Geological Survey has been examining these great fields as men and means were available for the purpose. The present report deals with a field occupying the southwest corner of North Dakota. (See pl. 1.) The field work upon which this report is based was done in 1911 and 1912, but as little development has taken place since that time, the report is reasonably complete in spite of the delay in publication, and it is placed before the public at a time when a growing interest is being manifested in the development of the lignite resources of this part of the country.

Although most of the time in the field was spent in examining and mapping lignite beds, considerable information concerning the general geology of the field was also gathered. The strata are well exposed in this field, and in most localities the topographic conditions are favorable to fairly detailed work. The greatest handicap to accurate field work was the lack of a topographic base map, and this need was only partly filled by the incomplete surveys made by the writer. Nevertheless, it is possible that no more detailed work will be done in this field for some years, and it has therefore been thought best to present such data as are available.

The report is divided into two parts—a general geologic description of the field and of its coal resources and a series of township descriptions in which the surface features, geology, and coal resources of

each township in the field are described in more detail. The first part is largely independent of the second, but the township descriptions merely describe local conditions and are intended to be supplemented by the broader discussions that precede them.

LOCATION AND RELATIONS OF THE FIELD

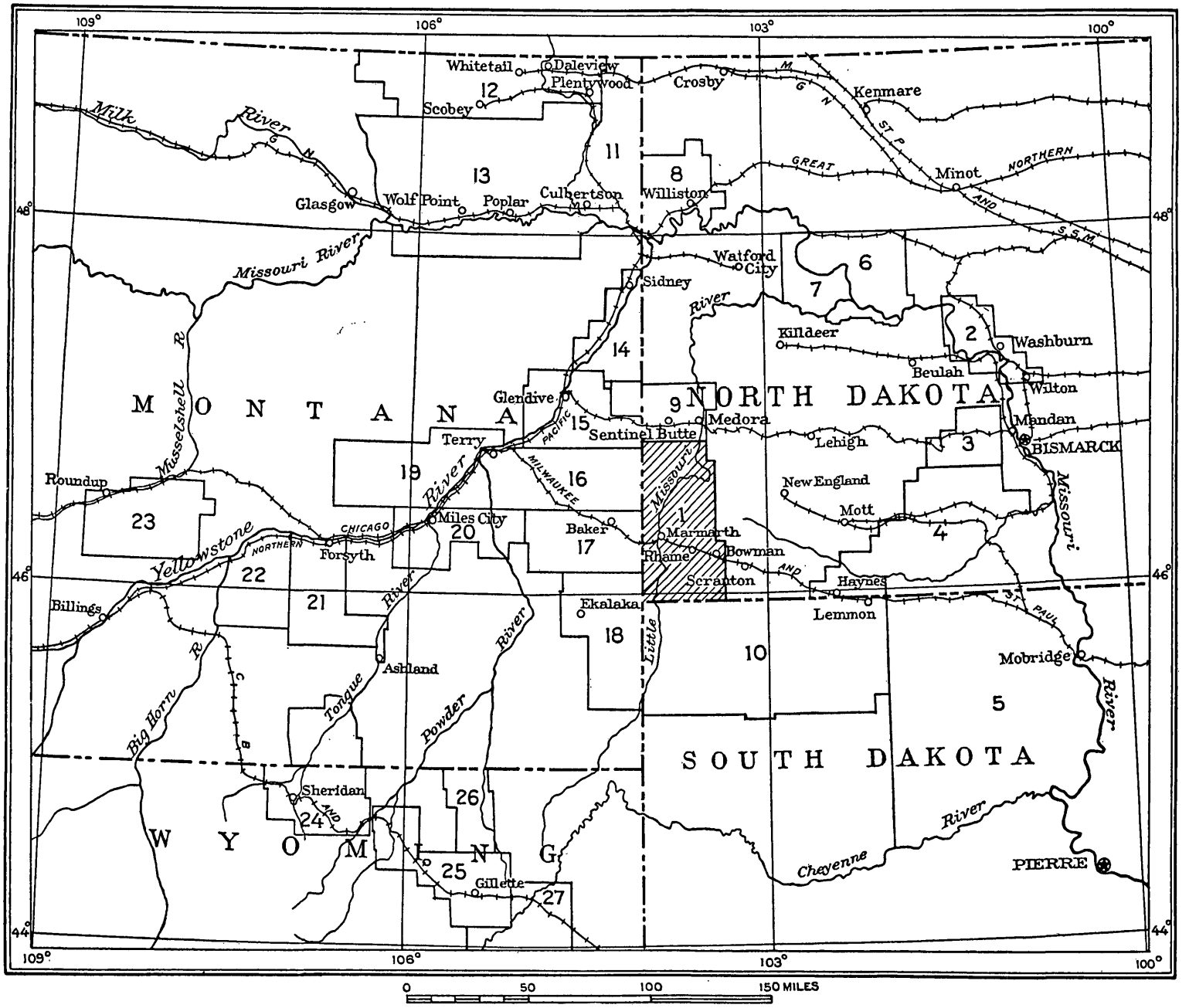
The Marmarth lignite field is a part of the great lignite-bearing region of western North Dakota, northwestern South Dakota, and eastern Montana and is not bounded by natural features. It includes an area of about 1,800 square miles in Slope, Bowman, Golden Valley, and Billings Counties, lying principally within the valley of Little Missouri River between the South Dakota line and the north line of T. 138 N. It is named from the town of Marmarth, although, as shown by Plate 14, the principal lignite beds are 5 or 6 miles from the town.

This field was selected for examination because the deep valley of Little Missouri River affords much better opportunities for a study of the lignite beds and the intervening rocks than the uplands on either side. As a result of the examination it was found that the field contains a reserve of lignite estimated at more than 15,000,000,000 tons, although more than half of the original quantity of lignite in the field has been eroded away by the streams, which are still engaged in cutting this valley and in extending the area of its noted badlands. The lignite is contained in the Lance and Fort Union formations and occurs in beds that are commonly as much as 8 to 10 feet thick. One bed in the Fort Union formation ranges from 20 to 30 feet in thickness over a large area. The heating value of the unweathered lignite of the two formations is about the same after the lignite is air dried, being approximately 9,000 British thermal units. The heating value of the lignite as mined, however, is somewhat less and is rendered variable by unequal water content. The geographic relations of the Marmarth lignite field and its location with reference to previously examined lignite fields in eastern Montana and western Dakota are shown by Plate 1.

FIELD WORK

The Marmarth lignite field, as implied above, was examined with three major purposes in mind—(1) to trace and map outcrops of lignite beds with reference to the land lines as established by the surveys of the General Land Office, that the land might be classified according to its lignite content as coal land or noncoal land;[1] (2) to determine the character, quality, amount, and accessibility of the lignite; and

[1] Land underlain by lignite beds 30 inches or more in thickness was considered as coal land, and the smallest subdivision of land classified was usually a 40-acre tract or a lot.



INDEX MAP SHOWING LOCATION OF MARMARTH FIELD

Marmarth field (No. 1) indicated by shading. Other fields are described in U. S. Geological Survey bulletins as follows:

2. Washburn ---- 381-A
3. New Salem ---- 726-A
4. Cannonball River ---- 541-G
5. Standing Rock and Cheyenne River ---- 575
6. Fort Berthold ---- 381-A, 471-C
7. Fort Berthold ---- 726-D
8. Williston ---- 531-E
9. Sentinel Butte ---- 341-A
10. Northwestern South Dakota ---- 627
11. Culbertson ---- 471-D
12. Scobey ---- 751-E
13. Fort Peck ---- 381-A
14. Sidney ---- 471-D
15. Glendive ---- 471-D
16. Terry ---- 471-D
17. Baker ---- 471-D
18. Ekalaka ---- 751-F
19. Little Sheep Mountain ---- 531-F
20. Miles City ---- 341-A
21. Forsyth (in preparation).
22. Tullock Creek ---- 749
23. Bull Mountain ---- 647
24. Sheridan ---- 341-B, 806-B
25. Powder River ---- 381-B
26. Little Powder River ---- 471-F
27. Gillette ---- 796-A

(3) to add to the present fund of knowledge any scientific data that could be gathered about the geologic formations.

No topographic base maps of the southwestern part of North Dakota had been made, and the only available maps were the township plats of the General Land Office. The first step in the preparation of the map of a township was to lay off on a 15-inch plane-table sheet a land net on a scale of either 2 inches or 1 inch to the mile, exactly according to the survey notes as recorded on the township plats. The instruments used were a 15-inch plane table, a 13-foot stadia rod, and a Gale telescopic alidade.

The map of each township was as a rule controlled by a local system of triangulation established from the land corners. The land surveys were accepted and so far as ascertained are correct. This gave 133 primary points in each township to use as desired in a system of triangulation, or for locations, or as points from which to start traverses. Any convenient objects, such as cairns, houses, windmills, or conical hills (natural points), were chosen to be located by triangulation from known points, and in places monuments were built to be cut into the system as work progressed. With control established, locations were easily made wherever desired and readily checked on a near-by corner. When the system of triangulation was established, any desired corner was located instrumentally without the exasperating search and loss of time so often necessary in badland areas where the traverse is unfinished. From a point determined in this manner traverses were made on lignite outcrops, and altitudes were determined by observations on the nearest monument or other fixed point of which the altitude was known or was to be determined later. Frequently considerable traverse work was executed before a township was controlled by triangulation. Many townships were completely mapped by the traverse method and some almost wholly by triangulation, but most of them by a combination of these methods. Locations were made directly by stadia readings from section corners, by intersection from plane-table stations, by intersections on fences or roads known to be located along section or quarter-section lines, or by reference to instrumentally located houses, etc. Some of the lignite beds were mapped almost entirely by triangulation from known stations. Many of the plane-table stations chosen were on commanding hills from which numerous rod readings were made and sights taken along outcrops or scarps, etc., which were later cut in from other stations similarly situated.

Instrumental locations along outcrops of lignite were usually made every 1,500 to 2,000 feet, in some places as close as 500 feet, and rarely more than 3,000 feet apart. The spacing of located points on

the outcrop was determined by several considerations. If the lignite bed were the lowest bed of classifiable thickness the locations were close together and the outcrop was mapped with as much accuracy as time allowed and results demanded; if the bed were thick, locations were closely spaced; if the bed were unimportant, locations were spaced according to the character of the surface and convenience.

It was the object always to determine the position of the lignite back of the badly weathered portion and back of the burned portion. The locating of many outcrops was purely a matter of judgment, as perhaps 90 per cent of the outer limits of the lignite beds are concealed by grassy slopes, by alluvial cover, by baked rock, or by cultivated fields.

Numerous altitudes were determined by vertical angles on points on the outcrops of beds of lignite, section corners, houses, and prominent surface features. They were all based on altitudes of the stations on the Chicago, Milwaukee & St. Paul Railway or the primary triangulation stations established in the field in 1912 by the United States Coast and Geodetic Survey. Some altitudes were checked by closed circuits or by cross observation, but many of them were not checked at all; however, most of the checked altitudes were found to agree within a foot or two for short distances and within 10 feet for distances over 2 miles. Some of those not checked may be in error more than these figures. Less pains was taken with the altitudes in the area worked in 1911 (Billings, Slope, and Golden Valley Counties) than in that worked in 1912 (Bowman County). The altitudes of points throughout the field are recorded usually to the nearest 10 feet—for instance, 2,906 is given as 2,910, and 2,904 as 2,900.

The writer was assisted during the field season of 1911 by C. M. Bauer, W. A. Price, jr., A. C. Collins, and T. A. Birch, and during the field season of 1912 by E. M. Parks, Stuart St. Clair, J. B. Reeside, jr., and Louis Roark. E. G. Woodruff, to whom the writer is indebted for many suggestions, exercised general supervision during both seasons. This opportunity is taken to express appreciation to the people of the region for the many kindnesses shown to the parties during the progress of the work.

PREVIOUS WORK

In 1895 Darton made an examination of the artesian waters of part of the Dakotas, including areas adjacent to the Marmarth field, and some information concerning the occurrence of lignite at Medora and elsewhere is included in his report.[2] As shown in Plate 1, many

[2] Darton, N. H., Preliminary report on artesian waters of a portion of the Dakotas: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, pp. 603-694, 1896.

other fields in this general region have been described in bulletins of the Geological Survey.[3]

In addition to the studies made by members of the United States Geological Survey, data on the occurrence, composition, and utilization of North Dakota lignite obtained by Wilder and Leonard, of the North Dakota Geological Survey, are published in the biennial reports of that survey. Of these examinations, one of especial interest is that conducted by Leonard between 1904 and 1908, covering the Marmarth field and adjacent areas.[4]

GEOGRAPHY

LAND FORMS

Within the Marmarth field active erosion by Little Missouri River and its tributaries has developed a belt of badlands along the river. In the northwestern and southeastern parts of the field, however, which have not yet been actively attacked by erosion, the surface is one of low relief, except where isolated buttes or clinker-covered ridges rise several hundred feet above the general level. Bright-red

[3] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, N. Dak. and Mont.: U. S. Geol. Survey Bull. 341, pp. 15–36, 1909.

Collier, A. J., and Smith, C. D., The Miles City coal field, Mont.: Idem, pp. 37–61.

Taff, J. A., The Sheridan coal field, Wyo.: Idem, pp. 123–150.

Smith, C. D., The Washburn lignite field, N. Dak.: U. S. Geol. Survey Bull. 381, pp. 19–29, 1910.

Smith, C. D., The Fort Berthold Indian Reservation lignite field, N. Dak.: Idem, pp. 30–39.

Smith, C. D., The Fort Peck Indian Reservation lignite field, Mont.: Idem, pp. 40–59.

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

Calvert, W. R., Geology of certain lignite fields in eastern Montana: Idem, pp. 187–201.

Bowen, C. F., The Baker lignite field, Custer County, Mont.: Idem, pp. 202–226.

Herald, F. A., The Terry lignite field, Custer County, Mont.: Idem, pp. 227–270.

Hance, J. H., The Glendive lignite field, Dawson County, Mont.: Idem, pp. 271–283.

Stebinger, Eugene, The Sidney lignite field, Dawson County, Mont.: Idem, pp. 284–318.

Beekly, A. L., The Culbertson lignite field, Valley County, Mont.: Idem, pp. 319–358.

Herald, F. A., The Williston lignite field, Williams County, N. Dak.: U. S. Geol. Survey Bull. 531, pp. 91–158, 1913.

Rogers, G. S., The Little Sheep Mountain coal field, Dawson and Rosebud Counties, Mont.: Idem, pp. 159–227.

Lloyd, E. R., The Cannonball River lignite field, N. Dak.: U. S. Geol. Survey Bull. 541, pp. 243–291, 1914.

Bauer, C. M., Lignite in the vicinity of Plentywood and Scobey, Sheridan County, Mont.: Idem, pp. 293–315.

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, 1914.

Winchester, D. E., and others, The lignite field of northwestern South Dakota: U. S. Geol. Survey Bull. 627, 1916.

Hancock, E. T., The New Salem lignite field, Morton County, N. Dak.: U. S. Geol. Survey Bull. 726, pp. 1–40, 1922.

Bauer, C. M., and Herald, F. A., Lignite in the western part of the Fort Berthold Indian Reservation south of Missouri River, N. Dak.: Idem, pp. 109–172.

Rogers, G. S., and Lee, Wallace, Geology of the Tullock Creek coal field, Mont.: U. S. Geol. Survey Bull. 749, 1923.

Collier, A. J., The Scobey lignite field, Valley, Daniels, and Sheridan Counties, Mont.: U. S. Geol. Survey Bull. 751, pp. 157–230, 1924.

Bauer, C. M., The Ekalaka lignite field, southeastern Montana: Idem, pp. 231–267.

Dobbin, C. E., The Forsyth coal field, Mont.: U. S. Geol. Survey Bull. — (in prepaation).

[4] Leonard, A. G., The geology of southwestern North Dakota with special reference to the coal: North Dakota Geol. Survey Fifth Bienn. Rept., pp. 29–114, 1908.

craggy hills composed of rock baked or fused by the burning of lignite beds enliven the landscape in many parts of the field.

BUTTES

Bullion and H T Buttes are landmarks, conspicuous for many miles around. H T Butte, in T. 134 N., R. 102 W., rises about 500 feet above the surrounding plain, to an altitude of 3,414 feet above sea level, and Bullion Butte, in T. 137 N., R. 102 W., stands nearly 1,000 feet above the river and 3,376 feet above sea level. These as well as Tepee and Roundtop Buttes are capped by massive and resistant sandstone and possibly represent monadnocks of an earlier erosion cycle. Pretty, Five Point, Haystack, and Postoffice Buttes are of somewhat rounded form and less prominent. They are capped by resistant porcellanite or clinker, which protects the underlying rocks from rapid erosion, thus maintaining their height and forms. The Medicine Pole Hills and Twin Buttes, which have flat tops due respectively to a hard cap of sandstone and to laminated quartzite, are other locally well-known features.

Throughout the area covered by the Hell Creek member of the Lance formation there are numerous large rounded hills, or "mud buttes," which the streams and rain are actively eroding. Such hills are common features of the landscape in western Bowman County.

BADLANDS

The noted badlands of North Dakota are found along Little Missouri River and its main tributaries, extending back from the river in places to a distance of 10 miles, in other places but a few miles. Through them the river meanders sluggishly, disappearing behind a group of hills, then coming into view only to disappear again behind more badland hills. These badlands are formed by the erosion of a former surface characterized by low relief, sluggish streams, and some monadnocks, which has been dissected by the streams until scarcely a flat-topped hill or ridge is left. The crests of the highest hills and ridges are at the same general level and merge with the more or less smooth surface of the rolling, grassy, and treeless upland, showing that at one time the upland was intact and covered the entire region but has been cut to pieces by the streams. All the larger streams in the badlands meander over flood plains, depositing detritus gathered in the upper parts of their courses when torrential rains wash down tremendous quantities of disintegrated material from the soft shale and sandstone. Small coulees are continuously being captured by larger ones that have greater tributary areas.

In the dissection of the region, which is composed of hard and soft rocks, hills of various and odd shapes are developed that, from some

vantage point, appear as serrated ridges, pinnacles, domes, cones, pillars of shale capped by sandstone, bare slopes with scanty vegetation, valleys of sharp acclivity, and vertical cliffs. To attain the summits of some of these hills and cliffs it is necessary to travel up a valley and approach them from a higher level. If the imagination is unrestrained it pictures nature in the process of sculpturing these weird and grotesque figures. Here a hard lens of sandstone juts out from the side of a bare hill; there one protrudes into the air as a huge log or connects two hills with a natural bridge. All these varied and fascinating erosion forms are repeated over and over again, until distinct outlines are lost to view and the myriad forms fade into the horizon.

No little amount of roughness in some parts of the badlands is contributed by the reddish porcellanite-capped hills, which add a pleasing touch of color to the landscape. This cap of craggy, slag-like material protects the underlying rocks from rapid erosion. Here and there such a cap crowns a conical hill or belts a terraced bluff. This material is formed by burning of lignite beds. The badlands are difficult to traverse not because of their great relief but because of their complete dissection, their precipitous slopes, the deep and in places vertical-walled gullies, and the almost endless repetition of angular features. The journey, if directed otherwise than along the drainage lines or divides, is one of continual ascent and descent and of heading by circuitous routes the numerous deep gullies and impassable box canyons of only a few feet in width. Such maneuvers are repeated over and over again as long as the journey remains in the rough land.

The growth of the badlands is interesting. In places the traveler may ride for some distance over a rolling grassy country and upon arriving at the crest of a divide or hill be confronted by abrupt downward slopes ("breaks") that merge into a chaos of badlands. As soon as the sod is broken good smooth country is rapidly transformed by erosion into an almost arid waste. Torrential rains falling on the bare soft rocks quickly run off, carrying tremendous quantities of mud and sandstone detritus. In most places in the badlands there is very little soil and on many slopes none at all; consequently plants have only the slightest chance to get a foothold—a condition favorable to rapid run-off and rapid erosion. All that seems necessary to start the process of forming badlands is a certain amount of relief, a semi-arid climate, a bare spot, soft rocks, and concentrated precipitation. When once started erosion continues until the profile of the valley is nearly flat. Here and there two or more badland areas may be working up the same valley. The younger ones may be caused by the deepening of the main stream or the giving away of a hard stratum of rock or, in very minor degree, even of tough sod.

The badlands along the Little Missouri in the area covered by this report have been formed chiefly since the terrace-building stage of the river's history. At that period there were probably very few if any badlands. Even to-day there are considerable areas of smooth grassy uplands and also of terraces, but both were far more extensive in the past and both are now being rapidly eroded by encroaching streams. The greatest extent of upland probably existed at the terrace-forming stage of the river, for many of the terraces partly merge with the uplands. Since then the river has deepened its valley in North Dakota by 50 to 350 feet. The larger tributaries have also deepened their valleys correspondingly, and many of the smaller branches have undoubtedly been formed since that time. Erosion, which had been essentially at a standstill, was quickened, and it is highly probable that a very large part of the badlands was subsequently developed.

Economically the badlands are of value in that they furnish shelter for livestock from severe winter storms. Considerably more forage grows in the coulees among them than would at first be suspected and affords a fairly abundant supply of food in winter as well as in summer. Here and there springs furnish water.

TERRACES

Broad level stretches of grassy land from a few acres to several square miles in extent lie here and there on both sides of Little Missouri River and usually within the major bends. The dissected terrace in the big bend of the river in Tps. 136 and 137 N., R. 102 W., is about 7 square miles in extent; there are also several large terraces in Bowman County. The altitude of the terrace remnants above the river at the South Dakota State line is about 100 feet; at Marmarth, 150 feet; at the big bend, 220 feet; and at Medora, 240 feet. The terraces slope downstream about 6 feet to the mile, whereas the grade of the river is about 7 feet to the mile, suggesting a rejuvenation of the present stream. At the T Cross ranch, in sec. 20, T. 133 N., R. 104 E., terraces occur at an altitude along Bacon Creek that would correspond to that of the terrace at Marmarth, if carried up Bacon Creek with due allowance for the grade of the stream. Likewise along Coyote Creek terrace remnants occur from its mouth to the Rhame gravel pit, which is excavated in one of the remnants. Similar terrace remnants are found up Garner, Williams, Bullion, Sand, Deep, Little Beaver, and Boxelder Creeks. These remnants represent a part of the same general system of terraces and were formed at about the same time and in much the same manner as the terraces along the present stream, though it is possible that some of the remnants may represent an older and higher set of terraces.

The material composing the terraces is soil and gravel. The gravel consists of sandstone, quartz, quartzite, diorite, gneiss, porphyry, basalt, porcellanite, clinker, fragmentary waterworn bones, and other materials. The bones in part were derived from the White River formation, and the igneous rocks probably from the Black Hills. The age of the terraces, which represent a former flood plain of the river, is probably early Pleistocene. Since the old flood plain was formed the river has renewed its degrading power and has cut a deep, narrow trench into the old valley floor, now represented by the terraces, allowing the minor streams to develop the badlands. This phase of the river valley is more fully treated in the section on badlands. Just what condition caused the river to deepen its channel is not entirely clear, as only a small part of the valley has been examined.

Regional studies by several geologists have shown that the waters of the upper Missouri and Yellowstone probably flowed to Hudson Bay prior to the advance of the early continental ice sheets of the Pleistocene epoch. It is probable that Little Missouri River was tributary to the same system, flowing northeastward across McKenzie County, N. Dak., from the present mouth of Bowlin Creek through a broad valley leading past Watford City to the present Missouri River channel near Nesson. When flowing on the 240-foot terrace at Medora the stream was probably at a high enough level to occupy this old valley past Watford City. This old valley is now drained partly to the north by Tobacco Garden Creek and partly to the southeast by Cherry and Red Wing Creeks.[5]

According to Leonard[6] the Little Missouri was forced from its old course along Cherry Creek by the advance of the great ice sheet in Kansan or pre-Kansan time, inasmuch as glacial drift is found on the floor of the old valley near its junction with the Missouri at Nesson. It has been recently suggested by Alden[7] that the advance of the ice sheet that crossed the gorge of Missouri River in North Dakota may have occurred as late as the Iowan stage of glaciation. To this advance may have been due the easterly diversion of the Little Missouri, and to rapid deepening of its new channel after regional uplift may have been due the cutting of the Little Missouri below the terrace described above. The present mouth of Little Missouri River is about 200 feet lower than the old one at Nesson, a difference in height which is nearly the same as the height of the terrace south of Bullion Butte.

[5] Wilder, F. A., Water supply and its relation to irrigation: North Dakota Geol. Survey Third Biennial Rept., map, p. 16, 1904. Bauer, C. M., A sketch of the later Tertiary history of the upper Missouri River: Jour. Geology, vol. 23, p. 52, 1915.

[6] Leonard, A. G., Pleistocene drainage changes in western North Dakota: Geol. Soc. America Bull., vol. 27, pp. 295-304, 1916.

[7] Alden, W. C., Physiographic development of the northern Great Plains: Geol. Soc. America Bull., vol. 35, pp. 385–424, 1924.

DRAINAGE AND WATER SUPPLY

The field is almost wholly in the drainage basin of Little Missouri River, which traverses it from south to north. The southeastern part of the field drains either directly into the North Fork of Grand River, a stream scarcely deserving the name, or into its tributaries. Both rivers eventually unite with the Missouri, the Little Missouri near Elbowoods, N. Dak., and the Grand near Mobridge, S. Dak. The divide between these two drainage basins is a low, interrupted grassy upland circling from Twin Buttes westward to Postoffice Butte, then southward to Table Mountain, in South Dakota, the culminating point from which waters flow into both North and South Forks of Grand River and Little Missouri River. The valley of Little Missouri River, deeply intrenched in the badlands, is a very striking feature. Meanders are well developed, oxbows are numerous along its course, old cut-offs occur here and there, and new cut-offs may be made at any time. The main tributaries of the Little Missouri in this field are Boxelder, Little Beaver, Deep, Sand, and Bullion Creeks; lesser ones, beginning at the South Dakota line, are Coyote, Bacon, Indian, Boyce, Cannonball, Bull Run, Williams, Third, Bear, Dantz, and Garner Creeks. Alkali and Spring Creeks are tributaries of the North Fork of Grand River. The smaller creeks are mostly intermittent, but the main ones may be classed as perennial if the interpretation is liberal.

The mean annual precipitation in the region is about 13.5 inches or slightly more, which falls mostly between April and September. The region is consequently to be classed as having a semiarid climate. Little Missouri River affords the greatest available supply of good water; supplementary to it are the creeks, which in extremely dry seasons have only water holes or springs along their courses. The water in these creeks is usually alkaline. Probably 100 springs were observed during the field examination; of these about nine-tenths issue from lignite beds and yield rather poor water, but most of the remainder flow from sandstone and yield water of better quality. The poorest, most contaminated water is the discolored, alkaline seepage water in the low boggy places in the valleys.

Considerable difficulty is encountered in obtaining good wells. The water from some is so alkaline as to be unfit to drink and would not be used if better water could be found. A large proportion of the wells derive their water from lignite beds. The wells on the Fort Union formation (see pl. 14) yield better water than those on the Lance or Pierre, probably owing to the greater amount of sandstone in the Fort Union formation.

Artesian wells have been obtained at two localities. One well on the Moulton farm, in the NE. ¼ sec. 26, T. 138 N., R. 106 W., which is reported to be 106 feet deep, flows a fairly strong stream of water

from a 1-inch casing. A number of shallow artesian wells at Marmarth yield potable water. The source of this water is doubtless the Fox Hills sandstone, which crops out a short way up the Little Missouri and also on Little Beaver Creek, where surface water has a good opportunity to penetrate the porous sandstone. The intake area is somewhat higher than the surface at Marmarth, hence the water is under sufficient hydrostatic pressure to rise to the surface when the sandstone is tapped anywhere along the river from a point a short distance above Marmarth to a point a considerable distance below. Artesian wells have been obtained as far down the valley as Medora. It is not likely that flowing wells can be obtained from the Fox Hills sandstone in any of the upland areas, because most of the uplands are higher than the sandstone outcrops along the river.

TIMBER

The region as a whole is almost devoid of trees. Thinly scattered yellow pines (*Pinus ponderosa*) grow in T. 136 N., Rs. 102 and 103 W., where the physical condition of the soil favors their growth. A small number of pine trees grow on the red hills in other parts of the field and would make mine timber, but the supply is scanty. Cottonwood trees in considerable abundance grow on Little Missouri River, and boxelder, ash, and elm grow along the creeks. Buffalo berry bushes, which flourish along the river and large creeks, are a source of native fruit.

SURVEYS

The western State boundary and some of the township lines were surveyed in 1884 and 1885. The State boundary between North Dakota and South Dakota was surveyed in 1892 and is well marked every half mile by large monuments of red sandstone. Accurate surveys were made by the General Land Office in 1900, 1902, 1903, and 1904. Township, section, or quarter corners, if they have not been destroyed by traffic on roads, plowed out, or otherwise carelessly obliterated, may be found in almost every section.

In the districts that are settled it is common to find the corners on roads destroyed, mutilated, or crushed beyond recognition by the passage of traction engines and other heavy vehicles over them, or carelessly plowed out by power breaking outfits. Such destruction, though it may not be willful, is civil negligence, and the misdemeanor is punishable by fine or imprisonment.

A survey made by the Northern Pacific Railway passes in the vicinity of Bessie.

During the summer of 1913 a primary triangulation control net was carried by the Coast and Geodetic Survey from the Canadian line to the Black Hills, and three of the stations are in this field—one on H T Butte, one on Twin Buttes, and a third near milepost 333 on the

State line between North Dakota and South Dakota, near the southwest corner of T. 129 N., R. 102 W.

COMMERCIAL RELATIONS

The Northern Pacific Railway parallels the northern boundary of the field at a distance of about 8 miles, and since the field work for this report was completed a branch line has been built from the Northern Pacific at Beach into the northwest corner of the field. The Chicago, Milwaukee & St. Paul Railway crosses the field a short distance south of the middle. The Yellowstone Trail crosses the southern part of the field, and stage, mail, and telephone routes extend from Sentinel Butte to Alpha; a mail route from Ollie, Mont., to Stuart; stage and mail routes from Medora to Hanly; stage, mail, and telephone routes from Bowman by way of Bessie and Slope Center to Ranger; stage and mail routes from Rhame to Bierman by way of Mound; a mail route from Marmarth to Elder and Camp Crook, S. Dak.; stage and mail routes from Bowman to Langberg by way of Amor; and a mail route from Bowman to Ring.

In the areas taken up by homesteaders roads are numerous and are usually located on section lines, but in the badlands they are few and naturally follow the easiest grades. Throughout the zones in which the arable lands merge with the badlands the routes of travel are changed from time to time, and those of the early ranchmen are closed by fences as incoming homesteaders locate claims and force the highways onto the section lines.

The Marmarth field is sparsely populated, and a considerable percentage of the homesteaders have come into the country since 1900. Applications have been filed on virtually all the more arable tracts, and in 1912 ranches were located only along the "breaks" of the badlands bordering Little Missouri River or the larger stream valleys.

The town of Marmarth (population in 1920, 1,318) is a division point on the Chicago, Milwaukee & St. Paul Railway. Rhame (population 302), the highest point on this railway in North Dakota, is a thriving town, and Ives and Griffin are railway stations. Bowman (population 767) is an important business center and is the county seat of Bowman County.

The principal industry of the country until about 1905 was cattle and horse raising. Some of the well-known ranches were the H T, the 777, the T Cross, the LA, the Z Bell, and the Bullhead. Large herds of cattle ranged over the Government land, and the raising of beef cattle was a profitable industry. In later years bands of sheep superseded cattle in western Bowman County and southwestern Slope and Golden Valley Counties. But with the advent of homesteading, chiefly since the opening of the Chicago, Milwaukee & St. Paul Railway, the stock-raising industry has dwindled until it

is confined to the very roughest parts of the badlands along Little Missouri River. The homesteaders took up the smoother and better land in the eastern part of the field and also around the old post office of Burkey and gradually encroached upon the "breaks," even selecting the level isolated tracts along the river.

Away from the badlands the homesteaders have taken up nearly all the even sections of land except 16 and 36, which are school sections. The odd sections for a distance of 50 miles north and south of the Northern Pacific Railway were granted to that corporation by Congress in 1862; hence those sections can be acquired only by purchase, and few of them are settled. The regions of profitable dry farming are limited to the upland underlain by the Fort Union formation (see pl. 14), which gives rise to a sandy loam such as occurs about Golva, Bierman, Slope Center, Bessie, Rhame, and Bowman. The gumbo soil derived from the Pierre shale and the lower part of the Lance formation is very poorly suited for farming, and in the areas underlain by those formations the homesteaders are noticeably less prosperous, and many of the homesteads have been abandoned. Soil derived from the Ludlow member of the Lance formation is somewhat better than that from the Hell Creek member of the Lance but is not nearly as good as that derived from the Fort Union. Wheat, corn, rye, barley, and flax are the principal crops raised. The growing season is often too short or too dry for maturing corn, but even when climatic conditions are thus unfavorable for corn considerable fodder is produced.

The agricultural history of the region shows that crop failures have been rather frequent, being due mainly to abnormally dry seasons, hot winds, and hail, listed in the order of their importance. These failures, the nonarability of considerable areas, and the heavy soils of others render the lands of considerable parts of the Marmarth field poorly suited to dry farming.

STRATIGRAPHY

GENERAL SECTION

The outcropping rocks of the Marmarth field belong to the Cretaceous, Tertiary, and Quaternary systems. The Cretaceous is represented by some 350 to 400 feet of exposed strata belonging to the Pierre shale and Fox Hills sandstone, and the lignite beds of the field are contained in the Lance and Fort Union formations, which, according to Thom and Dobbin, constitute a transition group between Cretaceous and Eocene.[8]

The following composite section shows the general character of the formations in this field:

[8] Thom, W. T., jr., and Dobbin, C. E., Stratigraphy of the Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. America Bull., vol. 35, pp. 481–505, 1924.

Composite geologic section of the Marmarth lignite field

System	Series	Group	Formation and member	Character	Thickness (feet)
	Recent.			Sand dunes; silt, sand, and gravel on flood plains of the rivers and larger creeks.	0–20 (?)
Quaternary.	Pleistocene.		Terrace gravel.	Terrace gravel, composed of quartzite, vein quartz, granite, porphyry, syenite, diabase, baked rock, bones, etc.; pebbles probably derived in part from the White River formation; found chiefly along the Little Missouri but in part along its larger tributaries. Some of the higher remnants may be Tertiary.	0–20
			—Unconformity—		
	Oligocene (?).		White River (?) formation.	Massive light-gray or reddish nonfossiliferous sandstone, firmly cemented; caps H T and Bullion Buttes; continental deposits. The former existence of definite White River beds is indicated by the presence of fossil mammalian bones lying on this massive sandstone and on top of the Medicine Pole Hills.	250±
			—Unconformity (?)—		
Tertiary.	Eocene.		Fort Union (?) formation. Sentinel Butte shale member.	Somber colored sandy shale, gray sandstone, and lignite interbedded; lithologically very similar to the Hell Creek member of the Lance; continental deposits.	350
			Fort Union formation. Tongue River member.	Light-colored shale, sandy shale, limy sandstone, and thick persistent lignite beds; thin limestone lenses; peculiar fissile quartzite on Twin Buttes (about 300 feet from base); very resistant fine-grained quartzite 50 to 200 feet above base; base in places is massive conglomeratic buff channel sandstone; abundant Fort Union leaves and shells; continental deposits.	600
			Local unconformity		
Tertiary(?).	Eocene (?).		Lance formation. Ludlow lignitic member.	Prevailingly dark sandy and carbonaceous shales and limy sandstone with interbedded lignite, which is extremely variable; here and there the sandstone and shale are light-colored; Fort Union leaves and fresh-water shells; continental deposits. Merges eastward into Cannonball marine member of Lance formation represented in this field by brackish-water beds containing *Ostrea glabra* near Yule and Mound.	250+
			Hell Creek member.	Dark-gray and brown sandstones and shales, very much cross-bedded; variable, nonpersistent strata; abundant ferruginous nodules; gives rise to a very poor soil; weathers to rounded hills, many of which protrude through grassy areas; *Triceratops* remains; continental deposits.	575
Cretaceous.	Upper Cretaceous.	Montana.	Fox Hills sandstone. Colgate sandstone member.	Medium fine-grained light-gray sandstone, partly marine.	17–40
				Light-brown sandstone; thin layers of shale in places; locally a band of shale at top; contains *Halymenites major* and a few other marine fossils; marine.	24–45
			Pierre shale.	Dark-gray or tan shale containing marine fossils; gives rise to a gumbo soil; weathers to low, smoothly rounded hills; marine.	400+

CRETACEOUS SYSTEM

MONTANA GROUP

PIERRE SHALE

Distribution and thickness.—More than 400 feet of dark-gray marine shale of Pierre age crops out along the Cedar Creek anticline in a strip about 75 miles long and from half a mile to 6 miles wide,[9] extending from Yellowstone River near Glendive, Mont., nearly to the North Dakota and South Dakota State line. The surface of the country underlain by the Pierre is one of low, rounded hills with smooth-sided valleys, which present a sharp contrast to the "mud buttes" of the Lance or the flat-topped hills of the Fort Union. It is uninviting and uninteresting. Throughout a large part of the Great Plains the formation lies nearly flat, and no good data are available as to its local thickness. In this vicinity it is probably about 2,000 feet thick.

Composition.—The shale is well exposed at the Allison ranch, on Little Missouri River, and at the Ash ranch, on Little Beaver Creek. It is remarkably homogeneous except for abnormally indurated clayey masses, which are present in almost all exposures. The grayish-brown dense clay masses weather to a reddish-brown color due to a large percentage of iron. They break with a conchoidal fracture and resemble similar masses in the Fox Hills sandstone. Small irregular masses of fibrous calcite are scattered through the shale, and crystals of selenite, often incorrectly spoken of as mica, are common upon bare surfaces, but the quantity is so small that they have no economic importance. Small amounts of gypsum are disseminated through the shale and are the source of a part of the alkaline impurities in the water flowing through the formation. The surface of the shale after a dry period is frequently coated white with alkaline salts left as the water evaporates. Cone-in-cone structure is a characteristic feature of the formation in almost all outcrops. The shale is a soft, crumbly rock, and fresh specimens of almost black color, taken from the Ash ranch, can readily be cut with a knife but harden upon exposure and turn to a gray or light slate color. It is even textured and is composed of particles so minute that none of them can be identified, even with a hand lens. The Pierre shale when wet is treacherous and slippery, but when the ground begins to dry it is very sticky and forms a soil known as gumbo. Ranchers or farmers seldom locate on this shale, for it gives rise to an extremely poor soil that supports only a sparse growth of grass, salt sage, and cactus and cracks deeply and bakes in drying.

[9] Leonard, A. G., Geology of southwestern North Dakota, with special reference to the coal: North Dakota Geol. Survey Fifth Bienn. Rept., p. 42, 1908. Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, pp. 187–201, 1912.

Fauna.—The part of the Pierre shale exposed in the Marmarth field contains an abundant and varied marine invertebrate fauna, which is found best preserved in the numerous calcareous concretions of the formation and which includes many species that are also found in the overlying Fox Hills sandstone. Such species as *Inoceramus barabini, Baculites ovatus,* and *Scaphites nodosus* are, however, restricted to the Pierre. Collections obtained in secs. 23 and 24, T. 132 N., R. 107 W., on Little Beaver Creek 4 miles southwest of Marmarth, by Leonard [10] and also by the writer, include the following species:

Micrabacia americana Meek and Hayden.
Ostrea pellucida Meek and Hayden.
Chlamys nebrascensis Meek and Hayden.
Avicula linguaeformis Evans and Shumard.
Inoceramus barabini Morton.
Trigonarca (Breviarca) exigua Meek and Hayden.
Nucula cancellata Meek and Hayden.
Yoldia evansi Meek and Hayden.
Leda subnasuta Hall and Meek.
Eriphyla gregaria Meek and Hayden.
Protocardia subquadrata (Evans and Shumard).
Lucina occidentalis Morton.
Lucina subundata Hall and Meek.
Callista deweyi Meek and Hayden.
Cuspidaria moreauensis (Meek and Hayden).
Margarita nebrascensis Meek and Hayden.
Aporrhais biangulata Meek and Hayden.
Vanikoro ambigua Meek and Hayden.
Pyrifusus newberryi Meek and Hayden.
Fasciolaria (Cryptorhytis) flexicostata Meek and Hayden.
Anisomyon patelliformis Meek and Hayden.
Anisomyon subovatus Meek and Hayden.
Haminea occidentalis Meek and Hayden.
Baculites ovatus Say.
Scaphites nodosus var. plenus Meek and Hayden.
Scaphites nodosus var. brevis Meek.

FOX HILLS SANDSTONE

Geographic distribution and thickness.—The Fox Hills sandstone, consisting of 60 to 85 feet of soft yellow to light-gray sandstone, rests conformably on the Pierre shale and surrounds the outcrop of the Pierre along the Glendive anticline and at its extreme southern extension crosses the State line into South Dakota. It is well exposed in the railroad cut 3½ miles west of Marmarth, in the bank of Beaver Creek in the same vicinity, in the southwest corner of T. 132 N., R. 106 W., and in numerous banks along Little Missouri River. (See pl. 2.) Its width of outcrop varies greatly from place to

[10] Leonard, A. G., North Dakota Geol. Survey Fifth Bienn. Rept., pp. 42, 43, 1908.

place, depending upon the surface of the ground. It is identified, on the strength of its fossils and its position above the Pierre shale, with the Fox Hills sandstone of the type locality, Fox Ridge, S. Dak.,[11] and it corresponds to the sandstones which have been mapped on both sides of the Glendive anticline in Montana from Yellowstone River to the North Dakota line under the name Colgate sandstone member and which as originally described[12] included not only the Colgate sandstone member of the Fox Hills as defined in this report but also the lower part of the Fox Hills.

Composition.—In the Marmarth field the Fox Hills formation consists of two members, the lower a brown fine-grained calcareous sandstone 24 to 45 feet thick and the upper (Colgate sandstone member) a light-gray massive cross-bedded sandstone 17 to 40 feet thick. Both members contain remains of the seaweed *Halymenites major*. The Colgate member in particular weathers into striking fluted forms much like organ pipes. (See pl. 2, *B*.) The two sandstones are locally separated by a layer of shale, and both are only slightly consolidated. A specimen microscopically examined consists of about one-half calcareous cement, one-fourth angular quartz, one-fourth fresh feldspar, and some mica and iron oxide. Detailed sections of the formation are given below.

Section of Fox Hills sandstone and adjacent formations on Little Beaver Creek in sec. 18, T. 132 N., R. 106 W.

	Ft.	in.
Lance formation:		
1. Sandstone, yellow.		
2. Shale, chocolate-brown, carbonaceous	3	
3. Sandstone, light gray, like No. 8	3	6
4. Shale, drab	8	
5. Sandstone, light gray, much like No. 8	4	
6. Shale, drab	2	
7. Sandstone, light gray, cross-bedded and shaly at bottom, wavy line at bottom, very much like No. 8; 0–10 feet	5	
Fox Hills sandstone:		
8. Sandstone, massive, gray, changing to yellow at bottom; *Halymenites major* (Colgate sandstone member)	35	
9. Shale	1	2
10. Sandstone, generally yellow, with lenses of shale; parts of sandstone are greenish; all finely laminated	24	
Total, Fox Hills sandstone	60	2
Pierre shale:		
11. Shale, dark, grading into the sandstone above.		

[11] Meek, F. B., and Hayden, F. V., Acad. Nat. Sci. Philadelphia Proc., vol. 13, pp. 419–427, 1862.

[12] Calvert, W. R., The geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, fig. 7, p. 189, 1912.

It is obvious that the rocks represented by Nos. 1 to 6 in the upper part of this section belong to the Lance formation, but it is difficult to determine just where the line separating the Lance from the Fox Hills should be drawn. No. 7 is similar in composition to the Colgate member of the Fox Hills sandstone, which underlies it, but as its base is an irregular surface it is regarded as the basal member of the Lance formation. Nos. 9 and 10 belong to the lower part of the Fox Hills.

Section of Fox Hills sandstone near Allison ranch, on Little Missouri River in the NW. ¼ NW. ¼ sec. 11, T. 130 N., R. 106 W.

	Feet
Top of terrace.	
Fox Hills sandstone:	
Sandstone, fine grained, massive, light gray, with *Halymenites* (?) (Colgate sandstone member)	17
Sandstone, light yellow or tan-colored, massive and exceedingly fine grained; contains many nodular limonitic masses very like *Halymenites;* also concretions and true *Halymenites major*	36
Total, Fox Hills sandstone	53
Pierre shale: Shale, dark, massive, arenaceous at top	32

Section of Fox Hills sandstone in sec. 33, T. 132 N., R. 106 W.

	Ft.	in.
Shale, with cabonaceous layers (Lance).		
Sandstone, soft, white, concretionary and cross-bedded; small amounts of bituminized wood; limonite concretions (Colgate sandstone member)	40	
Clay pebbles like Pierre shale		6
Sandstone, yellow, concretionary and cross-bedded; reed stems; flakes of white mica	45	
Total, Fox Hills sandstone	85	6
Shale, dark gray, with limy concretions (Pierre).		

On the north side of T. 131 N., R. 106 W., about 50 feet of the Fox Hills is exposed, including the gray Colgate sandstone member and the underlying brown ferruginous sandstone, which contains a few shark teeth. Locally the Colgate member contains lenses of brown ferruginous sandstone. Generally the subangular grains of sand are loosely cemented. Here the Fox Hills is distinct from the overlying Lance, but there is no abrupt break between them. At one place the Colgate grades laterally into a sandy carbonaceous shale such as is characteristic of the Lance, and the base of this brown carbonaceous layer is in places sharp and irregular to the extent of 30 feet, as in T. 131 N., R. 106 W. There the lower, brown, ferruginous sandstone of the Fox Hills is overlain by brown shale, gray shale, and sandstone of characteristic Lance appearance.

Associated with the Colgate member of the Fox Hills sandstone are nodules, some of which may be easily mistaken for *Halymenites.*

Both members of the Fox Hills give rise to a sandy soil that is easily distinguished from the gumbo soil of the Pierre shale and is more suitable for farming. It supports more and better natural grasses and less cactus and sagebrush.

Fossils.—The Fox Hills sandstone contains very few fossils in this field. Both members contain *Halymenites major*, and the lower member has yielded a few shark teeth at location AA, secs. 18 and 32, T. 132 N., R. 106 W. On Little Beaver Creek *Leda* (*Yoldia*) *evansi*, *Tellina scitula*, and *Entalis? paupercula* were collected by Stanton [13] at location B, sec. 7, T. 132 N., R. 106 W. The sandstone is designated Fox Hills by virtue of these fossils and its stratigraphic and geographic position. In other parts of Dakota this formation contains an abundant marine invertebrate fauna, which includes such common forms as *Cinulia concinna* Meek and Hayden, *Limopsis striatopunctata* Evans and Shumard, *Lunatia occidentalis* Meek and Hayden, and also the distinctive cosmopolitan species *Scaphites conradi* Morton and *Sphenodiscus lenticularis* Owen.

Stratigraphic relations.—The sandstone grades downward by alternation of beds of light sandstone and dark shale into the typical Pierre shale, so that it is almost impossible to be sure that the lower limit as determined is everywhere at the same horizon. According to Leonard,[14] there is, on Little Beaver Creek, an unconformity at the top of the Fox Hills. Stanton[15] suggests that this and the unconformities in the Lance are such as are common to continental deposits, and in view of the fact that in other places there is a transition by alternation of beds of Lance and Fox Hills character little weight is attached to such a phenomenon. The thickness of the Fox Hills is not more than 85 feet or somewhat less than at its type locality at Fox Ridge, S. Dak., a condition due either to unequal deposition in the two localities or to a longer duration of marine conditions in the Fox Ridge area. The Marmarth field was not affected by great erosion at the end of Fox Hills time, nor was there a large accumulation of sediment. The geologic record here seems to be complete in this part of its development. This conclusion has been verified by W. T. Thom, jr., C. E. Dobbin, and J. B. Reeside, jr., of the United States Geological Survey, as the result of field work done in 1923, and it is also corroborated by C. H. Clapp,[16] of the Montana Bureau of Mines, and by Ward and Wilson,[17] of the South Dakota Geological Survey.

[13] 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, p. 182, 1910.

[14] Op. cit., pp. 43-44, pl. 5.

[15] Op. cit., pp. 182-188.

[16] Clapp, C. H., and others, Geology and oil and gas prospects of central and eastern Montana: Montana Univ. Bull., Bur. Mines and Metallurgy series, No. 4, pp. 25-26, 1921.

[17] Ward, Freeman, and Wilson, A. A., The possibilities of oil in western Dewey County, S. Dak.: South Dakota Geol. and Nat. Hist. Survey Circ. 9, p. 7, 1922. Ward, Freeman, The Lance problem in South Dakota: Am. Jour. Sci., 5th ser., vol. 7, pp. 65-68, 1924.

TERTIARY (?) SYSTEM

LANCE FORMATION

GEOGRAPHIC DISTRIBUTION

Rocks of the Lance formation are found mainly in the southwest half of the field, surrounding the outcrops of the Fox Hills sandstone. However, they are exposed by erosion in a few areas on the river in T. 138 N., R. 102 W., and T. 136 N., R. 102 W.; on Sand Creek in T. 135 N., R. 102 W.; and on Deep Creek in T. 135 N., R. 103 W. The rocks assigned to the lower part of this formation are correlated with the "*Ceratops* beds" of Converse County, Wyo.;[18] and the Hell Creek member of the Lance of this report is correlated with the Lance of the old Standing Rock and Cheyenne River Reservation as described by Calvert and others;[19] the Lance around the northern portion of the Glendive anticline, Montana, as described by Calvert;[20] the lower member of the Fort Union of southwestern North Dakota as defined by Leonard;[21] and the lower unnamed member of the Lance of northwestern South Dakota.[22]

STRATIGRAPHIC RELATIONS

So far as was observed in this field, no notable break occurs between the Lance formation and the underlying Fox Hills sandstone. Exposures along this contact are very poor except as stated in the description of the Fox Hills. In places the Lance is separated from the overlying Fort Union by minor breaks in sedimentation, described on pages 36–37, which are probably the result of local scour in stream channels now filled by massive sandstones. From a comparison of sections measured at many localities in eastern Montana and western North Dakota it has been concluded[23] that the zone of lithologic change between Lance and Fort Union rises in the geologic column as the formations are traced eastward from Glendive, Mont., into North Dakota, thus explaining the existence of the Lance outcrops that are found in the northeastern part of the Marmarth field, in spite of the gentle northeastward dip of the strata.

COMPOSITION

The Lance is made up of limy sandstone, sandy shale, shale, and lignite. The sandstone is predominant and for the most part is dark

[18] Hatcher, J. B., The *Ceratops* beds of Converse County, Wyo.: Am. Jour. Sci., 3d ser., vol. 45, pp. 135–144, 1893.

[19] 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. 17–22, 1914.

[20] Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, pp. 194–198, 1912.

[21] Leonard, A. G., Geology of southwestern North Dakota, with special reference to the coal: North Dakota Geol. Survey Fifth Bienn. Rept., p. 42, 1907–8.

[22] Winchester, D. E., and others, The lignite field of northwestern South Dakota: U. S. Geol. Survey Bull. 627, p. 19, 1916.

[23] Thom, W. T., jr., personal communication.

gray or brown. A few beds are of buff color, and all of them contain a large proportion of lime. They are in many places cross-bedded and ripple marked. The lower or Hell Creek member of the Lance contains little lignite except thin, worthless layers, whereas the upper 250 feet, differentiated as the Ludlow lignitic member, contains several fairly thick though variable beds of lignite. The shales are of varied character and color. Some are light yellow or buff, but most of them are gray, drab, brown, or of general dark hue. Some are slightly sandy, and others highly sandy; some are brown and flaky, closely resembling lignite. Concretionary masses of sandstone in places weather out from the main mass of strata; some of the concretions are spherical; others are elongate and are often spoken of as "log" concretions. They probably represent greater lithification of the sandstone.

HELL CREEK MEMBER

Ferruginous nodules and layers are characteristic features of the Hell Creek member of the Lance and are sparingly present in the Ludlow lignitic member of the Lance, but are, as a rule, rare in the Fort Union, though fairly numerous in the Sentinel Butte shale member. The nodules are of various queer shapes and sizes, some round, some flat, some cylindrical, and some branching much like the fossil plant *Halymenites major*. They also resemble this fossil in the surface markings and are sometimes wrongly identified as fossils. The ferruginous masses occur in some places as lenses or irregular masses, in others as layers, associated usually with cross-bedding, which incline as high as 15° and are thick enough to be incorrectly interpreted as indicating the true bedding of the strata. The colors of the weathered material are brownish yellow, brown, dark red, and nearly black. Much of the nearly black material has a shiny luster. When broken the dark oxidized coating on many specimens is only a veneer, or the whole interior may be completely altered. The dense, compact, and gray unaltered material is largely iron carbonate. The coating marks the progress of oxidation from impure iron carbonate to iron oxide. In weathering the coating often shows a structure resembling that of a tortoise shell, and commonly the exterior markings extend to the unoxidized part. Some specimens exhibit a columnar structure in the coating. The content of iron probably varies greatly, the darker nodules carrying the larger amount.

Large numbers of these nodules accumulate at the foot of bare slopes, as the finer, lighter, and less resistant material washes or is blown away. They are contemporaneous in origin with the inclosing rocks, not due to secondary accumulation of the iron, as the material takes part in the cross-bedding and the nodules, so far as noticed, show no evidence of having grown and forced the laminae apart; however, no specimens were collected showing bedding planes.

Sandstone and sandy shale are the predominant rocks of the Hell Creek member of the Lance, and carbonaceous layers are common in it. The sandstones are gray, brown, and yellow. A large number have a pepper-and-salt appearance, being composed of small grains of light and dark minerals. They are weakly cemented, yet surprisingly tough. When dealt a forceful blow with a sharp pick point the effect is much like that of driving the pick into frozen earth. They weather into rounded and fluted surfaces and generally have a rough, coarse, and irregular appearance, which is in strong contrast to that of the sandstone of the Fort Union. Lamination in the sandstone is rare. The whole Hell Creek member is decidedly heterogeneous structurally, cross-bedded, and seemingly orderless. The sandstones that were examined microscopically are medium to coarse grained. Quartz grains are angular to subangular and as a rule form not more than 50 per cent of the rock, the remainder or cement being dirty calcite. The calcite in some specimens amounts to as much as 75 per cent, and in the feldspar, which usually exceeds the quartz in quantity, it is both fresh and altered, indicating that the rocks from which the Lance formation was derived did not suffer complete decomposition before the material was redeposited. One specimen contains a large amount of granular hematite mixed with the carbonate cement. Muscovite, biotite, and magnetite occur in small quantities.

The following stratigraphic section shows the character of the member:

Section of upper part of Hell Creek member of Lance formation in sec. 19, T. 132 N., R. 105 W.

	Ft.	in.
Ludlow lignitic member (lower part):		
1. Sandstone, yellow, fine grained, with almost equal proportion of white and dark grains stained yellowish by limonite; thick bedded, friable; contains large sandstone concretions, generally elliptical in cross section and rather long (maximum 20 feet), showing concentric structure. Many very small limonite concretions. Contains many mica flakes. Corresponds to basal bed of Tullock member.		
Hell Creek member:		
2. Shale, brown		8
3. Shale, black, carbonaceous		8
4. Shale, brown		5
5. Shale, carbonaceous		10
6. Shale, brown	1	
7. Shale, yellowish, soft, sandy	5	6
8. Shale, almost black	1	4
9. Shale, light yellow, slightly sandy	4	
10. Shale, brown, slightly sandy; contains reed fragments	2	6

Hell Creek member—Continued.	Ft.	in.
11. Sandstone, gray, "pepper and salt" appearance, fine grained, many mica flakes, some layers clayey; a thin layer of iron carbonate partly weathered to limonite in middle	27	
12. Shale, gray to dark, some layers fairly well laminated, others hardly laminated at all; many fragments of leaves and reeds throughout, but darker layers have more of the plant remains; some limonite concretions, probably once iron carbonate; slight and varying amount of sand. At base of this mass are peculiar large hard concretions, with very roughly concentric structure, containing fragments of leaves and smaller limonite concretions and traversed by a network of calcite veins	35	
13. Like No. 11 but with large sandstone concretions	8	
14. Like No. 12 but rather sandy and contains limonite concretions (weathered iron carbonate)	9	
15. Sandstone, yellowish gray, "pepper and salt," very friable, mica flakes, large sandstone concretions with concentric structure in layers; bottom 2 feet brown sand with fragments of reed stems	30	
16. Like No. 15 but rather clayey and extremely fine grained, smaller concretions; another brown sandstone layer at bottom with reed fragments	16	6
17. Shale, gray, mica flakes and full of fragments of leaves and stems; very slightly sandy	7	
18. Sandstone, gray, "pepper and salt," fine grained, with mica flakes; upper half rather tough and clayey, lower half friable and not clayey	13	
19. Like No. 17, with iron carbonate concretions weathered to limonite	8	
20. Sandstone, brown, bituminous, almost incoherent	2	6
21. Sandstone, yellowish gray, "pepper and salt," fine grained, some layers rather clayey, friable	10±	
22. Shale, gray; fragments of leaves	6	
23. Shale, dark brown, carbonaceous, with pieces of wood	1	6
24. Clay, sandy, mostly covered	5+	
	195	5

Within the Marmarth field the Hell Creek member is only sparingly fossiliferous but has yielded remains of turtles and other reptiles and of dinosaurs, among which are *Trachodon* and *Triceratops*. Although supposedly abundant, *Triceratops* remains were found only at three places—on Cannonball River in sec. 33, T. 135 N., R. 106 W.; on Spring Creek in T. 131 N., R. 105 W.; and on Bacon Creek in T. 133 N., R. 105 W. The first two of these localities are shown on the

map by the letters BB. Leonard[24] found specimens of *Trachodon* and Ceratopsidae on Bacon Creek, among which was one identified as *Triceratops horridus?* by C. W. Gilmore. The fossil found on Cannonball River was identified by C. W. Gilmore as a supraorbital horn core of *Triceratops*, species not determinable.

LUDLOW LIGNITIC MEMBER

The presence of numerous lignite beds in the upper or Ludlow lignitic member of the Lance is in strong contrast to the absence of such beds in the lower (Hell Creek) member, and the lack of marine fossils in the Ludlow is in contrast to the presence of such forms in the equivalent Cannonball marine member.[25] The type locality of the Ludlow member is in South Dakota near Ludlow post office; the type locality of the Cannonball marine member is on Cannonball River, where it is best developed. A glance at the maps of the South Dakota coal field,[26] the Cannonball field,[27] and the Marmarth field will show an abundance of lignite beds in the western fields and a conspicuous absence of lignite in the corresponding beds in the eastern fields.

The typical Cannonball member is of marine origin, and it is stratigraphically equivalent to the Ludlow lignitic member, brackish-water beds present in the Ludlow on the Little Missouri representing the marginal phase of Cannonball marine disposition. These brackish-water beds contain beds of shells of *Ostrea glabra* and *O. subtrigonalis* in Tps. 134, 135, and 136 N., R. 105 W., and the westernmost collection of the Cannonball marine fauna was obtained only 30 miles to the east, in sec. 21, T. 129 N., R. 100 W., 6 miles west of Haley. This collection was obtained within 100 feet, stratigraphically, of the T Cross lignite bed,[28] which was traced to the west side of T. 129 N., R. 101 W., from T. 134 N., R. 105 W. The oysters occur about 70 feet above the same lignite bed; therefore it is assumed that the seaward connection was to the east. The oysters also occur about 120 feet below the base of the Fort Union formation, which in this field has the same characteristics (channel conglomeratic light-yellow and somewhat massive sandstone) as in the Cannonball River country, where it rests directly on the Cannonball marine member. It is probable that the sea in which were deposited some 300 feet of marine sediments transgressed with some oscillation westward across the lignitic sediments of the Ludlow and that the

[24] Op. cit., p. 50.

[25] Winchester, D. E., and others, The lignite field of northwestern South Dakota: U. S. Geol. Survey Bull. 627, 1916. Lloyd, E. R., The Cannonball River lignite field, N. Dak.: U. S. Geol. Survey Bull. 541, pp. 252–253, 1914.

[26] Winchester, D. E., and others, op. cit. 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, 1914.

[27] Lloyd, E. R., op. cit.

[28] Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance and its bearing on the Lance-Laramie problem: Jour. Geology, vol. 23, pp. 523–527, 1915.

position of its westward limit is near the divide that separates the drainage of the Missouri from that of Grand and Cannonball Rivers. All of the *Triceratops* remains collected in the Little Missouri country were found below the T Cross lignite bed and the oyster shells above it. The T Cross bed is undoubtedly the "lowest persistent lignite" bed mapped in eastern Montana.[29]

The Ludlow lignitic member about Yule, on the Little Missouri, is very different from the Ludlow as found in Harding County, S. Dak. In Harding County it is rather light colored and fairly regularly bedded and closely resembles the Fort Union formation, but at Yule it is more like the underlying Hell Creek member of the Lance. It is this change in character and color of weakly consolidated rocks, coupled with the extremely low relief, that renders the formation so difficult to trace and accounts for the placing of the Lance and Fort Union contact at different horizons by different geologists. It also partly accounts for the confusion regarding the age of the fossil leaves from the Lance and Fort Union formations.

The following sections show the relations and character of the Ludlow and Cannonball members of the Lance:

Section of Ludlow lignitic member on Little Missouri River at location 522, sec. 10, T. 135 N., R. 105 W.

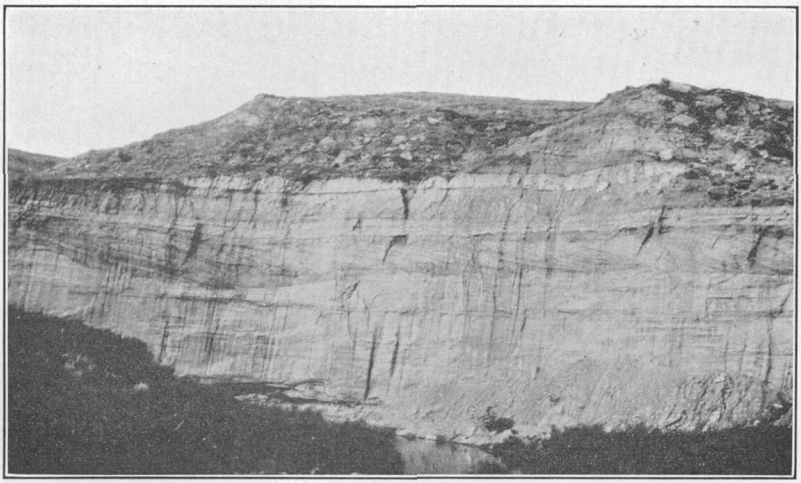
	Ft.	in.
Sandstone, light (possibly Fort Union)	15	2
Shale, dark	24	
Limestone, sandy	2	10
Shale, blue	7	2
Sandstone, gray, friable	4	
Shale, gray	3	7
Sandstone, clayey	1	4
Shale, drab, hard	1	2
Lignite, Yule bed	4	5
Shale, dark, hard	2	10
Shale, light, fossil leaves (lot 6213)	2	10
Lignite	2	6
Shale, carbonaceous	1	8
Sandstone	2	8
Shale	1	8
Sandstone and shale, alternating	2	8
Lignite	1	
Sandstone and shale	3	
Lignite		6
Sandstone	4	
Lignite	1	7
Sandstone, white, hard	3	
Sandstone in upper part and shale in lower part, bearing *Ostrea glabra* (believed to represent Cannonball marine member)	33	11
Lignite	1	11

[29] Calvert, W. R., U. S. Geol. Survey Bull. 471, p. 197, 1912.

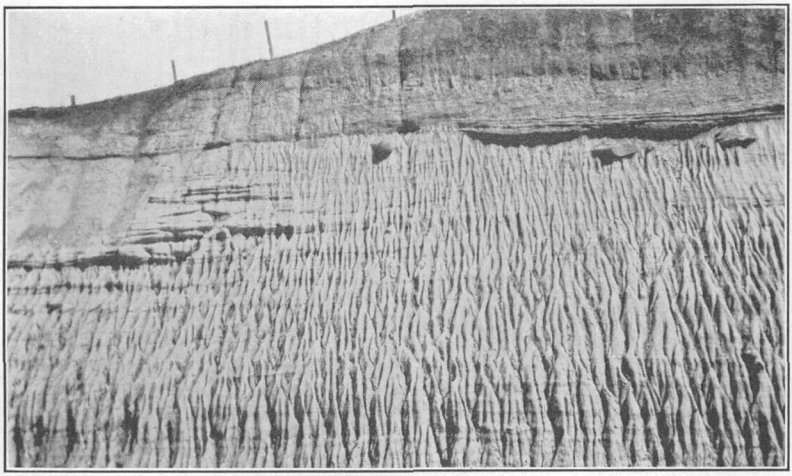
	Ft.	in.
Sandstone in upper part and shale below	27	
Lignite		10
Shale	11	
Lignite	3	
Shale	3	4
Sandstone, hard in upper part	13	2
Lignite	5	3
Shale	1	8
Lignite	1	2
Shale	1	4
Lignite	5	
Shale	8	6
Lignite	6	11
Shale, gray	4	8
Lignite		6
Shale	7	6
Lignite	5	4
Sandstone	15	4
Shale.		
Total section	250	11
Total lignite	39	11

Section of upper part of Ludlow lignitic member at location 154, sec. 36, T. 136 N., R. 150 W.

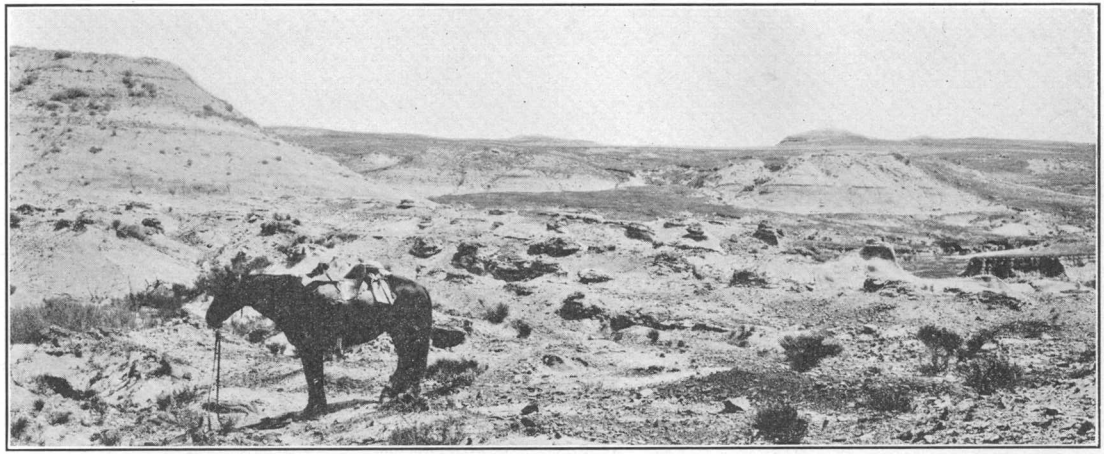
Terrace gravel.	Ft.	in.
Shale	10	
Lignite, Yule bed	10	6
Sandstone	7	5
Shale, gray, sandy	5	6
Lignite	2	10
Shale	2	
Sandstone	3	
Shale	22	
Sandstone, very friable	17	2
Shale, dark	5	
Lignite	2	8
Shale, carbonaceous	4	
Sandstone, soft	6	
Lignite		6
Shale	1	5
Lignite	1	2
Shale, sandy, light colored	16	
Sandstone, massive, with hard layer at top and very soft below	22	6
Lignite	3	7
Sandstone, clayey	12	2
Sandstone, with hard limy streaks; fossils (lots 7402 and 6215)	6	3
Water level.		
Total section	161	8
Total lignite	21	3



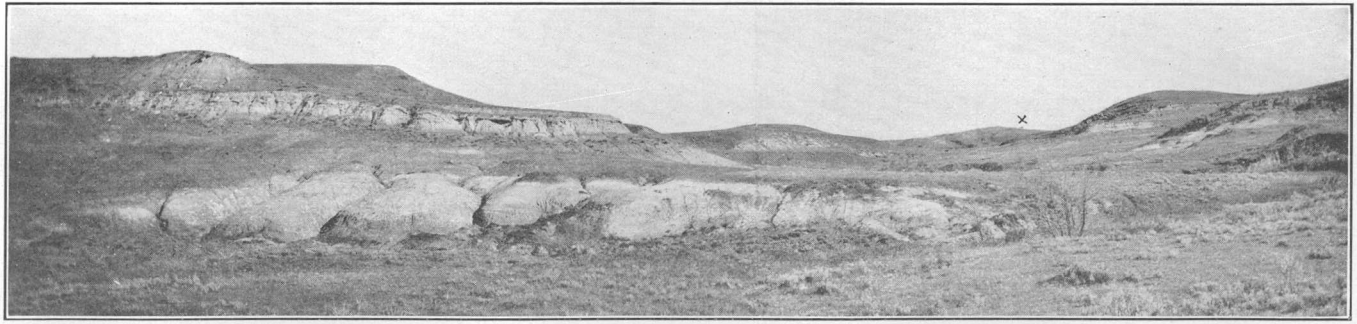
A. FOX HILLS SANDSTONE AND BASAL PART OF LANCE FORMATION IN BLUFFS OF LITTLE BEAVER CREEK, SEC. 18, T. 132 N., R. 105 W.



B. COLGATE SANDSTONE MEMBER OF FOX HILLS EXPOSED IN RAILROAD CUT 3½ MILES WEST OF MARMARTH

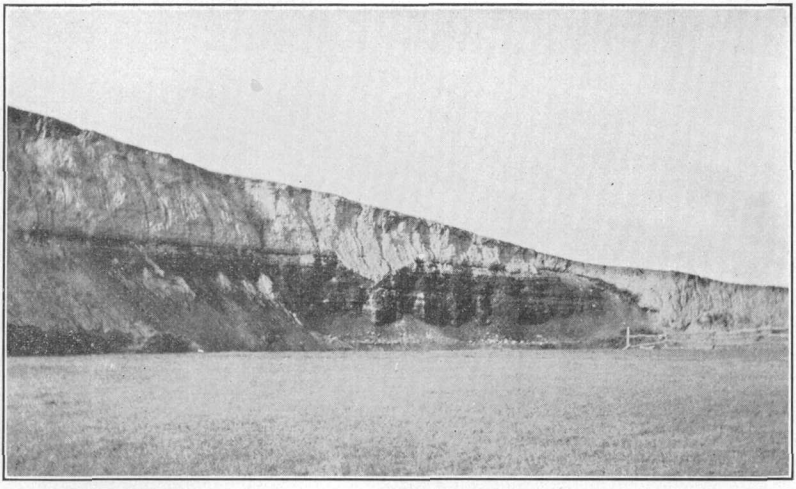


A. LOWER PART OF HELL CREEK MEMBER OF LANCE FORMATION IN LITTLE MISSOURI BADLANDS, SOUTH OF MARMARTH



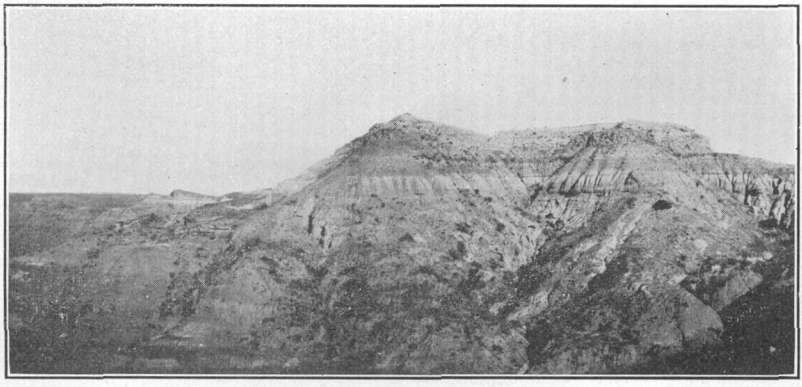
B. LUDLOW LIGNITIC MEMBER OF LANCE FORMATION NEAR MOUND

Dark clay above T Cross lignite bed in foreground; oyster-shell bed at point marked ×



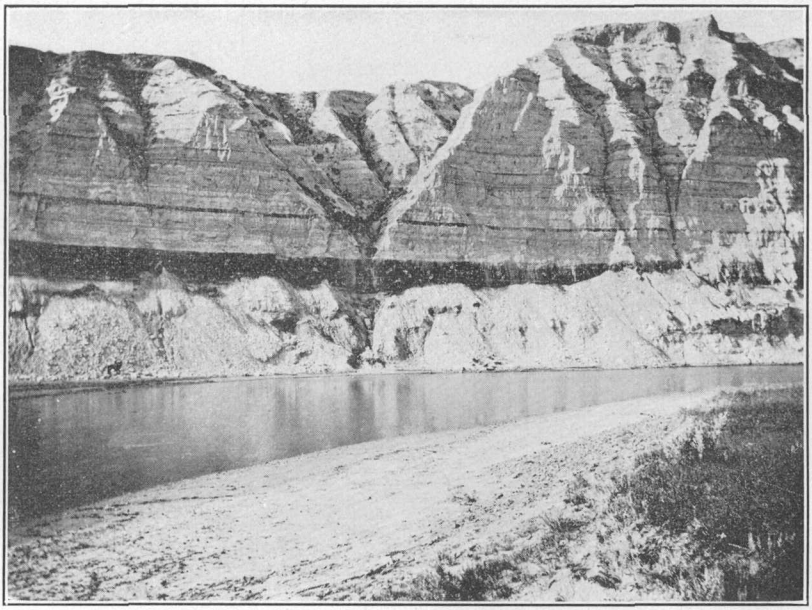
A. T CROSS LIGNITE BED AT T CROSS MINE, SEC. 20, T. 133 N., R. 104 W.

The bed is about 24 feet thick at this mine



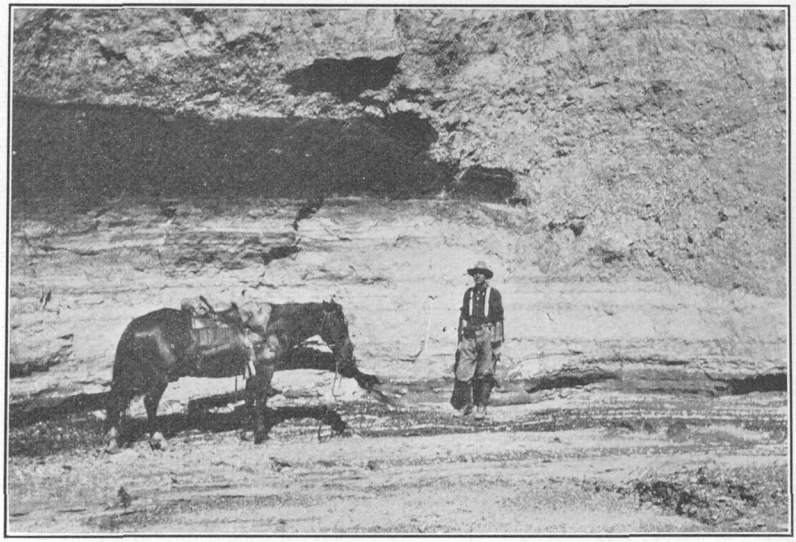
B. UPPER PART OF LUDLOW LIGNITIC MEMBER OF LANCE AND BASAL PART OF TONGUE RIVER MEMBER OF FORT UNION, SEC. 32, T. 136 N., R. 104 W.

Contact at base of heavy sandstone near top of hill

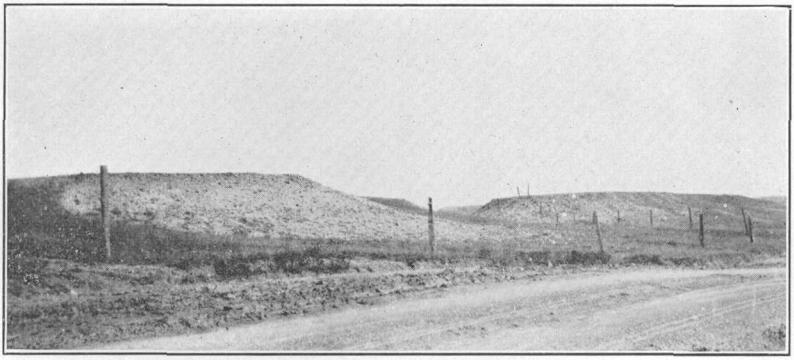


A. HARMON LIGNITE BED AND TONGUE RIVER STRATA EXPOSED IN BLUFF OF LITTLE MISSOURI RIVER IN SEC. 19, T. 137 N., R. 101 W.

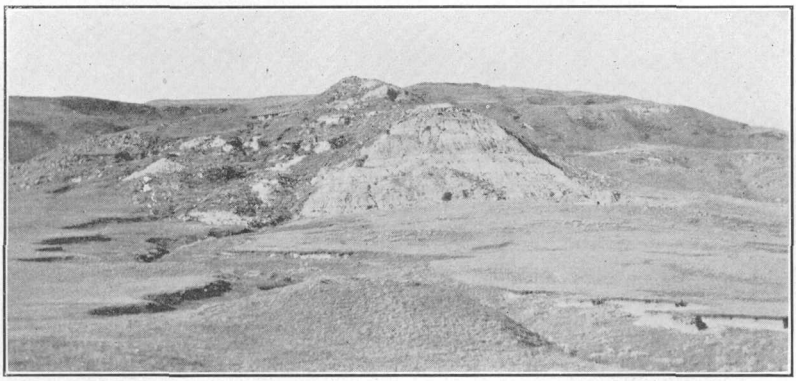
Horse on far bank of river near left margin



B. CHANNEL CONGLOMERATE AT BASE OF MASSIVE SANDSTONE OF TONGUE RIVER MEMBER, SEC. 15, T. 136 N., R. 105 W.

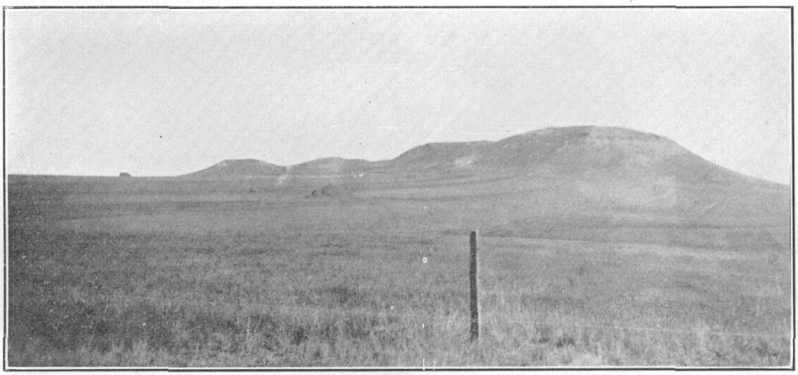


A. FLAT-TOPPED HILLS CAPPED BY QUARTZITIC STRATUM OF TONGUE RIVER MEMBER OF FORT UNION NEAR YELLOWSTONE TRAIL, NORTH OF RHAME



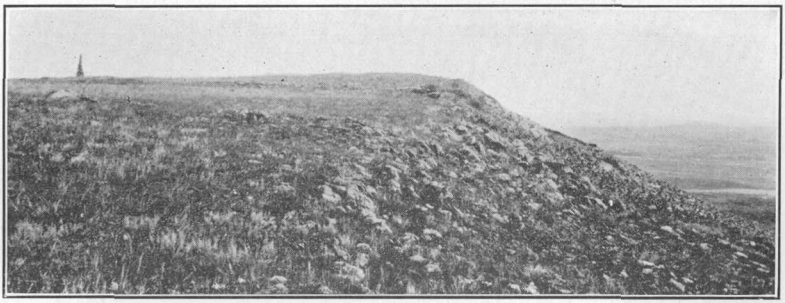
B. SENTINEL BUTTE SHALE EXPOSED ABOUT 4 MILES EAST OF H T BUTTE

Clinker mound in foreground



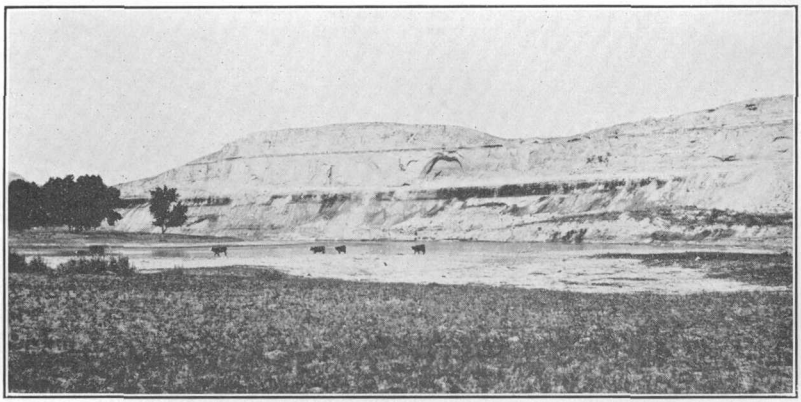
C. CHARACTERISTIC TOPOGRAPHY OF TONGUE RIVER MEMBER OF FORT UNION, NEAR HEAD OF BACON CREEK

Hills capped with clinker produced by burning of a lignite bed

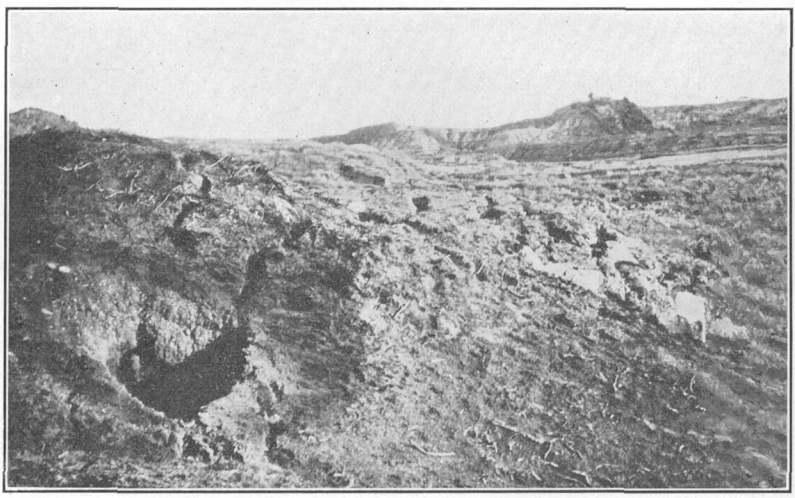


A. QUARTZITE CAPPING OF LUDLOW BUTTE, SEC. 27, T. 22 N., R. 6 E., SOUTH DAKOTA

Sheepherder's monument on sky line



B. HARMON LIGNITE BED OVERLAIN BY MASSIVE SANDSTONE IN BLUFFS OF LITTLE MISSOURI RIVER, SEC. 19, T. 137 N., R. 101 W.



C. SUBSIDENCE OF SURFACE PRODUCED BY BURNING OF 23-FOOT HARMON LIGNITE BED, SEC. 14, T. 136 N., R. 102 W

Section of part of Ludlow lignitic member, at location 575, sec. 22, T. 134 N., R. 105 W.

	Ft.	in.
Porcellanite or slag from burning of T Cross lignite	4	
Sandstone, yellow	25	
Shale, brown		6
Lignite	2	6
Shale, brown		6
Sandstone, light gray and white, and shale, including 4 feet of black shale	35	
Sandstone, white	3	
Shale, gray	1	6
Shale, brown		5
Lignite		7
Shale, dark brown	3	4
Lignite		10
Shale, brown to gray	5	8
Lignite	1	3
Shale, dark gray	1	1
Lignite	1	1
Clay, white; roots of fossil plants	1	
Shale, brown	2	
Creek level.		
Total section	89	3
Total lignite	6	3

THICKNESS AND CHARACTERISTIC TOPOGRAPHY

The maximum thickness of the entire Lance formation is about 825 feet, which is somewhat more than is ordinarily assigned to it in this general region. The greater thickness is due to the fact that the lithologic change on which the discrimination of the Lance and Fort Union is based occurs higher in the geologic column in this field than in those of eastern Montana.[30] The rocks as found here are loosely cemented and disintegrate very easily under the action of wind, frost, and rain. In fact on the surface much of the shale looks like clay and the sandstone like sand. Most of the area underlain by the Lance is highly dissected by innumerable streams, and many of the slopes are devoid of vegetation.

Many of the "mud buttes" or "elephant-back hills" so abundant in this region are erosion forms developed as the formation has broken down under the influence of the weather. They are common in T. 131 N., R. 105 W., T. 132 N., R. 106 W., and T. 133 N., R. 106 W., where it is not unusual to see them rising above a grassy field. They are no harder than the rest of the formation and have no resistant cap to protect them from erosion but simply represent so

[30] Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, pp. 187–201, 1912.

much unfinished work of degradation by wind, weather, and running water. Around each is a barren ravine the lower end of which opens or merges into the grassy field. This ravine is formed in part during showers by the run-off from the bare hill and in part by the wind. Most of the badlands in Bowman County and in the southwest corner of Billings County are developed in the Hell Creek member of the Lance.

No metamorphism has taken place in these rocks other than that of induration, save where a burned lignite bed has fused or baked the overlying strata, forming porcellanite, or "clinker," as it is frequently called. The attitude of the whole formation is essentially horizontal.

CONDITIONS OF DEPOSITION

There is the utmost variation in the rocks, both vertically and horizontally. Two detailed sections taken by the same person across the same statigraphic interval and less than 100 feet apart would not show marked likeness, and if separated by a distance of a mile very likely they would be absolutely different. A shale may grade in any direction into a sandstone or a sandstone into a shale, and many of the lignite beds grade laterally into shale or are split up by shale partings. Lenses are a marked characteristic of the beds, and cross-bedding is common. Many thick strata of sandstone or shale diminish laterally to nothing. It would seem that in this region the Lance was laid down in a continental body of water in which sedimentation was rapid, currents were strong, and sediments were being shifted from place to place or rapidly dumped in from places of active degradation. This is particularly true of the Hell Creek member. During the accumulation of the Ludlow lignitic member deposition was less rapid, and swamps developed in which abundant semitropical vegetation grew, later forming lignite. Subsidence occurred at intervals, with renewed deposition, which buried the swamps and their accumulations of plant remains. Relative quiet then ensued, which allowed the accumulation of more vegetation to make another lignite bed. This process was repeated many times, as shown by the numerous beds of lignite. At one locality conditions were favorable for the accumulation of lignite, whereas close by sand and mud were deposited. It is not improbable that many isolated swamps existed at the same time. The whole field was at a critical level, with the source of the sediments apparently to the west and southwest.

FOSSILS

The fossils obtained from the Hell Creek member are listed on page 23. The following fossils have been obtained from the Ludlow lignite member of the Lance or from the equivalent Cannonball marine member, which is represented by collections 7419 and 7975:

PLANTS

6213. Location C, on Little Missouri River 20 miles north of Marmarth, in sec. 10, T. 135 N., R. 105 W.:

Thuya interrupta Newberry.
Populus amblyrhyncha? Ward.
Fragments of leaves.

6215. Location E, on Little Missouri River south of Yule, in sec. 36, T. 136 N., R. 105 W.:

Trapa microphylla Lesquereux.
Selaginella n. sp., fine.
Carpites n. sp., very fine.
Carpites sp., ribbed.
Reticulate-veined leaf, new, fine.

6385. SW. ¼ SW. ¼ sec. 36, T. 129 N., R. 99 W., north bank of North Fork of Grand River, near milepost 311, 15 miles east of Ash post office:

Halymenites major Lesquereux.

This alga is usually most abundant in or near the Fox Hills sandstone, but it also ranges much lower.

VERTEBRATES

Location EE, sec. 20, T. 135 N., R. 106 W., 15 miles north of Marmarth, 40 feet above the T Cross lignite bed:

Fragment of crocodile jaw, not determinable.
Vertebrae of Champsosaurus.
Fragments of the shells of Basilemys and Aspideretes.

Location C, NW. ¼ SW. ¼ sec. 25, T. 135 N., R. 105 W., about 15 miles northeast of Marmarth, 3½ miles east of Little Missouri River:

Skull and anterior portion of vertebral column of Champsosaurus, with ribs and bones of fore limb, all articulated.

INVERTEBRATES

7400. Location C,[31] sec. 10, T. 135 N., R. 105 W.:

Ostrea glabra Meek and Hayden.

7401. Location D, southwest corner sec. 2, T. 135 N., R. 105 W.:

Unio priscus Meek and Hayden?
Sphaerium sp.
Corbula mactriformis Meek and Hayden.
Viviparus sp.
Campeloma multilineata Meek and Hayden.
Campeloma? sp.
Hyalina? sp.
Goniobasis tenuicarinata Meek and Hayden.

7402. Location E, in sec. 36, T. 136 N., R. 105 W., below T Cross (?) lignite bed, 5 feet above water in Little Missouri River:

Sphaerium formosum Meek and Hayden.
Physa sp.
Viviparus sp.
Hydrobia warrenana Meek and Hayden?
Campeloma? sp.
Helix? sp.

The identified forms are Fort Union species.

[31] Other localities in this and adjacent townships where the oysters shells were found are shown by letter C.

7419. Location F, sec. 13, T. 134 N., R. 105 W., 8 miles northeast of Marmarth:
Ostrea glabra Meek and Hayden.

7975. At quarter corner of secs. 21 and 28, T. 129 N., R. 100 W., 12 miles south and 3½ miles west from Haley, and 11½ miles east of Ash post office:
Nucula sp.
Callista sp.
Pholas sp.
Thracia sp.

TERTIARY SYSTEM

FORT UNION FORMATION

TONGUE RIVER MEMBER

Distribution.—The Tongue River member of the Fort Union formation is exposed over the greater part of the northern and eastern two-thirds of the Marmarth field, although Sand and Deep Creeks have eroded through it along parts of their courses. It is overlain by the Sentinel Butte shale member (Fort Union?) in small areas surrounding the higher buttes. The Tongue River and Sentinel Butte members are well exposed near the type locality of the Fort Union,[32] near Buford, N. Dak., and are essentially identical with the middle and upper members of the Fort Union as described by Leonard.[33] Rocks of like age underlie a large territory in eastern Montana, northeastern and central Wyoming, northwestern South Dakota, western North Dakota, and Canada.

Composition.—The rocks of the Tongue River member of the Fort Union are generally of lighter color than those of the Lance (see pl. 4, *B*) and contain a larger percentage of sandstone, also thicker and more persistent beds of lignite, the best example being the Harmon lignite. (See pls. 5, *A*, and 7, *B*.) The individual strata are also more persistent and regular. The sandstone is finer grained, cross-bedding is less abundant, and thin lentils of limestone are a distinctive feature. The cross-bedding of the sandstone in the basal Fort Union is of a peculiar swirly type and quite different from that found in the Lance.

The sandstone is mostly of light tints of tan, buff, cream, yellow, and white, with a lesser showing of brown, green, and gray. Some of it is so highly calcareous that it might well be called sandy limestone, but a few beds are apparently made up of grains of pure quartz. Some of the sandstone is spotted with small balls of limonite, which stain the surface a yellowish brown. Most of the beds are fine grained and massive, with few joints. Cross-bedding, except in the basal

[32] Hayden, F. V., Geological report of the exploration on the Yellowstone and Missouri Rivers, under direction of Capt. W. F. Raynolds, in 1859-60: 40th Cong., 2d sess., S. Ex. Doc. 77, p. 29, 1869; On the geology and natural history of the upper Missouri, being the substance of a report made to G. K. Warren: Am. Philos. Soc. Trans., vol. 12, new ser., pp. 92-103, 1863.

[33] Leonard, A. G., Geology of southwestern North Dakota, with special reference to the coal: North Dakota Geol. Survey Fifth Bienn. Rept., pp. 51-64, 1908.

part, is not highly developed, and ripple marks are somewhat rare. Most of the shale is of light colors, such as buff, grayish white, and greenish white, but some is gray, brown, drab, or black. Some of the shale is extremely sandy, some is limonitic, a little is gypsiferous, a small part is carbonaceous, and nearly all is calcareous. The member contains considerable very finely laminated cream-colored shale, the particles of which are so small as to remain in suspension in water for days. This shale closely resembles silt that collects in ponded water at flood times. Well-preserved fossil leaves are sometimes found in such material.

All the sandstone tested, except that composed of quartz grains, is calcareous, effervescing freely with weak hydrochloric acid. In thin section under the microscope the grains of sand are seen to be small and subangular and to make up less than one-half of the material, the remainder being chiefly dirty calcite. In some samples the calcite forms nine-tenths of the mass, and in many the quartz grains are not even in contact. Some of the samples contain small flakes of biotite and muscovite. Nearly all of them contain some fresh and altered feldspar, which is less in quantity than the quartz. As a whole, there is much less feldspar, much more calcium carbonate cement, and perhaps somewhat less quartz than in the sandstone of the Lance formation. In its regular bedding and smooth appearance the sandstone is in marked contrast to the knotty sandstone of the Lance. The sandstone of the Fort Union may for that reason be readily trimmed into hand specimens. In general, the rocks of the Fort Union are much finer grained than those of the Lance, a difference indicating either that they were laid down farther from the source, or that the land mass supplying the material was much lower. Possibly both of these conditions prevailed.

Thin lenses of dense, compact limestone occur in the lower 400 feet of the formation and were noted at several horizons and localities. They may be seen in the bluffs of the river in sec. 5, T. 138 N., R. 102 W., and sec. 32, T. 137 N., R. 103 W. The limestone breaks with a conchoidal fracture and is of a slate-gray color, which becomes tan or brown upon weathering. The limestone lenses are sparingly fossiliferous, and collection No. 7415 was gathered from one of them in sec. 5, T. 138 N., R. 102 W.

Five lignite beds over 30 inches thick and many thinner ones were found in the Tongue River member and are both regular and persistent. Silicified tree trunks and stumps that have been washed out of the clay and shale are common surface features of the member.

The Tongue River member gives rise to a sandy loam that supports good crops and is the best soil in the field, except that of the alluvial areas. The most prosperous homesteaders in the field farm this

soil, and farmers cultivating the soil derived from the Lance formation are noticeably less prosperous.

The composition of the Tongue River member is illustrated by the following stratigraphic sections:

Section of part of Ludlow lignitic member of Lance formation and Tongue River member of Fort Union formation on Deep Creek, sec. 31, T. 135 N., R. 102 W.

	Ft.	in.
Tongue River member of Fort Union formation:		
Porcellanite from burning of Harmon lignite	25	
Sandstone, clayey	28	9
Lignite, Shale, Lignite — Hansen bed		
Lignite	1	
Shale		3
Lignite	8	
Sandstone, buff, soft	16	
Shale, gray	8	
Lignite, Shale, brown, Shale, gray, Lignite — H bed		
Lignite	1	1
Shale, brown	1	
Shale, gray		7
Lignite	2	8
Sandstone, clayey, soft buff, with shale partings	16	
Ludlow lignitic member of Lance formation:		
Shale	2	
Lignite, shaly	4	8
Shale, drab	9	
Lignite and brown shale	1	
Shale to creek	30	
Total section	155	
Total lignite	18	5

Section of part of Tongue River member of Fort Union formation at location 369 sec. 14, T. 135 N., R. 104 W.

	Ft.	in.
Lignite, Harmon bed	10	6
Sandstone	5	4
Lignite	1	
Shale, brown	1	
Sandstone	4	
Lignite, Lignite, impure, Lignite — Hansen bed		
Lignite	1	1
Lignite, impure		2
Lignite	2	
Shale, brown	1	6
Sandstone	4	
Shale, carbonaceous	1	
Lignite	2	
Sandstone	30	
Shale, gray	1	
Lignite, Shale, Lignite — H bed		
Lignite	3	4
Shale		2
Lignite	2	
Sandstone.		
Total section	70	1
Total lignite	21	11

Section of part of Tongue River member of Fort Union formation at Postoffice Butte, in sec. 23, T. 132 N., R. 104 W.

	Ft.	in.
"Clinker" of the burned Harmon bed, which caps all the highland in this township and east for many miles	47	
Sandstone, very light yellow, almost white, fine grained, friable	68	
Clay, gray, sandy	11	
Shale, brown	1	6
Sandstone, yellowish, fine grained, friable	5	
Shale, gray	14	
Sandstone, yellowish to whitish, fine grained, some layers clayey, with two very thin streaks of carbonaceous shale	38	
Bone, rather clayey	1	8
Quartzite, brownish, variable in thickness, tufaceous-like rock, fairly hard, porous, with reed stems. Seems to be continuous throughout this township and the one to east. This is the quartzlike layer described more fully on pages 34–36	2	
	188	2

Section of Tongue River member of Fort Union formation and upper part of Ludlow lignitic member of Lance formation in sec. 24, T. 137 N., R. 103 W.

	Ft.	in.
"Clinker" from H T Butte lignite bed.		
Tongue River member of Fort Union formation:		
Sandstone, light	12	
Shale, brown, carbonaceous	3	
Lignite		6
Sandstone, light	17	
Shale, light gray	4	
Sandstone	35	
Shale, dark brown to dark green, containing pelecypod shells (lot 7414)	15	
Shale, gray, stained by limonite, sandy at top	15	
Shale, alternating layers of yellow and gray, fossil collections (lots 7413 and 6220)	30	
Shale, gypsiferous	5	
Sandstone	15	
Shale, light gray	4	
Lignite		4
Sandstone, soft, clayey	4	4
Shale	1	2
Lignite, Garner Creek bed	3	2
Shale	3	
Sandstone	50	
Sandstone, yellow	15	
Sandstone, light	32	
Shale	3	
Sandstone, light	20	
Shale, dark, sandy	5	

	Ft.	in.
Tongue River member of Fort Union formation—Con.		
Sandstone, yellow, soft	35	
Lignite		6
Shale		10
Lignite		8
Shale	8	
Lignite (Harmon bed)	6	6
Shale (Harmon bed)		7
Lignite (Harmon bed)		6
Shale (Harmon bed)		6
Lignite (Harmon bed)		4
Shale, gray	6	
Sandstone, light, soft, variable in thickness	10	
Total, Tongue River member	361	11
Total lignite	12	6
Ludlow lignitic member of Lance formation: Shale, dark gray, lavender, and brown, sandy with uneven upper surface and containing concretions and masses of light-brown rock	60	

Siliceous beds.—Among the most marked and characteristic surface features of the field are the peculiar gray quartzitic wind-polished boulders which locally occur in great numbers. The strata (see pl. 6) from which these boulders originated will be described because of their value as key rocks in interpreting the structure. Historically, the boulders have been a source of speculation ever since 1874, when N. H. Winchell made a trip from Bismarck, N. Dak., to the Black Hills. He called the material, which he observed all along the route, gray quartzite or siliceous limestone and found it in place only at one locality—Ludlow Cave, in the North Cave Hills, S. Dak.[34] Willis[35] spoke of the boulders as erratic blocks of quartzite containing silicified wood. Todd[36] described them as burrstone and believed them to be a part of the White River formation. According to Wilder,[37] fragments of quartzite, which he regarded as residual, are very abundant, literally paving many of the hilltops of the Cannonball River country. Lloyd[38] has also called attention to this feature.

The strata from which the boulders originated occur from 60 to 200 feet above the base of the Tongue River member in the Dakotas. A quartzite about 200 feet below the base of the Tongue River is present near Plevna, Mont.[39] The altitude of the remnants found in place

[34] Winchell, N. H., Report of a reconnaissance of the Black Hills of Dakota made by William Ludlow in 1874, pp. 23–26, 28, 29, 31, 57, 60, 1874.

[35] Willis, Bailey, The lignites of the Great Sioux Reservation: U. S. Geol. Survey Bull. 21, p. 11, 1885.

[36] Todd, J. E., A reconnaissance into northwestern South Dakota: South Dakota Geol. Survey Bull. 2, pp. 56, 61, 1898.

[37] Wilder, F. A., Lignite on the Missouri, Heart, and Cannonball Rivers and its relation to irrigation: North Dakota Geol. Survey Third Bienn. Rept., p. 40, 1904.

[38] Lloyd, E. R., The Cannonball River lignite field, Morton, Adams, and Hettinger Counties, N. Dak.: U. S. Geol. Survey Bull. 541, p. 251, 1914.

[39] Bowen, C. F., personal communication.

to the south is much greater than to the north and east, a fact due to the northeastward dip away from the Glendive anticline, described on page 44. Quartzite is found in place on a high hill in sec. 27, T. 136 N., R. 106 W.; in T. 135 N., R. 104 W., immediately beneath the lowest Fort Union lignite and 70 feet below the Harmon lignite bed; also in several places in T. 135 N., R. 103 W., in T. 134 N., R. 104 W., and in sec. 26, T. 133 N., R. 104 W., beneath the same lignite bed; but to the south the lignite is absent, as in sec. 31, T. 133 N., R. 103 W., in T. 132 N., R. 104 W., and at Postoffice Butte 148 feet below the base of the Harmon "clinker." In several places quartzite caps isolated buttes, as in T. 131 N., R. 104 W. In secs. 15 and 28, T. 131 N., R. 102 W., and in T. 131 N., R. 103 W., it is 200 feet below the Harmon lignite. It caps several conspicuous buttes in secs. 1, 2, and 3, T. 130 N., R. 104 W. In sec. 3 of this township there is a minor stratum of a similar character 25 feet below the main one, and in Medicine Pole Butte a thin bed of lignite lies above the quartzite. In South Dakota the quartzite is in place on the North Cave Hills, in secs. 21 and 36, T. 22 N., R. 5 E., 46 feet below the White River formation and 250 feet above the base of the Fort Union formation. It also occurs in sec. 12, T. 21 N., R. 5 E., on the highest point of the hills and caps two conspicuous buttes northwest of Ludlow post office in T. 22 N., R. 6 E. (See pl. 7, *A*.) It is found about 150 feet above the Cannonball marine member of the Lance in Anarchist Butte, sec. 34, T. 22 N., R. 9 E.; in sec. 10, T. 21 N., R. 10 E.; and in the vicinity of Lodgepole post office.[40] In the Cannonball River lignite field[41] it is found in several localities—one in the northwest corner of T. 130 N., R. 91 W., and in Pretty Rock Butte, T. 131 N., R. 89 W. It is also found in place in sec. 4, T. 2 N., R. 60 E., and sec. 13, T. 3 N., R. 59 E., Mont.,[42] about 30 feet above the base of the Fort Union. Near Plevna, Mont., a similar stratum occurs in Tps. 7 and 8 N., R. 57 E., about 100 feet above the T Cross lignite zone,[43] and this horizon may possibly be represented by a quartzite found in place on a high hill near the center of T. 34 N., R. 51 E., Mont.,[44] about 80 feet below the Richardson lignite bed. A very similar rock occurs in T. 148 N., Rs. 92 and 93 W., in the Fort Berthold Indian Reservation, N. Dak., but it is so much higher stratigraphically that its position can not be confused with lower occurrences.[45]

[40] Winchester, D. E., and others, The lignite fields of northwestern South Dakota: U. S. Geol. Survey Bull. 627, 1916.

[41] Lloyd, E R., The Cannonball River lignite field, Morton, Adams, and Hettinger Counties, N. Dak.: U. S. Geol. Survey Bull. 541, pp. 243-291, 1914.

[42] Bauer, C. M., personal communication.

[43] Bowen, C. F., personal communication.

[44] Bauer, C. M., personal communication.

[45] Bauer, C. M., Lignite in the western part of the Fort Berthold Indian Reservation, N. Dak.: U. S. Geol. Survey Bull. 726, pp. 109-172, 1922.

Boulders from these quartzitic strata may be observed at many places in South and North Dakota and Montana. They are highly resistant to weathering; consequently they remain on the surface for a long time and interfere with the cultivation of the soil. The rock is very fine grained and when weathered breaks with a hackly fracture, with very sharp, knifelike edges. It is gray to white where weathered, but some of the specimens that have not been subjected to leaching and weathering are of a light chocolate color or almost black, owing to included carbonaceous matter. Examination of thin sections shows the rock to be composed of very small grains of angular quartz cemented by silica, with a few black grains, probably of carbonaceous material. It contains also a few fragmentary crystals of augite and mica. Hand specimens show no calcite when tested with dilute hydrochloric acid. One peculiar feature of this rock is the large number of plant impressions which it contains. These are to all appearances simply molds of stems showing scars of knots and roots, but nothing identifiable has been found. These impressions range from half an inch to 4 inches in diameter and reach 2 feet or more in length. Some specimens show the branching nature of the roots.

The quartzite does not seem to have been present at every place where its horizon is represented, as otherwise it is highly probable that fragments of it would normally be present in the country where the Fort Union formation has been eroded away. There are square miles where not a single fragment of it is found, although in other places there are enormous numbers of residual boulders, as near the Tepee Buttes, S. Dak., or the Medicine Pole Hills, N. Dak. There is some evidence that all the quartzites consist of a kind of clay or sand underlying lignite beds, which becomes hardened upon exposure.

A layer of another type of quartzitic rock is found in place in the northeastern Twin Butte. Fragments of this rock are scattered over parts of Billings and Bowman Counties, N. Dak., and in Harding County, S. Dak., where one fragment was found on top of the Cave Hills. It is very brittle and easily splits parallel to the bedding planes. The flat surfaces are literally covered by reedlike plant impressions and rarely show what appear to be seeds of conifers, though no specimens were identifiable. The rock is of a vitreous yellow or gray color and consists of almost pure silica. The plant impressions are usually white and about a quarter of an inch in width, although some are as much as 2 inches. The stratum is only 2 feet thick and so far as ascertained occurs only in the Twin Buttes. Many of the buildings in Bowman have walls constructed of this material, for it breaks into flat pieces that are well adapted for that purpose.

Stratigraphic relations.—Minor channels beneath sandstones at the base of the Fort Union were noted at several places in the Marmarth

Field, and some of these channels contained lenses of conglomerate composed of material apparently of local derivation.[46] Such features were noted in sec. 15, T. 136 N., R. 105 W. (see pl. 5, *B*); in the center of sec. 3, T. 136 N., R. 102 W.; in the NW. ¼ sec. 3, T. 136 N., R. 103 W.; in the river bluff in the SW. ¼ SW. ¼ sec. 31, T. 137 N., R. 102 W.; in the SW. ¼ SW. ¼ sec. 8, T. 136 N., R. 102 W.; and in the NW. ¼ NE. ¼ sec. 10, T. 135 N., R. 104 W. On the sides of the present valley of Deep Creek, in T. 135 N., R. 103 W., the lowest sandstone of the Fort Union seems to have been laid down in a stream channel or trough in the Lance, and in T. 136 N., R. 104 W., the highest large lignite bed of the Lance has a greater dip downstream than the lowest big bed of the Fort Union formation. It is not apparent that this channeling is of great significance, however, and it is believed that the diminished thickness of the Fort Union and the increased thickness of the Lance of the Marmarth field as compared with the Sidney field of Montana are due to a progressive upward migration of the plane of lithologic change analogous to that observable in the eastern part of the Crow Indian Reservation, Mont.[47]

Fossils.—The following fossils were collected from the Fort Union formation:

INVERTEBRATES

7403. Location G, sec. 6, T. 136 N., R. 104 W., on Little Missouri River:
Unio priscus Meek and Hayden?

7404. Location H, NE. ¼ SW. ¼ sec. 6, T. 137 N., R. 103 W.:
Unio sp.
Campeloma multilineata Meek and Hayden.
Thaumastus limnaeiformis Meek and Hayden.

7405. Location L, SE. ¼ NW. ¼ sec. 32, T. 137 N., R. 103 W., on Little Missouri River, half a mile northwest of the Meyer ranch and about 5½ miles east of Alpha:
Unio, two species apparently undescribed.

7406. Location J, NW. ¼ sec. 33, T. 137 N., R. 103 W., on Little Missouri River, three-quarters of a mile northeast of the Meyer ranch and 6 miles east of Alpha:
Unio sp.
Corbula mactriformis Meek and Hayden.

7408. Location K, NW. ¼ sec. 7, T. 137 N., R. 103 W., about 7 miles northeast of Alpha:
Unio priscus Meek and Hayden?
Campeloma multilineata Meek and Hayden.

7410. Location L, SE. ¼ sec. 18, T. 138 N., R. 102 W., 1 mile below Denison ranch on Little Missouri River, just above Harmon lignite, near base of Fort Union:
Unio sp.
Corbula mactriformis Meek and Hayden.
Goniobasis nebrascensis Meek and Hayden.

[46] Lloyd, E. R., and Hares, C. J., The Cannonball marine member of the Lance formation of North and South Dakota and its bearing on the Lance-Laramie problem: Jour. Geology, vol. 23, pp. 538, 539, 1915.
[47] Thom, W. T., jr., personal communication.

7412. Location N, NE. ¼ sec. 22, T. 138 N., R. 102 W., half a mile northwest of S. N. Lebo ranch on Dantz Creek, 100 feet above Garner Creek lignite bed:

Corbula mactriformis Meek and Hayden.
Campeloma multilineata Meek and Hayden.
Viviparus sp.

7413. Location O, NE. ¼ sec. 25, T. 138 N., R. 103 W., west of Little Missouri River, near Denison ranch:

Viviparus leai Meek and Hayden.

7414. Location O, 70 feet above 7413, in NE. ¼ sec. 25, T. 138 N., R. 103 W., west of Little Missouri River, near Denison ranch:

Unio sp.
Campeloma multilineata Meek and Hayden.
Campeloma producta White.
Viviparus sp.

7415. Location P, limestone lens about 30 feet above Harmon lignite bed in NE. ¼ sec. 5, T. 138 N., R. 102 W., on Little Missouri River 9 miles south of Medora:

Unio sp.
Viviparus trochiformis Meek and Hayden.

7416. Location Q, NW. ¼ NW. ¼ sec. 27, T. 136 N., R. 103 W., on Deep Creek, 10 feet below Garner Creek lignite, below yellow sandstone, in thin shale:

Unio priscus Meek and Hayden.
Corbula mactriformis Meek and Hayden.
Campeloma multilineata Meek and Hayden.

7417. Location R, SW. ¼ SW. ¼ sec. 27, T. 136 N., R. 103 W., about 50 feet above Harmon lignite:

Acroloxus minutus Meek and Hayden?
Bulinus longiusculus Meek and Hayden.
Helix? sp.

7418. Location S, SW. ¼ sec. 9, T. 136 N., R. 103 W., about 60 feet above Harmon lignite:

Unio priscus Meek and Hayden.
Unio sp.

7420. Location T, NW. ¼ sec. 32, T. 137 N., R. 103 W., about 6 miles east of Alpha and three-quarters of a mile north of Little Missouri River at the Joseph Meyer ranch:

Unio priscus Meek and Hayden.
Corbula mactriformis Meek and Hayden.
Campeloma multilineata Meek and Hayden.
Campeloma producta White.
Viviparus leai Meek and Hayden.
Helix? sp.

PLANTS

6218. Location GG, sec. 33, T. 138 N., R. 103 W., on branch of Bullion Creek, 4 miles west of Little Missouri River and 16 miles southwest of Medora:

Corylus sp.?
Viburnum newberryanum Ward.
Populus cuneata Newberry.
Vitis cuspidata Ward.

6220. Location O, near Denison ranch, west of Little Missouri River at point where stratigraphic section was measured in NE. ¼ sec. 25, T. 138 N., R. 103 W.:

Taxodium occidentale Newberry.

6222. Location KK, NE. ¼ sec. 25, T. 136 N., R. 103 W., 7 miles northeast of Bierman:

Viburnum.
Taxodium occidentale Newberry.
Populus amblyrhyncha Ward.
Populus cuneata Newberry.

6223. Location LL, NE. ¼ sec. 35, T. 136 N., R. 103 W., near Deep Creek, 5½ miles northeast of Bierman:

Sequoia nordenskioldi Heer.
Taxodium occidentale Newberry.
Populus cuneata Newberry.
Populus amblyrhyncha Ward.
Populus daphnogenoides Ward.
Pterospermites whitei Ward.
Viburnum antiquum (Newberry) Hollick.
Corylus sp.?

6224. Location R, SW. ¼ SW. ¼ sec. 27, T. 136 N., R. 103 W.:

Onoclea sensibilis Linné.
Populus cuneata Newberry.
Viburnum newberryanum Ward.
Vitis cuspidata Ward.
Viburnum.

6225. Location NN, SW. ¼ sec. 7, T. 134 N., R. 102 W., 20 miles northeast of Marmarth:

Sapindus affinis Newberry.
Ulmus planeroides Ward.
Ulmus rhamnifolia? Ward.
Pterospermites whitei Ward.

6386. Location SS, NE. ¼ sec. 2, T. 131 N., R. 102 W., top of Twin Buttes:

A pine cone of the type of Pinus strobus Linné.

FORT UNION (?) FORMATION

SENTINEL BUTTE SHALE MEMBER

Above the Tongue River member of the Fort Union there is a unit of dark-hued sandy shale and clayey sandstone weathering to an adobe soil. This unit is named the Sentinel Butte shale member, from Sentinel Butte, N. Dak., where it is typically exposed. The sandstone is fine grained and contains considerable dark mica (biotite). Even where the weak cement has gone, it has a peculiar compactness on a dry surface that resists the blow of a hammer, resembling the Hell Creek member of the Lance in this respect as well as in general appearance. Many concretions and dark-brown ferruginous nodules occur in the shale. At Sentinel Butte this member has a thickness of 450 to 500 feet,[48] and about 350 feet of it occurs in the Bullion, H T, and Tepee Buttes and the higher hills in T. 138 N., Rs. 102 and 103 W., and T. 137 N., Rs. 101 and 102 W. The H T Butte lignite is the basal bed. The member is overlain by the massive sandstone, of probable Oligocene age, that caps the high buttes and probably lies unconformably upon the Sentinel Butte shale.

[48] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, North Dakota and Montana: U. S. Geol. Survey Bull. 341, pp. 18–21, 1909.

Very few fossils were collected from Sentinel Butte shale. It contains some vertebrae of the reptile *Champsosaurus* and fairly abundant silicified wood in the form of stumps and logs. A few lignite beds occur in it. The lower 210 feet of the Sentinel Butte shale is present in the Sidney lignite field, Mont.,[49] and strata correlated with the upper part of the member overlap[50] upon the sandstone of Great Pine Ridge in the Sussex and Salt Creek fields of Wyoming, as described by Wegemann.[51] Because of this relation Thom and Dobbin[52] believe that the Sentinel Butte shale member should be referred to the Wasatch, and for that reason its Fort Union age is here questioned, although its equivalent was probably included in the type section of the Fort Union formation.

Fossils.—The following fossils were collected from the Sentinel Butte shale in the Marmarth field.

7411. Location M, NW. ¼ SW. ¼ sec. 14, T. 138 N., R. 102 W., in valley of Dantz Creek:

Viviparus trochiformis Meek and Hayden.
Viviparus sp.
Campeloma producta White.
Thaumastus limnaeiformis Meek and Hayden.

Location PP, sec. 26, T. 138 N., R. 102 W., 12 miles south of Medora:

Vertebra of Champsosaurus, evidently pertaining to an undescribed species.

WHITE RIVER (?) FORMATION

Within the Marmarth field the Sentinel Butte shale is overlain by a few feet to 250 feet of sandstone interbedded with a small amount of shale. The sandstone is massive, resistant, coarse grained, and of a light-gray, tan, white, or locally red color and is unfossiliferous. A specimen from H T Butte is composed of medium-sized angular quartz grains cemented by calcium carbonate, with small amounts of accessory muscovite. This sandstone forms high cliffs about Bullion and H T Buttes, which it caps and protects from rapid disintegration. The top stratum of the sandstone on Bullion Butte is of a peculiar purple color, at first sight suggestive of burnt rock, but it is only a fine-grained purple sandstone. Tremendous blocks of the main sandstone have broken off and accumulated as talus about the sides of these buttes. Presumably the same sandstone is the protective cap of other buttes near by, such as the Square Top and Camels Hump Buttes, just north of the Marmarth field, and the Rainy Butte about 20 miles east of H T Butte.

[49] Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, p. 199, 1912.

[50] Wegemann, C. H., personal communication.

[51] Wegemann, C. H., The Sussex coal field, Johnson, Natrona, and Converse Counties, Wyo.: U. S. Geol. Survey Bull. 471, p. 447, 1912.

[52] Thom, W. T., jr., and Dobbin, C. E., Stratigraphy of the Cretaceous-Eocene transition beds in eastern Montana and the Dakotas: Geol. Soc. America Bull., vol. 35, pp. 481-506, 1924.

This sandstone is classed as Oligocene (?) because of the striking contrast of its lithology with that of the underlying rocks; because of a probable erosional unconformity at its base suggested by marked local irregularities of thickness of the Sentinel Butte shale; and because of the apparent conformability of the sandstone with the normal White River Oligocene deposits that overlie it in White Butte, 6 miles southeast of H T Butte, and also in Sentinel Butte, in T. 139 N., R. 104 W. Fragments of white calcareous rock resembling normal White River material are present on the top of Bullion Butte, which is capped by the massive sandstone under discussion.

The former widespread distribution of the White River formation in the Marmarth field is indicated by the numerous porphyritic and granitic pebbles that occur on many of the high hills and divides—for instance, on Talbert Butte, 2 miles southeast of Bowman, on the high hills in T. 131 N., R. 103 W., and on the prominent point in sec. 14, T. 138 N., R. 102 W. Some pebbles in the Rhame gravel pit are also clearly derived from the White River formation, and fossil bones found lying on the surface plateau of the Medicine Pole Hills (location R), south of Rhame, are evidently residual from White River deposits that once covered these hills. These fossils have been identified by J. W. Gidley, of the National Museum, as *Megacerops prouti* (anterior portion of foot bones, horn core, and lower jaw fragments), *Leptomeryx* sp. (proximal end of radius), *Hemipsalodon? grandis* (phalanx), and *Stylemys nebrascensis*.

QUATERNARY SYSTEM

PLEISTOCENE SERIES

Terrace gravel.—Along Little Missouri River, terrace gravel rests unconformably on beds of the Pierre, Fox Hills, Lance, and Fort Union formations. It is also found on Coyote, Boxelder, Little Beaver, Bacon, Williams, Deep, and Garner Creeks. The pebbles composing the gravel are mostly derived from igneous and metamorphic rocks such as those of the Black Hills or of the Front Ranges of the Rockies, or from the disintegration of the conglomerate of the White River (?) formation, which in turn was doubtless derived from the mountains. The terraces are more fully described on pages 8 and 9.

Pebbles similar in composition to those of the terrace gravel were noted in many places above the stream terraces. They were found on some of the high hills in T. 138 N., R. 102 W., and on the divides in Tps. 134 and 135 N., Rs. 103 and 104 W., and they occur abundantly on Talbert Butte, 2 miles southeast of Bowman, and on the hills in T. 131 N., R. 103 W., southeast of the Rhame gravel pit. These pebbles were probably derived from the White River formation, being left on the surface as the softer materials disappeared, but they have not been worked over by streams like those on the terraces.

No positive evidence of glaciation was found in this field, though two igneous boulders of extraneous origin, about 10 inches in diameter, were noted in sec. 19, T. 131 N., R. 105 W., and sec. 32, T. 131 N., R. 103 W. They may have been derived from the White River formation, but if not then they are probably of glacial origin, though they show no striations.

RECENT DEPOSITS

Alluvium.—Alluvial areas, some of which are half a square mile in extent, occur within the meanders of Little Missouri River. Much smaller areas border the larger creeks. The river is continually undercutting the bluffs on the outer sides of its numerous meanders and filling with previously gathered material the inner sides. By this process of cutting and filling the river is widening its valley and gradually adding to the alluvial deposits.

Alluvial fans and cones are common in the deeper valleys. Many small streams emerging from youthful valleys among the badlands fully loaded with detritus deposit the material as fans or cones. An excellent example of an alluvial fan occurs in the NE. ¼ sec. 3, T. 136 N., R. 102 W., and in sec. 34, T. 137 N., R. 102 W.

Dunes.—In T. 130 N., R. 106 W., on Little Missouri River, there are small areas of sand dunes. These are very noticeable east of Kirk post office. The sand is mostly derived from the Fox Hills sandstone.

STRATIGRAPHIC SUMMARY

The oldest rock exposed in the Marmarth field is the dark Pierre shale. This material was deposited in the Upper Cretaceous sea that covered the Great Plains province and large parts of the area now occupied by the Rocky Mountains. The Fox Hills sandstone overlies the Pierre conformably and consists of sandy beds laid down as the coastal plain which fringed land areas to the west was built eastward or northeastward into the basin of the Pierre sea. In consequence of these conditions, and because of the free communication of the interior sea with the oceans then existent, the Fox Hills of the Missouri Valley, to the east, contains a marine fauna known at distant localities, and the lower part of the Fox Hills of the Marmarth field contains a few marine shells. Seaward extension of the coastal plain continued throughout Fox Hills time, and consequently the upper or Colgate sandstone member of the formation was laid down under strand rather than purely marine conditions and is therefore comparatively barren of fossils in this field, yielding only impressions of seaweed, although near Glendive it contains fossil leaves of dicotyledonous trees.

During the deposition of the Hell Creek member of the Lance the region about Marmarth subsided gradually, but the rapid accumulation of a great delta or deltas, now represented in the somber-colored Hell Creek strata, temporarily prevented the return into the local field of the marine waters still existing in a part of the former basin of the interior sea, probably the eastern part of the Williston structural basin. After Hell Creek time sedimentation was less rapid, and subsidence gained relatively upon it, with the consequent progressive westward extension of the marine Cannonball member of the Lance and the deposition of the coal-bearing coastal-plain or fluviatile strata of the equivalent Ludlow lignitic member. The oyster-shell beds found near Mound and Yule probably indicate the brackish margin of the maximum extension of the Cannonball sea, and the very persistent T Cross lignite bed consists of vegetation accumulated in a swamp that was probably produced by regional subsidence occurring simultaneously with uplift farther west, now reflected by the unconformity between the Lance and Fort Union in the Big Horn Basin of Wyoming. The fossils of the Cannonball marine member of the Lance, as well as the delta character of the Hell Creek member, indicate the local persistence of marine waters after Fox Hills time, although the modification undergone by the Fox Hills fauna prior to Cannonball time may indicate that delta extension or uplift in remote regions had almost completely isolated the sea in which the Cannonball fauna survived.

After Ludlow time sedimentation was once more predominant over subsidence, resulting in the deposition of the river-laid sandstone and flood-plain clay of the Tongue River member of the Fort Union. Within relatively brief intervals, however, in Fort Union time, subsidence became preponderant, and the plant remains now contained in the extensive and thick lignite beds of the region were deposited in the resultant swamps. Locally scour in the beds of Fort Union streams caused some channeling in the upper strata of the Ludlow. (See pl. 5, *B*.)

After the local conglomerates were deposited interbedded clay, carbonaceous material, and sand were laid down on extensive flood plains or in comparatively large fresh-water swamps, as indicated by the uniformity and continuity of the strata. These materials are now shale, lignite, very fine-grained calcareous sandstone, and thin beds of limestone. The fineness of texture, the uniformity, the small amount of feldspar in the rocks, and the persistence of the beds indicate also that the source from which the sediments were derived was possibly somewhat farther removed than during the Lance epoch, or that the source of supply was much lower in altitude. Perhaps both conditions may have prevailed. Yet another cycle of depression was

heralded by the formation of the swamp in which was developed the widespread H T Butte lignite bed, and it continued during the deposition of the Sentinel Butte shale, which consists of dark clay apparently deposited as a delta built into a fresh-water lake that occupied the Williston syncline.

After the deposition of the Sentinel Butte shale regional uplifts of Northern Plains areas took place periodically, and the uplifted formations were extensively eroded. After erosion had lowered the surface of the region, probably to one of relatively low relief, sandstones such as those capping H T and Bullion Buttes were deposited in old river channels, and in some places the white calcareous beds of the Oligocene White River formation were laid down upon these sandstones with apparent conformity in ponds, lakes, or stream beds.

Since Oligocene time erosion has been more or less active in wearing down the surface of the region, which progressive uplift has recently elevated to its present position. That uplift has not proceeded uninterruptedly, however, is indicated by the deposits of terrace gravel and alluvium, which were laid down during intervals of comparative quiet.

STRUCTURE

GLENDIVE ANTICLINE

The Glendive anticline is a low, narrow uplift that is expressed by the gently arched beds striking southeast from the vicinity of Glendive, Mont., to the northwest corner of South Dakota, a distance of 100 miles. The axis of the anticline trends approximately N. 30° W., roughly parallel to the major axes of the Black Hills, Big Horn Mountains, Laramie Mountains, and minor flexures in this immediate vicinity, a fact which suggests the genetic relationship of all these features.[53] The anticline involves the Pierre shale, the Fox Hills sandstone, and the Lance and Fort Union formations but not the White River formation. A plan of the anticline shows in the middle an elongated strip of Pierre shale, the oldest outcropping formation, which is flanked first by a narrow belt of the Fox Hills sandstone, then a wide band of the Lance formation, closed around at the north end by the Fort Union.

As shown by the structure cross section on Plate 14 the dip of the Fox Hills sandstone on the west limb of the anticline ranges from 5° to 20°, but on the east it is very much less, ranging from 3° at points near the axis to a few minutes at greater distances.

A concrete example of the effect of the anticline on the relative altitude of the Harmon lignite bed at different points is shown on page 45.

[53] Thom, W. T., jr., The relation of deep-seated faults to the surface structural features of central Montana: Am. Assoc. Petroleum Geologists Bull., vol. 7, pp. 1–13, 1923.

Altitude of Harmon lignite bed

	Feet
Medicine Pole Hills	3,364
Postoffice Butte, near Rhame (the base of the heavy red rock being assumed to be the base of the bed)	3,330
Twin Buttes near Bowman, about	3,050
Scranton mine, at Scranton	2,770
Open pit in sec. 19, T. 133 N., R. 101 W	2,968
Open pit west of H T Butte	2,853
Burning bank in sec. 14, T. 136 N., R. 102 W	2,580
Sec. 3, T. 137 N., R. 102 W	2,515
Medora, in T. 140 N., R. 102 W.[54]	2,140

Again, the altitude of the T Cross bed at the Hamilton Bros. mine is 2,900 feet; at the Durkin mine, 2,998 feet; at the Johnston prospect, 3,189 feet; at the Funston ranch, 3,085 feet; at the Duckhorn mine, 2,980 feet; at the T Cross ranch, 3,000 feet; and at the base of the red clinker on top of Pretty Butte, 3,100 feet.

These altitudes indicate a very gentle dip of the beds to the northeast, which gradually decreases toward the east and north boundaries of the field. The average dip per mile of the Harmon bed from Postoffice Butte to H T Butte is less than 30 feet; from Postoffice Butte to the Twin Buttes, 18 feet; from the Medicine Pole Hills to the Twin Buttes, 23 feet; from Postoffice Butte to the burning bank in sec. 14, T. 136 N., R. 102 W., 26 feet; from Postoffice Butte to Medora, 21 feet. From the altitudes of these points the average strike is calculated as about N. 30° W., virtually parallel with the axis of the anticline, and the average dip on the east flank is about 26 feet to the mile northeastward.

The effect of the Glendive anticline is very slight in the northeastern portion of this field. The Harmon bed, for instance, in sec. 31, T. 137 N., R. 102 W., northwest of Tepee Butte, is only a few feet above the level of the river. At Hanley post office it is somewhat nearer the river level, and it disappears beneath the river in the south side of T. 139 N., R. 102 W., showing in that direction only a slightly greater dip than the fall of the river, which is about 7 feet to the mile.

This very slight dip of the strata is illustrated also by the Garner Creek lignite bed, which at the north side of T. 137 N., R. 102 W., is about 200 feet above the river. It disappears beneath the river in sec. 32, T. 141 N., R. 101 W., but remains beneath the river for only about 10 miles, and from the place where it emerges it is continuously exposed to the mouth of Beaver Creek, where it is 45 feet above the river, indicating a marked flattening of the strata to the north of Medora. This is bed C of the Sentinel Butte field[55] and bed K of Leonard.[56]

[54] Darton, N. H., Preliminary report on artesian waters of a portion of the Dakotas: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, p. 664, 1896.

[55] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, N. Dak. and Mont.: U. S. Geol. Survey Bull. 341, p. 25, 1909.

[56] Leonard, A. G., Geology of southwestern North Dakota, with special reference to the coal: North Dakota Geol. Survey Fifth Bienn. Rept., pp. 90–96, 1908.

ECONOMIC GEOLOGY

LIGNITE

GENERAL FEATURES

The term lignite is here used in accordance with the nomenclature of coal as adopted by the Geological Survey. The material is nearly black, and much of it is exceedingly woody, showing the grain of the wood and some of the trees and plants from which it was derived. Logs and knots are frequently seen in open cuts or in mines. These are usually flattened by pressure from the overlying shale and sandstone, but in places they are almost circular in cross section, indicating but little distortion by the overburden. As a rule the lignite is exceedingly tough, owing largely to its woody structure, and for that reason it is mined with considerable difficulty. Perhaps the Fort Union lignite has more of the woody structure preserved than that of the Lance, though some of the latter is rather woody. The lignite of the Lance formation is slightly darker than that of the Fort Union; indeed, some is almost black and breaks with an even fracture and a shiny luster. The browner lignite of the Fort Union formation, like that of the Lance, becomes black on exposure, breaks with a shiny luster, and on continued weathering turns to dust. Earthy parts of beds do not break with a shiny luster. Another feature is the greater number of joints in the lignite of the Lance formation, which is a characteristic going hand in hand with the apparently less woody structure. These features are perhaps due to the fact that the lignites of the Lance, being below the Fort Union, have been under greater pressure, or they may indicate that the materials composing the Lance lignites were more subjected to the action of anaerobic bacteria before carbonization than those composing the Fort Union lignites. The Fort Union lignite as a rule carries less impurities, such as shale, sand, and marcasite (FeS_2), than the Lance lignite. The iron sulphide occurs as sheets filling crevices in bedding planes or as irregular masses in cavities. Most of it is secondary to the formation of the lignite, and it was segregated or grew chiefly as feather-like, rosette-like, or ball-shaped masses. Molecular replacement of the cell contents of wood by marcasite has also occurred, with the result that the grain of the original wood can be seen in the iron sulphide. A clinker commonly found in the ashes of burnt lignite is the result of the iron sulphide being melted. Iron sulphide is a detriment when used in furnaces, because the liberated sulphur unites with hydrogen and oxygen and forms sulphuric acid, which corrodes the boiler flues.

Shale is probably the most common impurity in the lignite, occurring as thin partings in the beds. Sandstone is less common. Some of the lignites are so impure that they are virtually carbonaceous

shale, and in places lignite grades horizontally as well as vertically into shale. Gypsum occurs abundantly in the shale both above and below the lignite beds and here and there in the beds themselves.

PRINCIPAL LIGNITE BEDS

The Fort Union lignite beds (see fig. 1) are far more persistent and usually thicker than those of the Lance. There are, of course, many lenticular, nonpersistent beds in the Fort Union, and there are some extensive thick beds in the Lance—for instance, the T Cross bed, which is well exposed at the old T Cross ranch (see pl. 4, *A*), near Ives, is very extensive and is the principal lignite bed in the Ludlow lignitic member of the Lance, corresponding to the Giannonatti bed[57] of northwestern South Dakota. It has been traced from T. 20 N., R. 8 E., S. Dak., to the vicinity of Yule and thence westward to Montana. The lignite bed or beds mapped at the contact of the Lance and Fort Union formations around the Glendive anticline occur at this general horizon.[58] Throughout most of this distance the T Cross bed is of fair thickness, usually being more than 3 feet and at many places 6 or 8 feet thick. In the vicinity of the T Cross ranch (see pl. 4, *A*) it is 24 feet thick, but on the north side of T. 134 N., R. 105 W., and T. 135 N., R. 105 W., the bed is of little value. However, it increases in thickness in the bluffs of the river in T. 135 N., R. 105 W., where it is from 6 to 9 feet thick. From this place west to the Montana State line it is somewhat thinner. It is mined at the Durkin, Johnson, Funston, Hamilton, Duckhorn, and T Cross mines and at several other smaller strip pits.

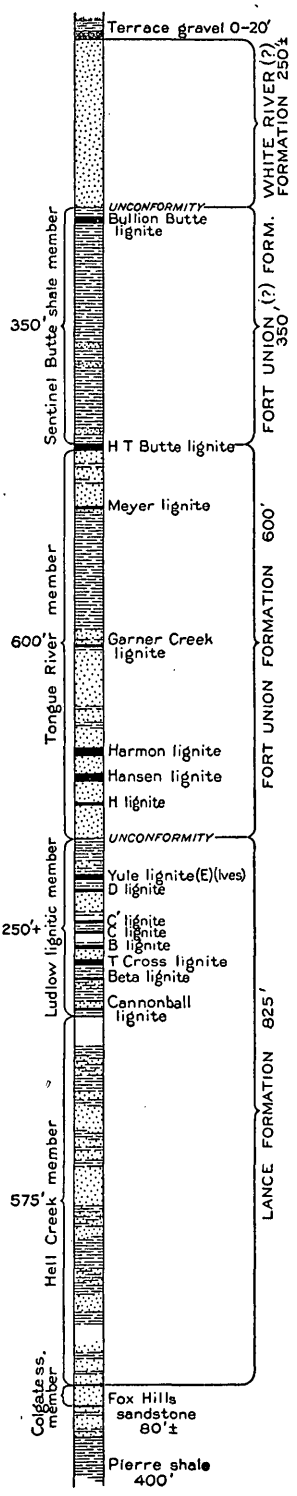


FIGURE 1.—Generalized columnar section showing stratigraphic position of the principal coal beds in the Marmarth field

[57] Winchester, D. E., and others, The lignite fields of northwestern South Dakota: U. S. Geol. Survey Bull. 627, p. 73, 1916.

[58] Calvert, W. R., Geology of certain lignite fields in eastern Montana: U. S. Geol. Survey Bull. 471, p. 196, 1912.

The lignite bed in the valley of Cannonball River is the lowest valuable bed in the Ludlow lignitic member of the Lance. For a few miles east of the Montana line it is less than 2 feet thick, but two exposures in Montana show 4 feet each, and in the east side of T. 135 N., R. 106 W., it is 3 to 6 feet thick.

About 100 feet above the T Cross bed at Ives is the lenticular Ives bed, which is exposed along the railroad east of the town and in the upper part of the valley of Bacon Creek. The several measurements made on it average about 3 feet. The quality of the lignite in this bed is rather poor. The Yule or E bed occurs at about the same horizon as the Ives bed. It crops out in the bluffs of the river and on Williams Creek in the vicinity of the Lang ranch at Yule, where it is about 6 feet thick and of good quality. To the south and west the bed thins and could not be traced definitely. Possibly the bed at the Blue ranch, in T. 134 N., R. 105 W., is the same bed.

These thicker beds of Lance lignite are associated with many lesser and lenticular beds. All the beds found to be over 2 feet thick and of any considerable extent are shown in Figure 1.

Near the base of the Fort Union formation is a group of thick lignite beds called by Leonard[59] the Great Bend group. Bed H, the lowest of the group, in T. 135 N., R. 104 W., is about 60 feet above the Lance formation and rests upon the quartzitic layer, which is an excellent horizon marker. The bed is best developed in this township and the one to the north, where it averages about 5 feet thick. The greatest thickness determined on the bed is 10 feet 2 inches, measured in sec. 14, T. 135 N., R. 104 W. A characteristic feature of the bed in many exposures is a shale parting about 2 inches thick a little above the middle. This feature is well shown in the sections on Plate 12. The bed could not be found in the grassy slopes in T. 137 N., R. 105 W.; in T. 136 N., R. 102 W., it is not well defined; and in T. 137 N., R. 102 W., it possibly merges with the Harmon bed. On Deep Creek, in T. 135 N., Rs. 102 and 103 W., the bed is in places less than 2 feet thick. To the south, in T. 134 N., R. 104 W., near Mound, the bed diminishes so as to be of no economic value. Even farther south in places it appears above the quartzite but is less than 2 feet thick. It is assumed with reasonable certainty that the thin lignite bed above the quartzite bed in Anarchist Butte, in T. 22 N., R. 9 E., and about Lodgepole post office, in Tps. 21 and 22 N., R. 12 E., S. Dak., is the same lignite as bed H,[60] and the Haynes bed, in T. 129 N., R. 104 W., is thought to be at the same horizon.[61]

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[59] Op. cit., pp. 80–90.

[60] Winchester, D. E., and others, The lignite field of northwestern South Dakota: U. S. Geol. Survey Bull. 627, pp. 121–122, 142–143, 1916.

[61] Lloyd, E. R., The Cannonball River lignite field, Morton, Adams, and Hettinger Counties, N. Dak: U. S. Geol. Survey Bull. 541, p. 252, 1914.

The Hansen bed, in Tps. 135 and 136 N., R. 104 W., is separated by about 30 feet of soft yellow sandstone from bed H. It averages about 10 feet of extra good lignite. There are very few shale partings, and other common impurities occur in small quantities. The Hansen bed is well exposed in secs. 26, 27, 28, and 34, T. 136 N., R. 104 W., and is mined at the Lombard prospect, in sec. 8, T. 132 N., R. 102 W., and west of Bessie, in sec. 15, T. 133 N., R. 102 W. It is the lignite immediately below the heavy "clinker" in T. 135 N., R. 103 W., and is the middle one of the three beds just below the terrace in secs. 4, 5, and 6, T. 136 N., R. 102 W. Down the river, in T. 137 N., R. 102 W., this bed appears to have united with the Harmon bed.

The Harmon bed is the upper one of three beds in the Great Bend lignite group and ranges in position from immediately above the Hansen bed to 20 feet above. It is the most valuable lignite bed in this field. It is of excellent quality, and at most exposures it is very thick. (See pls. 5, *A*, and 7, *B*.) The thinnest sections are those measured on the west side of T. 137 N., R. 103 W., where it is less than 3 feet thick, and the thickest are those near the old Russell ranch, on Sand Creek, at location 273, in sec. 30, T. 135 N., R. 101 W., where there is a total of 34 feet of lignite. The upper 3 feet of lignite is separated by 3 feet of shale from 31 feet of lignite below, which is the thickest measurement of lignite obtained in this field and, so far as known, the thickest in the State. The bed was traced throughout this field from a point a few miles east of the Montana-North Dakota State line, in T. 136 N., R. 104 W., northward down the river to the south side of T. 139 N., R. 102 W., where the bed, more than 13 feet in thickness, dips beneath the river. From this place it was followed south on the east side of the river nearly to Scranton, where 19 to 23 feet of lignite is mined on a considerable scale. Outliers of it occur beneath the Twin Buttes and Medicine Pole Hills and at Mound.

Fused rock, possibly formed by the burning of the same bed, was found on top of the high butte northwest of Ludlow post office, S. Dak., at a horizon higher than any other lignite in the State.

Leonard and Smith[62] correlated the Harmon bed with the one mined on Beaver Creek below Wibaux, Mont., and Stebinger[63] correlated it with his bed G, which he traced throughout the Sidney lignite field. The 20-foot lignite bed penetrated in the deep well at Medora is probably the same bed, but the thick lignite in the Dickinson well, believed by Darton[64] to be the same bed, is almost certainly a higher one. An estimate based on the mapped outcrop of the Harmon bed or zone

[62] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, N. Dak. and Mont.: U. S. Geol. Survey Bull. 341, pp. 24–25, 1909.

[63] Stebinger, Eugene, The Sidney lignite field, Dawson County, Mont.: U. S. Geol. Survey Bull. 471, p. 288, 1912.

[64] Darton, N. H., Preliminary report on artesian waters of a portion of the Dakotas: U. S. Geol. Survey Seventeenth Ann. Rept., pt. 2, p. 664, 1896.

indicates that it underlies at least 5,500 square miles, and it may be workable over a much greater area in adjacent fields. This compares with the areal distribution of the great Pittsburgh bed[65] of Pennsylvania, Ohio, and West Virginia, which underlies somewhat less than 6,000 square miles.

About 180 feet above the Harmon is the Garner Creek bed, which underlies a small area in the northeast corner of this field. It is correlated with bed C of the Medora group of lignite beds[66] and with bed K or L of the same group north of Medora, which was traced to the mouth of Beaver Creek.[67] The bed is not found south of T. 137 N., having been eroded away. It ranges here from a foot or less to 8 feet in thickness, and to the north of this field is in places over 12 feet thick.

The Meyer bed is thin and of poor quality in T. 137 N., Rs. 102 and 103 W. It is 9 to 16 feet thick and of excellent quality in T. 138 N., R. 103 W., but underlies only a small area in that township. It is about 200 feet above the Garner Creek bed and 80 feet below the H T Butte bed.

The H T Butte lignite, which is the basal bed of the Sentinel Butte shale, averages about 9 feet in thickness, but in sec. 1, T. 138 N., R. 102 W., it is over 16 feet thick. The lignite has been largely eroded or burned out in this field, and now occurs only as remnants beneath H T and Bullion Buttes and the high hills in Tps. 137 and 138 N., Rs. 102 and 101 W. Extensive "burns" of it cap the highland in T. 138 N., R. 103 W. This is bed F of the Sentinel Butte lignite group[68] and probably bed R of Leonard.[69] The bed is of considerable extent and is correlated with bed K in the Sidney lignite field[70] and may correspond to the Roland coal bed of northern Wyoming.[71] A still higher bed is the Bullion Butte bed, which is 16 feet thick and, so far as found, occurs only in Bullion Butte.

SPONTANEOUS BURNING OF LIGNITE BEDS

Beds of lignite in the process of burning were noted near the mouth of Cannonball River; on Boyce Creek in sec. 35, T. 135 N., R. 104 W.; in sec. 6, T. 138 N., R. 102 W.; in sec. 16, T. 135 N., R. 102 W., and in the NE. ¼ NE. ¼ sec. 14, T. 135 N., R. 102 W. At the

[65] White, I. C., West Virginia Geol. Survey, vol. 2, pp. 165-166, 1903.

[66] Leonard, A. J., and Smith, C. D., op. cit., p. 25.

[67] Leonard, A. G., Geology of southwestern North Dakota, with special reference to the coal: North Dakota Geol. Survey Fifth Bienn. Rept., pp. 90-102, 1908.

[68] Leonard, A. G., and Smith, C. D., op. cit., p. 30.

[69] Leonard, A. G., op. cit., p. 105.

[70] Stebinger, Eugene, The Sidney lignite field, Dawson County, Mont.: U. S. Geol. Survey Bull. 471, pp. 284-292, 1912.

[71] Taff, J. A., The Sheridan coal field, Wyo.: U. S. Geol. Survey Bull. 341, pp. 130, 142, 1909. Stone, R. W., and Lupton, C. T., The Powder River coal field, Wyo., adjacent to the Burlington Railroad: U. S. Geol. Survey Bull. 381, pp. 121-122, 1910. Davis, J. A., The Little Powder River coal field, Campbell County, Wyo.: U. S. Geol. Survey Bull. 471, p. 428, 1912.

last-mentioned locality the Harmon lignite, 20 feet thick, was burning with an intense white heat. (See pl. 7, *C*.) Many thinner beds burn, but the combustion is slow and weak, generating little heat. Inhabitants of the vicinity state that to their knowledge the Harmon bed has been burning for more than 20 years. The ground for several acres around the "burn" is baked, and fused rock near the vent is evident. The vent when visited was some 3 feet across and increased in size downward, with a cavern at the bottom of the natural furnace as large as a small room. However, only a vague idea could be obtained of the size because of the strong draft of hot gases and smoke which rose visibly to a height of 40 or 50 feet and at times could be seen for several miles. Snowballs 2 feet in diameter rolled into the opening apparently were converted immediately to steam. As the thick bed burns, the overlying rock and soil slump, giving rise to a hummocky and furrowed surface. This creates new avenues for supplying air to the burning mass of lignite. About small vents and cracks unstable crystals of sulphur were forming. Prairie fires have been known to start from this burning bed of lignite, and ranchmen now plow around the spot to prevent the spread of the fire. It is also conceivable that a lignite bed may be ignited by a prairie fire if conditions are favorable. No burning was noted where lignite beds crop out along the bottom of a valley, but all the burning beds were on the points of hills. From these facts it seems that to take fire a lignite bed must be high and dry.

Any attempt to place the time when these several beds first began to burn is purely speculative, but it may be worth while. First of all, the lignite must be exposed to the air. To do this the overlying rocks must be removed at numerous places, giving favorable conditions for the oxidation of the lignite and the liberation of combustible gases. Iron sulphide (marcasite) occurs in small quantities as radially formed balls or irregular masses filling small fissures or cavities in the lignite, and its oxidation undoubtedly contributes toward the process of burning by generating additional heat. Oxidation generates heat, which favors more rapid oxidation, thus generating greater and greater heat until the lignite begins to burn. Once started, the lignite will burn until the interstream blocks of lignite are burned out or the fire is smothered by excessive cover, when further burning must wait until the streams have had time to establish tributaries to dissect the covered areas and to expose fresh places for the attack of oxidation. From 30 to 50 feet of incoherent cover generally seems adequate in this field to prevent further burning, but the thickness necessary depends on the thickness of the lignite bed and the physical character of the rocks. Competent beds of massive rocks favor extensive burning of an underlying lignite far back from the outcrop, as under such a cover openings

are developed as the lignite burns, furnishing oxygen for continued burning. A study of the map will show the present relation of the drainage to the burned and unburned parts of the extensive Harmon bed. The process of burning may be intermittent at some places and continuous at others. Surely it progressed with erosion or lagged only slightly behind it. Even though there is no positive evidence, it seems reasonable to assume that some of the lignite burned before White River time, as that formation lies unconformably on the Fort Union and Lance. A hand specimen of White River conglomerate collected in Chalky Butte contains a very small red fragment which is probably baked rock, and Bauer[72] has found large fragments of burned rock in the White River formation in Montana. It is possible to conceive that the earliest burns may have dated back to early Tertiary time, when earth movements made erosion dominant over deposition in the Great Plains and Rocky Mountain provinces, causing the material already laid down to be cut deeply.

CHEMICAL COMPOSITION OF THE LIGNITE

The best method of comparing one coal with another is obviously to test them in a large way in the same furnace, or in whatever form of equipment is to be used, and determine which gives the best results, but such tests are not always possible, and the next best method consists in making chemical analyses of the coals and comparing the results thus obtained.

Chemical analyses of coals are made in two forms, proximate and ultimate. A proximate analysis is one in which moisture, volatile matter, fixed carbon, and ash are determined. As none of these substances are chemical elements, it is impossible to determine them accurately, and hence the proximate analysis can be regarded only as indicating some of the properties of a coal. It is, however, easily and cheaply made and is the form generally depended upon for determining the comparative value of a coal. An ultimate analysis, as its name implies, gives the composition of the coal in its ultimate elements, such as hydrogen, oxygen, sulphur, nitrogen, and lastly ash, which, because it is not a part of the combustible matter of the coal, is generally not separated into its component parts.

The laboratory of the Bureau of Mines is intrusted with the duty of making all analyses of coal for Government work. In addition to the proximate and ultimate analyses, the heating value of the coal is generally determined and is expressed in terms of British thermal units and calories. A British thermal unit may be defined as the amount of heat required to raise the temperature of 1 pound of water from 62° to 63° F. As the calorie is expressed in the centi-

[72] Bauer, C. M., personal communication

grade scale a calorie bears the same relation to a British thermal unit as the degree on one scale to that on the other—that is, a calorie is nine-fifths of a British thermal unit. The heating value as given in the table means that the complete combustion of 1 pound of the coal would yield the stated number of British thermal units or calories.

A chemical analysis alone is of little value, but when coupled with a calorimeter determination it gives data for a fairly reliable comparison of one coal with another, but it must be remembered that the results obtained in a laboratory are merely theoretical and that they probably can not be equaled in actual field practice, and also that several factors other than those shown in a chemical analysis may affect the burning of a coal and cause it to yield very different results from those which are theoretically possible. Although it may be impossible to attain the full heating value of a coal when it is burned under ordinary conditions, the calorific values of two or more coals can be compared and an idea can be obtained as to their relative efficiency. Thus a coal having a calorific value of 12,000 British thermal units will give 50 per cent more heat than one having only 8,000 British thermal units.

The factors that tend to reduce the value of lignite as a fuel for ordinary purposes are high moisture, low heating value, and tendency to slack or crumble when exposed to the weather. For certain purposes high volatile matter as compared with the fixed carbon tends to increase the value of the lignite, for if the volatile matter equals or exceeds the fixed carbon, the lignite is "fat," or much like cannel coal, and it may even be so "fat" as to yield considerable oil on destructive distillation.

In order that the lignite of this field may be compared with that of adjacent fields, or even with high-rank coal of other fields, the following analyses are given. The first 12 represent samples of lignite obtained either in this field or in adjacent parts of this State or of Montana. A comparison of the analyses shows that there is a great similarity in the lignite throughout the territory from Missouri River near Bismarck to Musselshell River in Montana. West of this territory, however, are coals of better quality, with which doubtless the lignite will have to compete. These coals are now classed as subbituminous, and they may be considered as represented by the best coal in the Bull Mountain and Red Lodge fields of Montana. The analyses of two samples from each of these fields are given in the table. Last are given analyses of representative eastern coals with which the lignite of North Dakota comes into direct competition. As shown by the tables these coals are much better than the lignite, but for many purposes they may not give better results per unit of cost, in view of the cost of the long haul.

Analyses of lignite samples from the southwestern North Dakota and adjoining lignite fields

[By the United States Geological Survey and the Bureau of Mines; E. E. Somermeier and A. C. Fieldner, chemists in charge]

Mine	Location				Laboratory No.	Air-drying loss	Form of analysis	Proximate				Ultimate					Heating value	
	Quarter	Sec.	T.	R.				Moisture	Volatile matter	Fixed carbon	Ash	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Calories	British thermal units
Scranton mine, Scranton, Bowman County, N. Dak.	SW.	24	131 N.	100 W.	14485	22.5	A	34.8	31.1	26.0	8.1	0.66					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
Durkin mine, Bowman County, N. Dak.	SW.	34	130 N.	103 W.	14857	35.8	A	43.6	23.2	27.0	6.2	.65					3,240	5,830
							B	12.2	36.2	42.0	9.6	1.01					5,045	9,080
							C		41.2	47.8	11.0	1.15					5,745	10,340
							D		46.3	53.7		1.29					6,450	11,610
Nipper and Monroe mine, near Haynes, Adams County, N. Dak.	NW.	16	129 N.	94 W.	14542	14.5	A	32.6	30.6	28.5	8.3	1.53					4,085	7,360
							B	21.2	35.8	33.3	9.7	1.79					4,780	8,600
							C		45.4	42.3	12.3	2.27					6,070	10,920
							D		51.8	48.2		2.59					6,920	12,460
U. S. Bureau of Reclamation mine near Williston, Williams County, N. Dak.		7	154 N.	100 W.	19367	32.8	A	44.1	23.8	26.3	5.76	.56	7.28	36.11	0.63	49.66	3,355	6,040
							B	16.9	35.4	39.1	8.58	.84	5.40	53.74	.94	30.50	4,990	8,980
							C		42.6	47.1	10.32	1.00	4.25	64.68	1.13	18.62	6,005	10,810
							D		47.5	52.5		1.12	4.74	72.11	1.26	20.77	6,695	12,060
Mine of Dakota Products Co., New Salem, Morton County, N. Dak.		15	139 N.	85 W.	20033	32.7	A	38.5	27.6	26.6	7.28	1.31	7.03	39.22	.60	44.56	3,725	6,700
							B	8.6	41.0	39.6	10.83	1.95	5.04	58.31	.89	22.98	5,535	9,970
							C		44.9	43.3	11.84	2.13	4.47	63.79	.98	16.79	6,055	10,900
							D		50.9	49.1		2.42	5.07	72.36	1.11	19.04	6,870	12,360
Mine of Consolidated Coal Co., Lehigh, Stark County, N. Dak.		8	139 N.	95 W.	1971	35.6	A	42.2	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
Mine of Washburn Lignite Coal Co., Wilton, McLean County, N. Dak.		1	142 N.	80 W.	1935	32.3	A	40.5	27.1	27.4	5.0	.76					3,690	6,640
							B	12.2	39.9	40.4	7.5	1.12					5,450	9,810
							C		45.5	46.0	8.5	1.28					6,205	11,170
							D		49.7	50.3		1.40					6,785	12,210
Prospect, 3 miles southeast of Sentinel Butte, Golden Valley County, N. Dak.		5	139 N.	104 W.	5784	32.6	A	43.5	25.2	24.9	6.4	1.04					3,230	5,810
							B	16.2	37.4	36.9	9.5	1.54					4,790	8,630
							C		44.7	44.0	11.3	1.84					5,720	10,290
							D		50.4	49.6		2.08					6,445	11,610

Mine of G. A. Horner, Carter County, Mont.	------	12	3 S.	62 E.	20370	34.3	A	41.3	24.6	26.9	7.2	.62	------	------	------	------	3,440	6,190
							B	10.6	37.5	40.9	11.0	.95	------	------	------	------	5,240	9,430
							C	------	42.0	45.8	12.2	1.06	------	------	------	------	5,860	10,550
							D	------	47.8	52.2	------	1.21	------	------	------	------	6,680	12,020
Kircher mine near Miles City, Custer County, Mont.	------	19	8 N.	48 E.	5694	18.1	A	29.6	27.4	33.0	10.0	.68	------	------	------	------	4,155	7,480
							B	14.0	33.5	40.3	12.2	.83	------	------	------	------	5,075	9,130
							C	------	38.9	46.8	14.3	.97	------	------	------	------	5,905	10,630
							D	------	45.4	54.6	------	1.13	------	------	------	------	6,885	12,390
Snyder mine, near Glendive, Dawson County, Mont.	------	27	17 N.	55 E.	11045	23.4	A	32.1	25.6	34.2	8.1	1.36	------	------	------	------	3,950	7,110
							B	11.4	33.3	44.7	10.6	1.77	------	------	------	------	5,155	9,280
							C	------	37.7	50.4	11.9	2.00	------	------	------	------	5,815	10,470
							D	------	42.7	57.3	------	2.27	------	------	------	------	6,605	11,890
Astrope mine, Roosevelt County, Mont.	------	15	29 N.	55 E.	11005	35.0	A	40.8	25.2	27.8	6.23	.72	7.11	36.57	.68	48.69	3,415	6,150
							B	8.8	38.8	42.8	9.58	1.10	4.96	56.26	1.04	27.06	5,255	9,460
							C	------	42.5	47.0	10.51	1.22	4.35	61.71	1.15	21.06	5,765	10,370
							D	------	47.5	52.5	------	1.36	4.86	68.95	1.29	23.54	6,440	11,590
Mine No. 2, of Republic Coal Co., Roundup, Musselshell County, Mont.	------	36	8 N.	25 E.	8802	7.1	A	13.6	28.0	51.8	6.6	.64	------	------	------	------	6,210	11,180
							B	7.1	30.1	55.7	7.1	.49	------	------	------	------	6,685	12,040
							C	------	32.4	60.0	7.6	.53	------	------	------	------	7,195	12,950
							D	------	35.1	64.9	------	.57	------	------	------	------	7,785	14,020
Mine A, of Roundup Coal Mining Co., Roundup, Musselshell County, Mont.	------	22	8 N.	25 E.	29004	3.5	A	13.6	32.9	45.5	8.05	.70	5.56	61.98	.98	22.73	5,935	10,690
							B	10.5	34.0	47.2	8.34	.72	5.37	64.20	1.01	20.36	6,150	11,070
							C	------	38.0	52.7	9.31	.81	4.69	71.70	1.13	12.36	6,870	12,360
							D	------	41.9	58.1	------	.89	5.17	79.06	1.25	13.63	7,575	13,630
Southside mine, Bear Creek, Carbon County, Mont.	------	5	8 S.	21 E.	15130	3.0	A	10.0	33.9	44.8	11.31	2.26	5.28	59.13	1.41	20.61	5,885	10,590
							B	7.1	35.0	46.2	11.66	2.33	5.10	60.96	1.45	18.50	6,065	10,920
							C	------	37.7	49.7	12.56	2.51	4.63	65.66	1.57	13.07	6,535	11,760
							D	------	43.1	56.9	------	2.87	5.29	75.09	1.80	14.95	7,475	13,450
Mine of International Coal Co., Bear Creek, Carbon County, Mont.	------	31	7 S.	21 E.	18694	3.6	A	11.7	34.1	45.8	8.39	1.68	5.50	60.56	1.63	22.24	5,975	10,760
							B	8.5	35.3	47.5	8.70	1.74	5.29	62.80	1.69	19.78	6,200	11,160
							C	------	38.6	51.9	9.51	1.90	4.76	68.61	1.85	13.37	6,770	12,190
							D	------	42.7	57.3	------	2.10	5.26	75.82	2.04	14.78	7,485	13,470
Average Pittsburgh (Pa.) coal	------	------	------	------	------	2.9	A	3.9	33.6	56.8	5.70	1.04	5.33	77.21	1.37	9.35	7,675	13,820
							B	1.1	34.5	58.5	5.87	1.07	5.16	79.52	1.41	6.97	7,905	14,230
							C	------	34.9	59.2	5.93	1.08	5.09	80.38	1.43	6.09	7,990	14,380
							D	------	37.1	62.9	------	1.15	5.41	85.44	1.52	6.48	8,495	15,290
Hocking Valley (Ohio) coal	------	------	------	------	------	------	A	7.6	34.0	52.6	5.85	.77	5.52	70.05	1.42	16.39	------	12,510
							B	------	------	------	------	------	------	------	------	------	------	------
							C	------	36.8	56.9	6.33	.83	5.07	75.81	1.54	10.42	------	13,530
							D	------	39.3	60.7	------	.89	5.41	80.93	1.64	11.13	------	14,440
Best southern Illinois coal	------	------	------	------	------	5.4	A	9.2	27.3	55.4	8.12	.90	5.10	68.45	1.14	16.29	6,675	12,020
							B	4.0	28.9	58.5	8.58	.95	4.76	72.36	1.20	12.15	7,055	12,700
							C	------	30.1	61.0	8.94	.99	4.49	75.37	1.26	8.95	7,350	13,230
							D	------	33.0	67.0	------	1.09	4.93	82.77	1.38	9.83	8,070	14,530

In recent years dried and crushed lignite has been successfully used as a powdered fuel, thus overcoming to an extent the disadvantage which it otherwise suffers because of the rapidity with which it crumbles when exposed to the air. Experiments are also being conducted by the United States Bureau of Mines looking toward the production of briquetted fuel from lignite that has been heated until its moisture and volatile matter are almost wholly removed.

Four forms of analyses, labeled A, B, C, and D, are given in the table. Analysis A represents the composition of the sample of lignite as it is received from the mine. Because of the varying conditions under which the samples are taken the amount of moisture in the sample is largely a matter of accident; consequently this form is not well adapted for comparisons. In view of this fact, all the samples are dried at a temperature slightly above normal until the weight becomes constant; they are then known as air-dried samples. The analysis of the air-dried sample is given under form B, which is better adapted for most purposes of comparison. Analysis C represents the composition of the lignite after all the moisture has been theoretically removed, and analysis D after all the moisture and ash have been so removed. Both forms are obtained by recalculating A and B. Form D is of value for comparing weathered samples of lignite.

The lignite of this field, as shown by the analyses given, compares favorably with the other lignites of the northern Great Plains province. The sample of lignite from the Scranton mine may be properly considered a fair representative of the important Harmon bed in the Marmarth field, which is of Tongue River age. This sample, in spite of a slightly greater ash content, shows a higher heating value than the sample from Roosevelt County, Mont., which is also from a Tongue River lignite bed, as is also the one at Haynes. The Bureau of Reclamation mine near Williston is on a lignite bed in the Sentinel Butte shale. The sample obtained from the Durkin strip pit of the T Cross lignite bed of the Ludlow lignitic member of the Lance was somewhat weathered, and consequently its analysis (No. 14857) apparently indicates that the unweathered lignite of this bed has a good heating value and what may be regarded as about a normal ash content. The sample from the Snyder mine, near Glendive, Mont., is from a lignite bed approximately at the T Cross horizon and shows a normal amount of ash and a higher heating value than the sample from the Durkin mine.

The analysis of the Roundup coal from mine A of the Republic Coal Mining Co., Roundup, Mont., is given for the sake of comparison of subbituminous coal and lignite and also because that coal is used in competition with lignite from the Haynes and Scranton mines at Bowman, Marmarth, Rhame, and other places in the field covered by this report.

PORCELLANITE

The Marmarth field contains great quantities of fused or baked rocks formed during the burning of lignite beds. (See pl. 6, *C*.) Allen[73] has summarized the literature on the subject, and Bastin[74] has given an excellent description of the material, which is known as porcellanite.

The fused material is formed at points of greatest heat—for example, about vents or over thick lignite beds as they burn. (See pl. 7, *C*.) Some of this material is very heavy, as if there were a segregation of the iron content from the fused rocks. Some of it is very light and porous, as if it had solidified from frothy material in the presence of a great amount of air and other gases. Other specimens are glassy and dense, with only here and there a gas cavity, and some break into long columnar pieces, as at Hat Rock, in T. 129 N., R. 102 W. Others even exhibit flow structure, as if cooled from a flowing viscous mass. By far the largest part of the material is very similar to ordinary red brick, is soft and light, and breaks readily in any direction desired. It rattles and rings when moved much like chips and fragments of bricks or draintile. In fact, it seems to be a fine example of natural brick. In places it attains a thickness of 30 to 50 feet and is composed of angular pieces of rock fused together. Through the mass are great numbers of large and small cavities. A considerable portion of the material is simply oxidized reddened soil. Although the predominating hues are dark red or dark purple they are by no means the only ones, for various shades of red, brown, yellow, orange, pink, blue, green, and purple occur. Much of the material shows only a suggestion of colors, which is due mostly to the oxidation of the iron content of the rocks caused by the burning of the underlying lignite. The product of this metamorphism by heat, where fused, forms a distinct rock type, and some specimens are thoroughly crystallized like an igneous rock. So far as noted, the underlying rocks are not metamorphosed, the only change being a slight breaking or cracking, indicating that most of the thermal effect is upward. Therefore the base of the porcellanite in place marks very closely the horizon of the lignite bed and may be used in tracing beds from one outcrop to another or in driving an entry to strike a desired lignite bed. Large quantities of the material occur in T. 138 N., Rs. 102 and 103 W. (see pl. 14), from the burning of the H T Butte bed, and in Tps. 136, 135, 134, 133, and 132 N., Rs. 102 and 103 W., from the burning of the Harmon bed. Other beds, such as the T Cross, also show large "burns." In T. 135 N., R. 105 W., the lignite beds on the west side of the river have burned extensively, but across the river the same

[73] Allen, J. A., Boston Soc. Nat. Hist. Proc., vol. 16, p. 246, 1874.

[74] Bastin, E. S., Notes on baked clays and natural slags in eastern Wyoming; Jour. Geology, vol. 13, pp. 408-412, 1905.

series of beds have burned only slightly, a phenomenon probably due to differences in surface conditions coupled with differences in character of the lignites and in their position with reference to the surface. In many places the red rock discloses the presence of lignites that are otherwise concealed.

The baked and fused material makes fine track ballast, especially in a region where gravel or crushed rock is not accessible. It occurs usually in small pieces but if not suitably sized is easily crushed to any desired size. The Northern Pacific and Chicago, Burlington & Quincy railroads have used it for ballast where they pass through such areas of baked rock, and in Nebraska many of the railroads have made such material artificially for ballast. It is useful as road metal, though it is a little too soft for heavy traffic. Locally it is often used for covering dirt roofs to homesteaders' dwellings. The lively red color sets off the building in the landscape, and the burned material keeps the underlying dirt from blowing away. Being porous, it allows free drainage. The better grade of baked rock is used occasionally for building material, and when it is used with other stone the red color gives a pleasing effect.

TOWNSHIP DESCRIPTIONS

As lignite is the most valuable mineral resource of this field the data collected regarding the outcrop, thickness, and composition of the several beds will be given in detail, and as the township is the most convenient areal unit the descriptions will be given by townships or by groups of townships.

T. 138 N., R. 106 W.

The topography of fractional T. 138 N., R. 106 W., is that of a hilly grassy upland, somewhat dissected in the southern part by the tributaries of Bullion Creek. Fair water is obtained in the valleys from shallow wells. In the NE. ¼ NE. ¼ sec. 25 a good flow of artesian water was struck in a well reported to be 106 feet deep.

A slight eastward dip of the rock strata is shown by the outcrop of the Burkey lignite bed, which rises toward the west at about the same rate as the valley of Bullion Creek. From the geologic structure of the region and the occurrence of lignite in numerous beds that are exposed near this township, it is believed that the township is underlain by several beds of lignite beneath those that crop out.

One lignite section was measured in the SE. ¼ sec. 25 (see pl. 14), and the bed contains 4 inches of lignite separated by 2 inches of shale from 24 inches of lignite below. This may possibly represent the Burkey bed, the burning of which has produced the red hills in secs. 22, 23, 24, 26, and 27. It is not, however, comparable in thickness

with that lignite bed as shown by the sections around Burkey, in T. 137 N., R. 105 W. The position of the bed as traced in this township is entirely inferred by burned soil and baked beds of sandstone and shale. A small high area of porcellanite was noted in sec. 3 and probably was formed by the burning of the Meyer bed, which is described in the section on T. 138 N., R. 102 W.

The Burkey lignite is of very good quality and burns well in stoves when properly dried. It is mixed with coal of better grades from other fields and is burned in steam tractors used for plowing. It is brown, tough, and woody.

T. 138 N., R. 105 W.

T. 138 N., R. 105 W., as a whole consists of a grassy upland dotted with clinker-capped hills and has a total surface relief of about 350 feet. The water supply of the township is limited to that obtained from shallow wells or from the intermittent creeks.

The rock strata dip slightly to the northeast, as shown by the attitude of the Burkey lignite, the slope of which along Bullion Creek, is slightly more pronounced than the gradient of the stream. About 350 feet of strata belonging to the Tongue River member of the Fort Union are exposed in the township, and two high buttes are probably capped by some of the Sentinel Butte shale.

It is highly probable, from the nearly horizontal position of the numerous lignite beds both of Fort Union and Lance age occurring lower in the geologic section than the surface rocks of this township and exposed in the townships to the south and east, that considerable lignite underlies this township. The only lignite bed exposed (see pl. 14), the Burkey bed, crops out along the valley of Bullion Creek. The total thickness of the bed was not ascertained at the one section measured (location 7, in sec. 35), because the strip pit was filled with water. However, it contains at least 6 feet of lignite. Its outcrop was traced along the grassy slopes up Bullion Creek Valley, largely by the occurrence of red baked soil, the outcrop being entirely inferred, but experience in other townships showed that the approximate limit of good lignite is probably marked by the inner edge of the red and oxidized soil. This may be the same lignite as the Garner Creek bed, or it may be a lower bed. The Garner Creek bed was traced from sec. 6, T. 138 N., R. 104 W., up to the east township line near sec. 1, and there its outcrop is concealed in grassy slopes. However, it underlies a considerable portion of the township.

The Burkey lignite is of good quality and is considered to be a good domestic fuel by those who use it. It is mixed with the better coals from other fields for use by steam tractors doing plowing work. It is brown, tough, and woody. Very little impurity, such

as shale and clay, was here noted in this bed. The entire township is classified as coal land on the basis of the beds exposed and those believed to underlie it.

T. 138 N., R. 104 W.

The surface of most of T. 138 N., R. 104 W., consists of rolling uplands except for 5 or 6 square miles in the middle eastern portion, which is almost wholly covered by red clinker-capped hills. Along the banks of Garner Creek there are several isolated gravel terraces, which are similar in altitude and origin to those along Little Missouri River. Garner Creek contains pools of water throughout the dry season, and water may be generally obtained in shallow wells.

In addition to Tongue River strata about 50 feet of the Sentinel Butte Shale is exposed in this township. Numerous beds of lignite crop out within the township, and other lignite beds exposed farther northwest are believed to underlie it.

The lowest bed exposed along the valley of Garner Creek, or Garner Creek bed, is provisionally correlated with bed C of the Medora group of Smith and Leonard.[75] This bed is 3 to 4 feet thick and was measured at location 8, in sec. 6, at location 9, in sec. 4, and at location 10, in sec. 9. The thickness observed is shown graphically on Plate 8. The Garner Creek bed is worked for local consumption at location 13, in sec. 36 of the township to the north. At location 12, sec. 24, a partial measurement of the H T Butte lignite was obtained. The exposure was very poor, and only 3 feet of the bed was measured. There is an indication of a bed of lignite at location 11, sec. 34, but no data were procured regarding its thickness at that place. The lignite found in this township is generally of good quality and of woody texture.

T. 138 N., R. 103 W.

T. 138 N., R. 103 W., is within the Little Missouri badlands and has a total surface relief of about 500 feet of the Tongue River member of the Fort Union and the lower 100 feet of the Fort Union (?) Sentinel Butte shale member are exposed within the township, dipping slightly northeastward.

The Harmon bed underlies most of the township and crops out in the eastern bluffs of the river and in small coulees. It is about 6 feet thick, and measurements at locations 17, 20, 24, and 25 are shown on Plate 8. This bed is economically by far the most important in the township. The Garner Creek bed crops out above the Harmon, at an interval of about 180 feet, as shown by the exposures in sec. 25. Good exposures of this bed are found along Garner Creek, where it is about 4 feet thick, but in secs. 31, 32, and 33 it is of little value.

[75] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, N. Dak. and Mont.: U. S. Geol. Survey Bull. 341, pl. 2, 1909.

The bed at location 27, in the south side of sec. 29, is composed of 40 inches of lignite split by 8 inches of shale parting, but at location 29, sec. 33, there is only 20 inches of lignite. The variations in thickness at locations 14, 15, 16, 18, 19, 21, 22, 23, 26, 27, 28, and 29 are shown on Plate 8. The Garner Creek bed in the northern part of the township is extensively burned along its outcrop; consequently in mapping its limits the position of the outcrop was placed back of the innermost burns. The Meyer bed, which is 180 feet above the Garner Creek bed, is wholly burned out over this township unless a small body of it remains in sec. 19.

The Harmon lignite is of good quality, and the Garner Creek is fair. The impurities occurring in them are chiefly shale and a small amount of iron pyrite. Both beds underlie most of the township, and undoubtedly lower beds of lignite underlie all of it.

T. 138 N., R. 102 W.

Save for the flood plain of the Little Missouri and the adjacent terraces, the surface of T. 138 N., R. 102 W., is dissected into badlands having a relief of about 500 feet. Little Missouri River and Bear and Dantz Creeks, together with the numerous springs scattered over the township, furnish its surface water supply.

About 500 or 600 feet of strata are exposed in this township, dipping only a few feet to the mile northeastward. Three good workable beds are found within the township, and all of it is classed as coal land. The Harmon lignite,[76] which is the lowest and best bed, crops out along the river bluffs and disappears beneath the river a short distance to the north, in T. 139 N., R. 102 W. It ranges from 8 to 13 feet in thickness and has very few thin shale partings. Except where it is cut out by the narrow river valley the bed underlies the whole township. This bed is mined for local use from an exposure in the river bank at location 59, in the SE. ¼ sec. 18. Detailed sections were measured at locations 30, 33, 34, 56, 57, 58, 59, 65, 67, and 68 and are shown on Plate 8. At locations 32 and 36 there is a bed 3 feet 6 inches thick, intermediate between the Harmon and Garner Creek beds. Its outcrop was mapped only in and about sec. 4, and it is about 50 feet below the Garner Creek bed.

The Garner Creek bed, which corresponds to one of the Medora group of lignite beds of Smith and Leonard,[77] probably to bed C, crops out just beneath the terraces above described and 180 feet above the Harmon bed. Its outcrops wind up the valley of Bear Creek through the southern tier of sections to T. 138 N., R. 101 W.; also up the side of the valley of Dantz Creek above the Lebo ranch to location

[76] Leonard, A. G., and Smith, C. D., The Sentinel Butte lignite field, N. Dak. and Mont.: U. S. Geol. Survey Bull. 341, pp. 24, 25, 1909.

[77] Op. cit.

63, in sec. 23, and in the smaller stream valleys on the north side of the township, particularly in secs. 3 and 4. Measurements 31, 35, 38, 39, 52, 53, 54, 55, 60, 61, 62, 63, 64, 66, 69, 70, 71, and 72 were made on this bed, which averages about 4 feet in thickness and is shown graphically in detail on Plate 8.

The Meyer lignite crops out in the eastern portion of the township about the slopes of the higher hills, and sections of it at locations 40, 41, 42, 44, 45, 46, 47, 48, and 73 are illustrated on Plate 8. This bed measures from 9 to 16 feet in thickness and is of excellent quality. Extensive areas of baked or fused rock rim the outcrops of the bed and occur in isolated hills scattered over the eastern half of the township. In places the semifused mass of porcellanite (clinker) is 20 to 30 feet thick. Its base where not slumped marks very closely the level of the base of the Meyer bed, which is about 180 feet above the Garner Creek bed.

The H T Butte bed, which is of little value and small extent within this township, is found only in the highest hills, about 100 feet above the Meyer bed. Only three measurements were taken on it. One at location 49, in the SE. ¼ SW. ¼ sec. 14, shows 46 inches of poor lignite; another, at location 50, in the SE. ¼ sec. 11, was taken on a 4-foot bed of poor shaly quality; and a third, at location 41, showed 2 feet 6 inches of lignite.

The lignite of this township is of good quality and thickness. It is extremely tough and woody and has few joints, so that it is difficult to dig out of open pits. The impurities consist chiefly of shale and a small amount of iron pyrite. No samples were taken, because the outcrops were too weathered for proper analysis.

Aside from the lignite beds exposed it is highly probable that many of Lance age underlie the township, for they are exposed along the river in T. 136 N., R. 104 W., and T. 135 N., R. 105 W., in beds that dip to the northeast and are here less than 500 feet below the river valley.

T. 137 N., R. 106 W.

The surface of fractional T. 137 N., R. 106 W., consists of a rolling prairie that has a total surface relief of about 300 feet and is drained by intermittent streams. The surface rocks belong entirely to the Tongue River member of the Fort Union formation, which in the few exposures within the township consists largely of light-colored shale and sandstone with very thin beds of lignite.

No lignites of economic importance are exposed in this township, but it is probably underlain by an abundance of lignite in beds that are exposed elsewhere in the bluffs of the Little Missouri. Red hills caused by the burning of the H T Butte lignite bed occur in sec. 3, also just over the boundary line from sec. 15 in the State of Montana. No exposures of unburned lignite at the H T Butte horizon were seen,

but this bed may underlie the high hill in sec. 27, and it is reported as worked a few miles across the State line in Montana. This township is all classed as coal land.

T. 137 N., R. 105 W.

The relief in T. 137 N., R. 105 W., is very moderate, and bedrock exposures are rare because there are few actively eroding streams. The area is so grassy or so much occupied by cultivated fields that observations of the rocks are difficult to obtain. The surface rocks of the township consist of about 250 feet of the Tongue River member of the Fort Union, which dip northeastward at about 20 feet to the mile. Except for the lignite all the rocks exposed are so soft and loosely consolidated as to be of no value as a roof in any mining operations.

One lignite bed, known as the Burkey, was traced by exposures along Bullion Creek in the northern portion of the township and partly by the occurrence of red burned rocks fringing the outcrop. At locations 1, 2, 3, and 6 this bed is worked by the inhabitants for a portion of their fuel supply. Its average thickness is about 6 feet. The bed is somewhat broken up at location 2 by shale partings and is not as good as at locations 3, 4, 5, or 6. (See pl. 8.)

At location 1 a second bed of lignite 11 feet below the upper bed occurs, but the position of its bottom was not ascertained. However, it is more than 3 feet thick. To the east the bed disappears beneath Bullion Creek in sec. 1, and it does not reappear unless the lignite traced up Bullion Creek in the township to the east as far as sec. 3 is the same bed.

The quality of the Burkey lignite is exceedingly good, and it burns well for domestic purposes, as reported by the farmers. It is dark brown, tough, and exceedingly woody. Upon exposure to the air it quickly breaks down by slacking, finally crumbling to a fine powder. It is probable, from geologic conditions, such as the high altitude of the land in this township, the nearly horizontal position of the rock strata, and the common occurrence of numerous lignite beds of Fort Union and Lance age beneath the horizon of the Burkey bed, that an abundance of lignite occurs beneath this township, and the township is therefore all classed as coal land.

T. 137 N., R. 104 W.

The western part of T. 137 N., R. 104 W., is hilly, grassy upland; the surface of the eastern part is of semibadland character; and a rather dissected divide extends across its south side. Springs were noted in the SW. ¼ SW. ¼ sec. 34, the SW. ¼ sec. 24, the SE. ¼ sec. 10, and sec. 1. These springs and Bullion Creek, which contains running water most of the year or has water holes along its course, are

the sources of surface water. Water is also procured in wells at shallow depth. About 300 feet of the Tongue River member of the Fort Union formation is exposed in this township, and terrace gravel occupies small areas in the NE. ¼ sec. 13.

Only two beds of lignite were traced in this township. The lower one crops out along both sides of Bullion Creek from the east range line west to the northwest corner of sec. 10, where it disappears beneath the creek and does not come to the surface again unless the Burkey bed traced east as far as sec. 1, T. 137 N., R. 105 W., is the same bed.

At locations 132 to 138, along Bullion Creek, and 141, in sec. 35, measurements were made on this bed, which is very possibly at the Harmon horizon, as is a prospect at location 141–A in a bed 6 feet 6 inches thick. The thinnest sections are those on small outliers in sec. 13, where the bed is only 3 feet thick. The sections are shown graphically on Plate 8. The lignite is usually succeeded by 1½ feet of shale, which is in turn succeeded by several feet of soft sandstone.

The second bed is separated by 30 feet of sandstone and shale from the lower bed. It crops out in secs. 1 and 2 but was not traced west of sec. 2 because of grassy fields. At a spring at location 131, in the NE. ¼ sec. 1, the bed is 3 feet 3 inches thick; at location 139, in sec. 36, 3 feet 9 inches; and at location 140, in sec. 35, 3 feet 4 inches. The bed in the southeast corner of the township is burned considerably along the outcrop, which was not traced west of the middle of sec. 33 because of grass-covered country.

It is highly probable that numerous beds of lignite of Lance age underlie this area, for such lignites are exposed in the two townships immediately adjacent to the south.

T. 137 N., R. 103 W.

Bullion Creek, which traverses the northern part of T. 137 N., R. 103 W., is a perennial stream bordered by picturesque badlands. A good spring issues from the west side of Bullion Butte, and there are doubtless other springs of less value within the township. These with the creek and river constitute the surface water supply for the township. The total relief within the township is about 1,000 feet, and, except for the level summit of Bullion Butte and terrace areas in secs. 34, 35, and 36, the higher tracts consist of typical badlands.

There is an abundance of lignite in this township, which is all classed as coal land. No less than eight beds over 2½ feet thick are exposed, and undoubtedly several Lance lignites underlie the area.

The lowest bed of lignite noted is one 2 feet thick measured in sec. 33. This bed being less than 2½ feet thick was not mapped. The lowest workable lignite occurs in the center of sec. 15, where at location 113 it is 3 feet 4 inches thick. This was the only measure-

ment obtained on the bed, and its outcrop was largely inferred from its relation to the overlying Harmon bed, from which it is separated by 20 to 30 feet of strata. The Harmon bed was mapped in considerable detail, as it is here the lowest valuable lignite bed of the Fort Union. Measurements at locations 108, 109, 110, 116, 119, 120, 122, 123, 124, 127, and 129 are shown in detail on Plate 9. The thickness of the bed ranges from 2 feet 8 inches to 8 feet 7 inches. It is correlated with the Harmon bed as traced in Tps. 137 and 138 N., R. 102 W. There is some doubt whether the bed at locations 119, 120, 122, 123, and 124, along the river, is the same as at locations 108, 109, 116, and others on Bullion Creek. The Harmon bed underlies the greater part of the township and is of fine quality.

About 180 feet above the Harmon bed is a third bed, which is possibly the same as the Garner Creek bed of T. 138 N., R. 103 W. At locations 104, 111, 112, 114, 121, 125, 126, 128, and 130 measurements, shown graphically on Plate 9, were made on this bed of lignite. The general thickness of the bed is about 3 to 4 feet. At location 122–B it is 4 feet 4 inches thick, but at location 104 it seems to be only 24 inches thick. At locations 114, 104, and 128 a bed from 2 to 3 feet thick lies 7 to 12 feet below the Garner Creek bed.

A fifth bed, which ranges in thickness from 3 feet 6 inches at location 122–A, sec. 32, to 2 feet 6 inches at location 115, sec. 21, occurs about 12 to 20 feet above the Garner Creek bed. The bed is 2 feet 8 inches thick at location 117, sec. 27. The area underlain by this bed is small. About 200 feet above it occurs a sixth bed, the Meyer lignite, small areas of which remain intact underneath the high divide in secs. 22, 27, 28, 13, and 24. Measurements 105 and 118 (pl. 9) represent this bed of lignite and show that it is from 5 feet 8 inches to 7 feet 6 inches thick. The bed is burned considerably along its outcrop, and exposures are rare. The lignite is somewhat impure from the presence of large quantities of gypsum and shale.

At 75 feet above the Meyer bed is the H T Butte bed, which lies at the base of the Sentinel Butte shale and crops out in secs. 12 and 13 about the slopes of Bullion Butte. The area underlain by the H T Butte bed in this township is but a few acres. At location 107 the bed is 11 feet 2 inches thick. Red burns from the bed occur on the high divide between Bullion Creek and Little Missouri River and in two high red cones in secs. 3 and 4.

About 325 feet above the H T Butte lignite is an eighth lignite, the Bullion Butte bed, which underlies only a small area in sec. 13, where it crops out on the side of Bullion Butte. At location 106 it is 11 feet 10 inches thick. This is the highest lignite that crops out in this township and in the Marmarth field and also the highest one in this general region.

T. 137 N., R. 102 W.

In T. 137 N., R. 102 W., the flood plain of Little Missouri River is bordered by bluffs about 200 feet high. Southwest of the river there are broad flats or terraces several square miles in extent separated by extensive badland tracts from Bullion Butte, which is a notable landmark. The surface rocks of this township include about 500 feet of the Tongue River member of the Fort Union, the Sentinel Butte shale member of the Fort Union (?), and the White River (?) sandstone of Bullion Butte.

At least five lignite beds more than 30 inches thick are exposed in this township, which is all classed as coal land. The Harmon bed was the lowest one traced and is excellently exposed near the base of the river bluffs, showing thicknesses ranging from 8 to 16 feet, generally without any shale parting. Sections taken at locations 79, 80, 81, 82, 88, 91, 93, 94, 98, 102, and 103 are shown graphically on Plate 9. It underlies all the township except where cut out by the river and is of fine quality. The bed is mined from the river bank just south of Hanley post office (see pl. 7, B) and in sec. 36, and when the township is exploited for fuel this bed will be one of great importance, for it can be mined from adits driven on the bed with portals opening from the bluffs along the river, from which the lignite can be readily loaded. About 180 feet above the Harmon bed occurs the Garner Creek bed, which crops out among the badlands in the northeast corner of the township and in a small ravine in secs. 8, 9, and 16, but it was not found in the south side of the township. Its thickness ranges from 18 to 69 inches, as indicated by measurements made at locations 83, 87, 89, 92, 95, and 96, shown in detail on Plate 9. The Meyer bed lies about 200 feet above the Garner Creek bed and crops out around the slopes of Bullion and Tepee Buttes and among the badlands in the northeast corner of the township. The thickness of this bed ranges from about 3 feet 1 inch to 5 feet 11 inches, and the measurements at locations 84, 86, 97–A, 100, and 101–A are shown on Plate 9. Its quality is poor. About 25 feet above the Meyer bed, occurs the H T Butte bed, at the base of the Sentinel Butte shale member. This bed is about 11 feet 3 inches thick where it crops out on the side of Bullion Butte, but at Tepee Butte and among the badlands in the northeast corner of the township it is much thinner, as illustrated by sections 85, 97, 99, and 101 shown graphically on Plate 9. The Meyer and H T Butte beds are separated by strata that consist mostly of sandstone. About 300 feet above the H T Butte bed is the Bullion Butte bed. The only measurement obtained on this bed showed 11 feet 10 inches of solid lignite at location 106, in sec. 24, T. 137 N., R. 103 W.

All these lignites have burned considerably along their outcrops. Large burned areas of red hills from the H T Butte bed occur among

the badlands in the northeast part of the township, and a number of burns fringe the outcrop of the Harmon bed along the river.

These beds all belong to the lignitic class of coals and are of very good quality. Particularly is this true of the Harmon bed where it is mined in sec. 36 and in the river bank just southeast of Hanly post office. Under the present system of classification this township is all coal land.

T. 137 N., R. 101 W.

The western two tiers of sections of T. 137 N., R. 101 W., included in this report, lie within the Little Missouri badlands, which have a maximum local relief of 500 or 600 feet. The surface rocks of this township belong to the Tongue River member of the Fort Union and the Sentinel Butte shale member (Fort Union?).

An abundance of lignite underlies this township. The lowest mapped bed is exposed along the valley of Third Creek, but data on it were taken only in adjacent townships. In the NW. ¼ sec. 1, T. 136 N., R. 102 W., at location 258, 4 feet 6 inches of lignite was measured. This bed crops out also on the north side of the valley, but no measurements were taken there. It seems that this bed either thins out or merges with the Harmon bed down the river, as no outcrops of it were found, but along Third Creek the following section was measured:

Section at location 271–A, sec. 6, T. 136 N., R. 101 W.

	Ft.	In.
Sandstone.		
Lignite	3	
Shale		2
Lignite	2	
Shale, arenaceous		3
Lignite	2	
	7	5

About 50 feet above the low lignite occurs the main Harmon bed, which underlies the whole township except the southwest corner. It was measured at locations 76, 77, 77–A, and 78 (pl. 9), in this township, and at location 271–B, in sec. 5, T. 136 N., R. 101 W., where a 9-foot shale parting separates the upper 8 feet of lignite from the lower 9 feet 8 inches. At location 77, in the SW. ¼ sec. 28, it shows similar conditions. At location 76, in the north side of sec. 19, there is over 7 feet of lignite, the bottom of the bed not being reached. It seems probable from the data taken in the adjacent township on the west that the shale parting is not present to the northwest.

About 450 feet above the Harmon lignite is the H T Butte bed, which crops out here and there about the highest hills and buttes. Two measurements were taken on it. One in the northeast corner of sec. 18, at location 74, shows 5 feet 5 inches of lignite; the other,

in the southeast corner of sec. 8, at location 75, shows 5 feet 11 inches. (See pl. 9.) Two other beds between the H T Butte and Harmon beds were mapped in T. 137 N., R. 102 W., but they were not traced in this township.

The quality of these lignites is extremely good. They are brown, woody, and very tough. Such impurities as occur in them are chiefly shale, with a small amount of iron pyrites and gypsum.

It is probable, from the slight northeasterly dip of the rock strata and the occurrence of lignites in the exposures of the Ludlow lignitic member of the Lance formation farther up the river, that considerable lignite of that formation occurs within 400 feet beneath the lowest exposures in this township. The entire township is coal land.

T. 136 N., R. 106 W.

The whole of T. 136 N., R. 106 W., is a grassy, rolling, and treeless prairie somewhat dissected along its south side, having a maximum surface relief of less than 400 feet.

The surface rocks of this township belong to the upper part of the Ludlow and to the basal 250 feet of the Tongue River member of the Fort Union and dip northeastward about 20 feet to the mile. A peculiar light-gray hard fine-grained quartzite about 100 feet above the base of the Fort Union occurs in place on the high hill in sec. 27. It is full of small holes, which are probably the molds of roots.

The only lignite measured in this township occurs in the southern part, where at location 143 two beds are exposed separated by about 15 feet of shale. The lower bed is 3 feet 4 inches thick, the upper one 4 feet. One of these beds possibly corresponds to the bed measured at location 549, in the extreme northeast corner of the township to the south. Red hills that cap the divide in the southwest corner were formed by the burning of the lowest bed of lignite of the Fort Union formation mapped in T. 135 N., R. 104 W., and possibly a remnant of this bed underlies the high land in secs. 19, 20, 29, and 30.

Lower lignite beds crop out in the townships to the south and east, and it is probable that some of them underlie this whole township only a few hundred feet from the surface, as the surface rocks are higher in the geologic section and the land surface is higher in altitude than exposures in the adjacent townships to the southeast. For these reasons the township is all classified as coal land.

T. 136 N., R. 105 W.

The surface of T. 136 N., R. 105 W., consists of a treeless upland which has been extensively dissected by Bull Run and Williams Creeks, moderate badlands having been developed in the southeastern part of the township. Little Missouri River, a few springs along Williams

Creek, and intermittent water holes along the larger valleys constitute the surface water supply of the township. About 150 feet of the Ludlow lignitic member of the Lance and the lower 100 feet of the Tongue River member of the Fort Union are exposed in this township and show a northeastward dip of about 15 feet to the mile.

Four workable beds of lignite and several thinner beds are exposed in this township. At location 154, in sec. 36, five beds over 30 inches thick, constituting the Yule group of lignites of Leonard,[78] are exposed in the cut bank of the river. The lowest one is 23 feet above Little Missouri River, and at locations 153 and 154 measurements were made on this bed. Its thickness is about 3 feet 8 inches. It is provisionally called the C′ bed.

About 50 feet above bed C′ occurs bed D, which is probably represented at locations 148, 149, 151, 152, and 154. It is only 1 foot 10 inches thick at location 149 and 1 foot 8 inches thick at location 151. At location 154 it is about 12 feet below the Yule bed and is 2 feet 8 inches thick, and at location 148 a bed of lignite 3 feet 7 inches thick lies 26 feet above 6 feet 10 inches of lignite split by a 20-inch parting into benches 2 feet 8 inches and 4 feet 2 inches thick.

The Yule or E bed is the thickest and best lignite in the township and is brought to the surface by erosion in the southeastern part. There are good exposures of it in sec. 24 and along the valley of Williams Creek. It ranges in thickness from about 3 feet to 10 feet 6 inches. Sections of the Yule bed at locations 154 to 165, 169, 170, and 174 are shown on Plate 9. The Yule lignite is commonly of very good quality, being one of the cleanest beds in the Lance formation, although very dirty at location 174. At locations 157, 165, 169, and 170 strip pits have been opened.

At 25 feet above the Yule bed is a still higher bed of Lance lignite, which was traced in the central portion of the township. Sections at locations 166, 167, 168, 171, 171–A, and 172 are considered to be on this bed, which ranges from about 2 feet 4 inches to 9 feet in thickness. At the strip pit at location 171 and also at location 167 the bed is split by a 2-foot shale parting. The outcrop was obscured by grassy slopes, and it is possible that all the sections named may not be on the same bed. In the southwestern part of the township several thin Lance lignites occur as shown by sections at locations 144, 145, 146, and 147. (See pl. 9.) The horizon of bed H, the lowest important bed of the Tongue River, was traced across the northeast corner of the township. Its position, however, was largely inferred from the red hills caused by its burning. Only one measurement was obtained—at location 173, in sec. 4, where the bed is 6 feet 3 inches thick, with 9 inches of shale parting 10 inches from the top.

[78] Leonard, A. G., Geology of southwestern North Dakota, with special reference to the coal: North Dakota Geol. Survey Fifth Bienn. Rept., 1908.

T. 136 N., R. 104 W.

The valley of Little Missouri River is about half a mile wide in T. 136 N., R. 104 W., and is bordered by broad terraces that rise abruptly 200 feet from the flood plain. The total surface relief of the township is about 400 feet, and the southeastern part is the highest. A small area of rolling upland lies in the southeast corner and is separated from the terrace area by about six sections of extreme badlands. A small area of less rugged badlands occurs in the northwest corner. Many cottonwood trees grow along the river, and some box elders are found along the larger tributaries.

The strata dip about 30 feet to the mile downstream, the general course of the river being approximately in the direction of the dip. About 200 feet of the Lance formation is exposed in the bluffs of the river in the southern part of the township, but this thickness decreases to the north. The lowest exposed lignite bed is found at location 209, on the south line of sec. 32, and is there 3 feet thick. Above this bed occurs the Yule bed, which was measured at locations 198, 199, and 201 to 208 (pl. 10) and ranges from 5 feet 4 inches to 8 feet 7 inches in thickness. It is about 100 feet above the river at the southern township boundary and disappears beneath the river bed in sec. 17. It is the highest valuable bed of lignite found in the Ludlow member of the Lance.

Bed H, which is the lowest bed of the Great Bend lignite group of Leonard,[79] lies about 100 feet above the Yule bed and was measured at locations 176, 177, 178, 182, 187, 188, 190, 194–B, 197–B, 200, 210, 210–A, 211, 212–C, 213, 214, 215, and 360 (pl. 10), its thickness ranging from 5 feet 6 inches to 8 feet 4 inches. The bed is largely pure lignite with a very persistent thin shale parting near the middle.

The Harmon bed is separated from bed H by about 32 feet of sandstone. At locations 179, 180, 180–A, 184–B, 185, 186–B, 189, 192–B, 194–A, 196, 197, 212–B, 216, and 217 it ranges in thickness from 4 feet 6 inches to 13 feet 4 inches.

Separated by about 20 feet of sandstone from the Harmon bed is bed J, which was measured at locations 184–A, 186–A, 192–A, 193, and 212–A (pl. 10) and found to average 6 or 8 feet in thickness. So far as known, these are the highest lignites that are exposed in this township. It is fairly certain that numerous lignites of Lance age underlie the lowest bed exposed in the township. The Fort Union lignites of the township are of good quality, with very few impurities such as shale, pyrite, gypsum, or sand. Those of the Lance are not so free from impurities.

[79] Leonard, A. G., Geology of southwestern North Dakota, with special reference to the coal: North Dakota Geol. Survey Fifth Bienn. Rept., 1908.

T. 136 N., R. 103 W.

The topography in T. 136 N., R. 103 W., is diversified, but the relief probably does not exceed 500 feet. Little Missouri River and Deep Creek are the controlling surface features of this township and are its chief sources of water supply. On each side of the main streams are recent alluvial flats of considerable extent, which are being continually enlarged by the cutting and filling of the streams. Along the river are bare almost vertical cliffs which show bands of variously colored rocks, black bands of lignite, and red bands where the lignite has burned. The bluffs are broken in many places by small coulees. The southeast corner of the township is wholly dissected into badlands, in which the predominating feature is the enormous number of red hills formed by the burning of the Harmon bed of lignite. The southwest third is a grassy and hilly upland. Broad well-developed isolated terraces border the river in parts of the northern two tiers of sections. Each terrace is at least a square mile in extent and lies about 200 feet above the present stream course. These terraces are similar to others found elsewhere along the river.

The rocks are almost horizontal, dipping northeastward at about 20 feet to the mile.

The lowest Fort Union lignite traced is bed H, which crops out along Deep Creek and the river. It ranges in thickness from 2 feet 6 inches to 5 feet 8 inches. Detailed sections taken at locations 221, 222, 223, 225, 228–C, 229–C, 233, 234, 236, 237, 238, 241, and 245 are considered to have been made on this bed and are shown graphically on Plate 10. The Hansen bed lies about 16 feet above bed H at location 228, but the interval varies from place to place. Locations 228–B, 229–B, 230–B, 239–B, and 240–B are probably on the Hansen bed and the measurements show that it ranges from 1 foot 8 inches to 4 feet 6 inches in thickness. At location 229–A the Harmon bed is separated by 40 feet of sandy shale from the underlying Hansen bed. Locations 219, 220, 228–A, 229–A, 230–A, 231, 232, 239–A, 240–A, and 242 are probably on the Harmon lignite. The sections are shown in detail on Plate 10. However, there is some uncertainty about the correlation of these sections because of the impossibility of tracing the bed from place to place, on account of lack of exposures. The correlation is based partly on the thickness of the beds and partly on their general position. The Harmon bed is split by 3 to 6 feet of shale at locations 219, 220, 232, and 242. Sections measured at locations 224, and 226 are believed to represent the lower bench of the Harmon bed. About 50 to 75 feet above the Harmon occurs a fifth lignite which was traced in secs. 28 and 33. At location 243 this bed is of unworkable thickness and the section shows but 1 foot

11 inches of good lignite separated by a parting of 20 inches of shale from 3 inches of lignite above. At location 244 the bed is 4 feet thick.

The Harmon group of beds have burned very extensively along the outcrop, a phenomenon well shown in the northern and eastern parts of the township. The burning forms great masses of red clinker-like material consisting of baked shale, and sandstones, which vary decidedly in quantity and lateral extent and hinder the tracing of the outcrops. However, the base of the baked material is taken as the former base of the lignite beds, and the innermost burns are considered the approximate limit between the burned and unburned areas of lignite. These criteria with the exposures of lignite were used as delimiting the area of good lignite, though of course the broken line on the map is at best approximate.

T. 136 N., R. 102 W.

Little Missouri River and its perennial tributaries Sand and Deep Creeks furnish a large supply of good water in T. 136 N., R. 102 W., and springs also occur here and there within it. The river flows in a narrow incised valley about a mile in width and about 250 feet deep, which is a marked physiographic feature. A well-developed high terrace adjoins the narrow river valley in the north side of the township. The total relief is a little more than 500 feet; the highest point is Tepee Butte, in the center of sec. 6, which has an altitude of 3,065 feet above sea level. Almost the entire township is of the bad-land type of topography.

The Great Bend lignite group in this township consists of three distinct beds of lignite which are well exposed in secs. 3, 5, 6, 7, and 8. Bed H, the lowest bed of the group, overlies a massive yellow sandstone 30 or 40 feet thick and is about 115 feet above the river. It is separated by about 7 to 30 feet of shale from the Hansen bed, which in turn is 14 to 30 feet below the Harmon bed. Bed H crops out around the large terrace in the northwest corner of the township and at the mouth of Deep Creek. Sections taken at locations 250–C, 251–C, 252–C, 253–C, 254–B, 256–B, 261–C, and 264–C are shown graphically on Plate 10. The bed ranges in thickness from 8 feet in sec. 14 to 1 foot 8 inches in sec. 16. Apparently it is of little value south of the river. The Hansen bed was measured at locations 247–B, 248–B, 249–B, 250–B, 251–B, 252–B, 253–B, 254–A, 255, 256–A, 258, 259–B, 260–B, 261–B, 263, 264–B, 265, 268–B, and 271–A, and the details are shown graphically on Plate 10. This bed ranges in thickness from 3 feet 6 inches in sec. 6 to 8 feet 8 inches in sec. 28 and averages about 6 feet. Its quality is very good. The upper or Harmon bed has burned over a large portion of the township, making extensive areas of red hills, and at present it underlies only one-

third of the township, including an area on the divide between Deep and Sand Creeks and large tracts in the eastern two tiers of sections. Generally shale partings in this bed are thin or absent, but at location 266, in the SW. ¼ NW. ¼ sec. 24, a 27-inch shale parting occurs in the middle of the bed. The parting thickens somewhat toward the north and east, reaching 9 feet in sec. 5, T. 136 N., R. 101 W. In the extreme northeast corner of sec. 14 this bed of lignite is now burning with tremendous energy. At location 261–A, only 200 feet from the burning lignite, the bed is 20 feet thick. The ground around this place is seared and baked, large furrows (see pl. 7, *B*) occurring in the hummocky surface, owing to the caving in of the ground as the burning progresses. Inhabitants of the vicinity state that the bed has been burning as long as they can remember. It often starts prairie fires. The thickness of the bed at locations 247–A, 248–A, 249–A, 250–A, 251–A, 252–A, 253–A, 257, 259–A, 260–A, 261–A, 262, 264–A, 266, 267, 268–A, 269, 270, 271, and 271–B is shown graphically on Plate 10. Its average thickness at all these locations is 17 feet. The thinnest measurement, 12 feet 8 inches, was made in sec. 3, and the thickest in sec. 35, where 24 feet 5 inches was exposed and the bottom had not been reached. At location 267, in sec. 24, only the upper bench was exposed. In this township erosion has cut deep valleys so that the bed can be easily mined from adits driven on the virtually flat-lying beds. It is usually thick enough to permit leaving part of the bed, if necessary, as a roof. No higher lignites were noted within the township, but in secs. 1, 12, 13, and 24 red hills were noted much higher than the Harmon bed, marking the horizon of the H T Butte lignite bed.

T. 135 N., R. 106 W.

The northern half of T. 135 N., R. 106 W., is a partly dissected upland surface, and the southern half includes extensive badlands, which give the township a total surface relief of about 500 feet.

The rock strata of the township dip northeastward at about 50 feet to the mile, which is a gradient not much greater than that of Cannonball River. The exposed rocks belong almost wholly to the Lance formation, approximately 400 feet of which crops out.

Several beds of lignite are found in this township. Most of them are of extremely poor quality and thin. The lowest one of value crops out along the sides of the valley of Cannonball Creek. It is exposed in a small coulee in the SE. ¼ sec. 24, where the bed is about 5 feet thick. The thickness of the bed gradually diminishes up Cannonball River, and at location 535, in the center of sec. 27, the bed contains 3 feet 10 inches of lignite lying above 8 inches of shale, with 20 inches of lignite below. At location 539, in the SE. ¼ sec.

28, there is only 1 foot 11 inches of lignite; at location 553–A, in the center of sec. 33, the bed is 1 foot 7 inches thick; at location 541, in the NW. ¼ sec. 28, 1 foot 8 inches; at location 543–A, in the NW. ¼ sec. 32, 1 foot 8 inches; at location 551, in the SE. ¼ sec. 30, 1 foot 6 inches; and at location 543, in the northwest corner of fractional sec. 31, 1 foot 9 inches. Locations 550 and 552 are thought to be on the same bed, which is 4 feet thick and underlies an isolated hill about half a mile due west of the southwest township corner, in the State of Montana. Thick measurements on the same bed at locations 531, 532, 532–A, 533, 534, 535, 536, 538, 539, and 540 are shown graphically on Plate 11. About 100 feet above the Cannonball lignite occurs a second bed, which is correlated with the T Cross bed. The general trend of the outcrop of this bed is northwest from sec. 13 across the township to sec. 7. But few exposures occur along the outcrop, and only four measurements were made that were known to be on this bed. These sections, at locations 544, 545, 546, and 547, are shown graphically on Plate 11.

At location 547, about on the line between secs. 9 and 16, there is 5 feet of lignite in a local mine. No other measurements were obtained along this outcrop west of sec. 16, and its approximate position was mapped wholly by the occurrence of porcellanite, or clinker, covering red hills, shown on Plate 14.

A third lignite crops out in the northeast corner of sec. 15. At locations 548 and 548–A it is 2 feet thick, but its outcrop was not traced any considerable distance. It occurs but a few feet above the lignite bed just described.

A fourth bed crops out in secs. 5 and 6, but only one measurement was made upon it, in the extreme northwest corner of fractional sec. 6, at location 549, where more than 4 feet of lignite is mined by farmers for fuel supply. The lignite is overlain by a massive buff sandstone belonging to the Tongue River member of the Fort Union. This same bed, or one at nearly the same geologic horizon, crops out in sec. 34, T. 136 N., R. 106 W.

T. 135 N., R. 105 W.

In T. 135 N., R. 105 W., lines of bluffs about 225 feet high rise from the flood plain of the Little Missouri to an extensive terrace that merges away from the stream into well-developed badlands. As elsewhere in the Marmarth field, the stratified rocks of this township dip northeastward at a few feet to the mile.

The Ludlow lignitic member of the Lance contains many beds of lignite in this township, as is indicated by the stratigraphic section measured at location 522, in sec. 10, given on page 25, and by a detailed section measured at location 484, sec. 34, which is as follows:

Section at location 484, sec. 34, T. 135 N., R. 105 W.

	Ft.	in.
Shale and sandstone	10	
Lignite (bed D)	3	3
Sandstone, argillaceous	10	
Shale, brown	5	4
Shale, carbonaceous	1	3
Lignite, Shale, brown, Lignite (bed C')	2	10
Shale, brown	3	
Shale, light, arenaceous	6	
Shale, brown	3	
Lignite (bed C)	1	7
Sandstone, argillaceous	18	
Shale, brown	1	8
Lignite	1	8
Shale, arenaceous	15	8
Shale, brown, carbonaceous	11	
Shale, arenaceous, and sandstone	15	
Shale, brown	8	
Lignite (bed B)	3	8
Shale and sandstone to river	59	
	181	6
Total lignite	13	8

The numerous lignite beds of this township recorded in these sections are extremely variable. The lowest one mapped was that at the base of the Ludlow lignite member, which was traced along the valley of Cannonball River, and was measured at locations 490, 491, and 492. The thickest measurement of this bed made showed 5 feet of lignite at location 491. Some 3 miles to the west, in the adjacent township, this bed of lignite is 6 feet 3 inches thick, but at location 531, farther up Cannonball River, it is too thin to be of economic value. The dip is slightly greater than the gradient of the river; consequently it disappears beneath the bed of the stream in sec. 29. So far as known, this is the lowest bed of lignite of workable thickness found in the Lance formation in this or adjacent townships.

A second bed of lignite (bed B) lies 50 or 60 feet above the Cannonball bed and was measured at locations 464, 471, 472, 484–D, 485–D, 486, 487, 488, 494, 496, 499, 501–E, 502, 503, 504, and 511–B (shown on pl. 11), unless an error was made in the correlation of the bed across the Little Missouri River Valley. On the east side of the river this bed is of little consequence except in sec. 34, at locations 484–D, 485–D, and 486, where it is about 3 feet 6 inches thick. Two sections were measured in the NW. ¼ sec. 35 on a 2-foot bed that very probably is the same bed of lignite. At locations 502 and 504

it is of fair thickness, but at location 503 it is only 1 foot 3 inches thick and at location 499 1 foot 10 inches.

A third bed of lignite (bed C) is separated from the bed just mentioned by a variable interval of about 7 feet of shale. At location 501–D bed C contains 11 feet 8 inches of lignite split in the middle by a shale parting 1 foot 11 inches thick. Sections taken at locations 431–D, 447–C, 450–B, 463, 466, 470, 474, 477–B, 479, 480, 482, 484–C, 485–C, 493, 501–D, 505, 510–B, 512, 513, 514, 516, 517–B, 518, 519, 521–B, 522–D, and 525–B (pl. 11) are thought to have been made on this bed of lignite. If this is true, then in the southeastern part of the township this bed is of little or no value, whereas downstream it becomes a very heavy bed of lignite, measuring as much as 13 feet 10 inches.

About 12 feet above bed C is a fourth bed of lignite (bed C′), which is well exposed in the bluffs of the river. Measurements at locations 425–B, 426, 427–B, 428–B, 430–B, 431–C, 434, 435, 444, 446, 447–B, 448–B, 449, 450–A, 452, 453, 454, 456, 458, 460, 465, 467, 468, 473, 476, 477–A, 478–B, 483, 484–B, 485–B, 500–B, 501–C, 510–A, 511–A, 515–B, 517–A, 521–A, 522–C, 523, 524–B, 525–A, 526, 527, and 528 (pl. 11) are thought to have been made on this bed of lignite, but of this there is some little doubt, because the correlation is carried across the river and because exposures are lacking at critical places and numerous beds of lignite occur at close intervals. This bed is very much like the bed immediately below in that toward the southern part of the township it is of little consequence economically, whereas down the river in the northern part of the township it is a considerable bed of lignite. The measurements range from 1 foot 11 inches to 9 feet.

Bed C′ just described, is separated from the overlying bed D by shale and sandstone ranging in thickness from 8 feet to 33 feet or more. Locations 425–A, 427–A, 428–A, 429–B, 430–A, 431–B, 432, 436, 445, 447–A, 448–A, 451, 455, 457, 459–B, 478–A, 484–A, 485–A, 495, 495–A, 497, 498, 500–A, 501–B, 515–A, 520, 522–B, 524–A, and 530 (pl. 11) are thought to represent bed D, and its thickness as determined by measurements at these locations ranges from 1 foot 4 inches to 7 feet 4 inches. However, there is some doubt whether all these measurements were made on the same bed. It seems from the data gathered that this bed is of little value in the southern and northern parts of the township. The thicker measurements made across the middle of the township indicate that this area was the center of the basin in which the coal accumulated.

Bed D is separated from the overlying bed E or Yule bed by about 16 feet of shale. Locations 429–A, 431–A, 433, 437, 438, 439, 440, 441, 442, 459–A, and 501–A are considered to represent the Yule. The thickest measurement was made at location 441, where the bed was found to be 5 feet thick, though the lower 1 foot was dirty.

At the other locations this bed is about 2 feet thick, and consequently it is of very little economic importance.

About 30 feet above bed E is bed F, which is 3 feet thick at locations 443 and 522–A. At location 529, bed F consists of an upper bench of 4 feet 3 inches of lignite. As the area underlain by it is very small, the only place where it is of consequence is at location 529.

A still higher bed is shown in secs. 10, 12, and 13, but this is so small in extent and so poor in quality that it is of no value. Here and there many other small beds of lignite were seen, but they were not mapped, and few of them were measured. The main beds are C, C′, and D. As will be noticed from the platted sections, there is the greatest amount of variation horizontally in these Lance lignites. A bed may at one place show a considerable thickness but a few miles away be of no value. These beds of course are in places of economic importance, and there are generally enough of them to warrant classification of the land under the present system as coal land.

These Lance lignites seem to be slightly less woody in structure and somewhat more impure than the lignites of Fort Union age. They are also slightly darker and much more lenticular. No samples for analysis were taken of any of the beds, because the outcrops were entirely too much weathered to yield suitable samples.

T. 135 N., R. 104 W.

Numerous small springs issue from the lignite beds in the bottoms of the coulees in T. 135 N., R. 104 W., and an exceptionally good one issues in the ravine between secs. 27 and 28. The surface of the township consists of moderately rough badlands having a total relief of about 400 feet.

The upper 120 feet of the Ludlow lignitic member of the Lance formation and the lower 200 feet of the Tongue River member of the Fort Union are exposed in this township, and the beds dip northeastward at 20 to 30 feet to the mile.

The lowest bed of lignite mapped in this township crops out in a cut bank of the river in secs. 5, 6, and 7. This bed is 2 feet thick at location 420. In short columnar sections measured at locations 421 and 422 this bed shows respectively, 2 feet 10 inches thick of impure lignite and 1 foot 11 inches of good lignite. A bed ranging in thickness from 2 feet 6 inches at location 421 to 3 feet at location 424 occurs about 15 feet above the lowermost lignite. It is 2 feet 9 inches thick at location 422. At 20 feet above this second bed, or about 38 feet above the lowest lignite, at location 421, 2 feet 5 inches of good lignite is exposed. Overlying this bed is about 30 or 40 feet of loosely cemented sandstone and shale that would make a very poor roof for

mining operations. The Yule lignite bed, which lies just above these soft strata, is believed to be represented by lignite measured at locations 406 to 419 (pl. 12), which ranges in thickness from 2 feet 6 inches to 5 feet. The bed decreases in thickness from the north township line southward and at locations 406 and 407 is only about 2 feet thick.

The Yule bed lies about 60 feet below the top of the Lance formation, and the next higher important lignite, bed H, lies about 45 feet above the Lance-Fort Union contact. This lowest Fort Union lignite bed was measured at locations 361 to 405 (pl. 12) and is rather constant in thickness, although its measurements ranged from 3 feet 11 inches to 8 feet 4 inches. Most of the measurements show shale partings from half an inch to 4 inches thick. The lignite is immediately or closely overlain by a soft sandstone, and it is underlain by a hard quartzitic layer. The outcrop of the bed was definitely traced.

The Hansen lignite bed lies about 40 feet higher in the stratigraphic section and is believed to have been measured at locations 330, 331, 332, 333, 335, 336, 337, 338, 339, 340, 340–A, 340–B, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 355–A, 356, and 359–B. There is however, some doubt whether all these locations are on the same bed, for in places the outcrop had to be correlated across grassy intervals. The thicknes: shown by these sections ranges from 4 feet 1 inch to 13 feet 8 inches. The bed underlies mostly the eastern two tiers of sections, and its maximum cover is about 100 feet.

The Harmon bed lies 4 to 30 feet above the Hanson bed, and the interval is greater in the southern part of the township than in the northern part. Measurements taken at locations 327, 328, 329, 341. 343, 344, 345, and 359–A, are considered to have been made on the Harmon bed, but the outcrop could not be easily traced for lack of exposures, and locations 341, 343, 344, and 345 are perhaps on a higher bed. The bed as mapped ranges in thickness from about 4 feet to 12 feet 11 inches. So far as ascertained this is the highest bed of lignite exposed in this township. It has burned considerably along parts of its outcrop, and for that reason its margin as mapped is not located with precision. The same is true of the Hansen bed in the southern part of the township.

T. 135 N., R. 103 W.

Deep Creek meanders across the northeast corner of T. 135 N., R. 103 W., and its course is marked by numerous water holes during the small part of the year when it does not contain at least a small flow of water. Springs in secs. 14, 16, 22, and 36 add to the surface water supply of this township. The high divide between Little Missouri River and Deep Creek is a marked feature of the township, being for-

the most part a rolling, grass-covered prairie. However, the northeastern third of the township is very rough and is completely dissected, the resistant capping of red baked shale and sandstone which covers considerable portions of the region adding materially to the roughness of the topography. Small level tracts covered by terrace gravel are present in secs. 11, 13, 24, and 25 and lie about 50 feet above the valley of Deep Creek.

The formations exposed range in age from Lance to Recent, and for most practical purposes the strata may be considered horizontal. About 25 or 30 feet of the cross-bedded brown and gray shale and ash-gray argillaceous sandstone of the Lance formation is brought to the surface by erosion along Deep Creek in secs. 1, 2, and 3. The channel sandstone of the Fort Union in sec. 13 seems to have been laid down in an old stream valley cut in the Lance formation, and the upper surface of the Lance seems to be uneven in this township, showing a slight break in sedimentation between Lance and Fort Union time.

The 200 feet or so of the Fort Union formation in this township in the main is distinguished from the Lance by its generally lighter hue and the greater predominance of sandstone. The sandstone is fine grained, massive, and somewhat micaceous. A stratum of hard, almost white, very fine grained quartzite about 2 feet thick underlies bed H in this township and is full of small holes, which are molds of plant stems or roots. It is probable that a number of lignite beds in the Lance formation that crop out elsewhere in the Marmarth field underlie this township, although not exposed within it.

Bed H was the lowest one traced in this township and was measured at locations 305, 307, 308, 312, 313, 314, 315, 316, 319, 321, and 323, as represented graphically on Plate 12. The bed ranges in thickness from 2 feet to 6 feet 3 inches, and commonly is of economic value. Bed H is separated by about 16 feet of sandstone and shale from the overlying Hansen bed at location 305. Apparently the Hansen bed merges with the Harmon bed in places in this township. Locations 306, 310, 311, 317, 320, 322, 324, and 325 (see pl. 12) are considered to have been made on the Harmon bed, though there is some uncertainty due to the concealment of the outcrop of the bed by grassy slopes or by the abundant clinker. In mapping it was considered that the lignite probably remained intact within the margin of the apparently unburned area. This conclusion is verified here and there by an exposure of unburned lignite and by an occasional report of lignite having been encountered in the wells of homesteaders. The Harmon bed is 16 feet 3 inches thick at location 325 and 16 feet thick at location 306. At location 324 16 feet 6 inches of lignite was exposed and the bottom of the bed was not reached. At the remaining locations the measurements are all partial, because the bottom could not be uncovered without unwarranted labor.

A fourth bed of lignite measured at locations 309 and 318 lies about 100 feet above the Harmon bed. At neither place was the entire thickness of this bed of lignite determined, although it is more than 3 feet thick.

T. 135 N., R. 102 W.

Deep and Sand Creeks are perennial streams within T. 135 N., R. 102 W., and are bordered by considerable stretches of rough land, which merge into a fairly smooth and rolling surface along the interstream divide. The total relief in the township is about 250 feet. Small springs were found in secs. 22 and 32, and others doubtless occur elsewhere within the township. Fair water is also procured in shallow wells.

Within this township the strata dip northeastward probably not more than 15 feet to the mile. The lowest bed of lignite that crops out in the township is 3 feet 6 inches thick at location 297–D, in sec. 30. A second Lance lignite 16 feet higher crops out along Deep Creek at locations 296–C and 297–C and is about 4 feet 6 inches in thickness. Bed H lies about 16 feet above this uppermost bed of Lance lignite and was measured at locations 278, 282, 283, 284, 287–C, 288–C, 294, 296–B, 297–B, 298, 299, 301, 303, and 304 (see pl. 12), where it ranges in thickness from 6 inches to 4 feet, 6 inches. Bed H is apparently of little value within this township and is of workable thickness only in small lenses. It is underlain in places by a peculiar hard, resistant fine-grained gray quartzitic sandstone, on which the identification of this bed of lignite largely depends.

A lignite bed thought to be the Hansen lies about 20 feet above bed H and was measured at locations 277, 279, 280, 281, 285, 286, 287–B, 288–B, 289, 290, 291, 292, 293, 295, 296–A, 297–A, and 302. Its thickness ranges from 2 feet 6 inches to 11 feet (see pl. 12); the thickest measurement was obtained at location 302, where it is split in the middle by a 2-foot shale parting. This is one of the most valuable lignites of the township, and homesteaders obtain a large portion of their fuel from this bed. It is worked at locations 292, 290, 285, and 286, in secs. 15, 22, and 24. It is reported to burn well.

A bed of lignite overlying the Hansen is 30 inches thick at location 288–A. It may perhaps be the same bed as one 45 feet above the Hansen bed at location 297, which is 4 feet thick with a 3-inch shale parting 9 inches from the top.

A remarkably thick bed of lignite, the Harmon, occurs about 40 to 60 feet above the Hansen bed. This is perhaps the most extensive and thickest bed of lignite that is known to occur in the State of North Dakota. Only two measurements were obtained on it in this township—at locations 275 and 276. (See pl. 12.) The total lignite found in this bed at location 276 is 26 feet 4 inches, and at location 275 more than 10 feet 6 inches. It is even thicker at locations 273

and 274, in secs. 30 and 31 of the township adjacent to the east. At location 273, near the old Russell ranch on Sand Creek, it attains a thickness of 31 feet of solid lignite, and if the 3 feet of shale parting is not considered, then the upper 3 feet of lignite may be added to this measurement, making a total of 34 feet of lignite. This extreme thickness of the lower bench, however, diminishes to 28 feet, at location 274. Extensive burns from this bed are now found on the divide between Sand and Deep Creeks and in all the higher hills to the west in the adjacent townships. The position of the bed is largely inferred by the aid of the heavy fused red rock. It is thought that in secs. 25, 26, 35, and 36 small remnants of the bed are still intact, and it is quite certain that a considerable part of the high divide in the northwest portion of the township is underlain by it, as it has been penetrated by wells. The lignite of the Harmon bed is of remarkably good quality and contains few impurities.

The township is probably underlain by several lignite beds in the Lance formation, and the whole township is classed as coal land.

T. 134 N., R. 106 W.

T. 134 N., R. 106 W., lies wholly within the Little Missouri badlands and has a maximum relief of about 525 feet. Little Missouri River, which flows along the east range line, is the only sure supply of running water in the township, and no springs were noticed during its examination, though pools of water are found along the larger valleys.

No lignite of importance was noted in this township. A dirty bed about 24 inches thick occurs at location 554, in sec. 15, about 1 mile northeast of the abandoned Twentyone ranch. The Cannonball lignite at location 553 is about 1 foot 10 inches thick and underlies a few square miles of land. Under the present system of classification the township is largely noncoal land. The northeast corner is classed as coal land, from the occurrence of the bed of lignite along Cannonball River to the north. Clinker beds produced by the burning of a lignite bed cap the hills in the northeast corner of this township; such a cap about 40 feet thick occurs on Pretty Butte.

T. 134 N., R. 105 W.

Narrow river flats and high river terraces are the notable features in the western portion of T. 134 N., R. 105 W., and small-scale badlands are developed in the eastern two-thirds. The total relief is about 400 feet.

The rocks of the township dip northeastward about 30 feet to the mile, and those of the Hell Creek member of the Lance are barren of lignite except for thin worthless layers. The upper 250 feet of the Ludlow lignitic member, however, includes several lignites of variable thickness.

Small areas of terrace gravel are present in secs. 2, 3, 22, and 23, and similar gravel was noted in sec. 36 and scattered elsewhere on hills in the township.

At least six beds of lignite over 3 feet thick crop out in this township, most of which is classed as coal land, the noncoal land bordering the river. The lowest lignite bed traced crops out along Indian Creek and in the next gully to the north, in sec. 20, and was measured at locations 588 and 591. At location 588, in the NW. ¼ sec. 28, the bed shows 2 feet 9 inches of lignite above, separated by about 10 inches of shale from 5 feet 6 inches of lignite below, but at location 591, on Indian Creek, it is only 2 feet thick.

A short distance above this bed of lignite is a second, on which locations 559, 560–C, 561, 564, 564–A, 564–B, 566, 577, 578, and 584 (pl. 13) are thought to have been made. The measurements taken at those locations show little variation in thickness, averaging about 2 feet.

Above the last-mentioned bed is 32 feet of shale, followed by a third bed of lignite, designated the Beta bed. The correlation of this lignite with any bed in the township to the north is somewhat uncertain. Locations 557, 557–A, 558, 560–B, 562–B, 563, 565, 567, 575, 576, 576–A, 580, 583, 585, 587, 590, 592, 593, and 594 probably represent this bed. If they do then its thickness ranges from 19 inches to 3 feet 4 inches. (See pl. 13.) Between the group of sections along Indian Creek, which are 30 inches or so in thickness, and those in the small draw that heads in sec. 28, this bed is too thin to be of any particular economic importance.

The T Cross bed, which is separated from the Beta bed by 11 to 23 feet of shale and sandstone, is by far the most valuable one in this township. The porcellanite or clinker that caps Pretty Butte, in T. 134 N., R. 106 W., is caused by the burning of this lignite, and similar outcrop burning has taken place extensively in this township. The outcrop is mapped behind these clinker tracts, but the mapping may include some burned-out areas. This bed is under no considerable amount of cover in this township, 100 feet being a probable maximum. Measurements at locations 556, 560–A, 562–A, 570, 571, 572, 573, 574, 579, 579–A, 582, 586, and 589, shown graphically on Plate 13, are assumed to have been made on the T Cross bed. If this assumption is correct, then the thickness of the bed in this township ranges from 3 feet 2 inches to 9 feet 9 inches. At several of the locations it was impossible to determine the total amount of lignite because of the concealment of its base. The thickest measurement, 14 feet 8 inches, was that at location 573, in the NE. ¼ sec. 26. Residents obtain a part of their fuel supply from the prospects at location 589, in the northeast corner of sec. 28.

At 80 feet above the T Cross bed is the highest bed, corresponding in stratigraphic position to the Ives bed in T. 133 N., R. 104 W., and locations 569, 596, 597, and 598 are considered to have been made on that bed. Its maximum thickness as shown by these sections is 3 feet, which was measured at location 597. However, it is probably more than 4 feet thick, because the bottom of the bed was not reached at locations 596 and 597.

T. 134 N., R. 104 W.

T. 134 N., R. 104 W., is crossed by intermittent streams tributary to Boyce and Indian Creeks, and its surface consists of a broken, treeless upland having a surface relief of about 300 feet. The surface rocks of this township dip northeastward about 30 feet to the mile. An extremely resistant bed of quartzite is present near the base of the Tongue River member of the Fort Union formation in this township and is particularly well developed in the vicinity of Mound and along the road leading to the Gamble ranch, in sec. 6. The lowest lignite bed mapped is one of the Lance formation, which occurs about 100 feet above the T Cross bed and probably is the same as the Yule bed of T. 135 N., R. 104 W., and may be the same as the Ives bed of T. 133 N., R. 104 W. It crops out in secs. 18 and 19 at locations 599 and 600, where its maximum thickness is 6 feet of good lignite. It is possible that locations 601 and 602 are on this same bed, but of this there is some uncertainty because of the difficulty of tracing the outcrop through the grassy fields. Sections measured at location 599 to 602 are shown on Plate 13.

Bed H, near the base of the Tongue River member, lies about 100 feet higher in the section and was measured at locations 603 to 611. These measurements are given in detail in Plate 13. No other measurements were obtained along the southern extension of its horizon in this township or in the one adjacent to the south. In the township to the north this bed is of value.

The Hanson bed occurs about 30 feet above bed H. No measurements were made on it in this township, and its outcrop is largely inferred around the base of the hills capped by the baked sandstone and shale caused by the burning of the Harmon bed. The measurement nearest to this township was obtained in sec. 34 of the adjacent township to the north, where it is 5 feet 7 inches thick.

The Harmon bed lies some 20 feet above the Hansen bed, and small patches of it remain at the south common corner of secs. 34 and 35, also in secs. 20 and 21 and beneath small areas in the eastern part and the northeast corner of the township. Eight feet of lignite on this bed was exposed at location 612, but the bottom was not reached. It is 12 feet 11 inches thick 1,000 feet north of sec. 2.

The Lance bed of lignite mapped in this township is less woody in structure than the beds of the overlying Tongue River member and for that reason slacks more readily on exposure to the air and sunlight. Its maximum cover within the township is about 300 feet. Bed H contains more thin shale partings than it does in the townships to the north and becomes too thin to be workable, though of fair quality except for the partings. The Harmon bed is very good lignite. The township is all coal land.

T. 134 N., R. 103 W.

T. 134 N., R. 103 W., lies almost entirely within the drainage system of Deep Creek and contains no perennial streams. One spring was found in the SW. ¼ NW. ¼ sec. 28, and one along the west line of sec. 7. The western part of the township is a rolling upland, mostly covered by treeless grassy slopes, but the eastern half contains numerous red hills capped by red baked rock which protects the underlying softer rocks from erosion and leaves a very rough surface. The total relief of the township is about 200 feet. The surface rocks belong entirely to the Tongue River member of the Fort Union formation and dip northeastward at about 20 feet to the mile. Round Top Butte is capped by a heavy, massive resistant sandstone, much like that which covers H T Butte, about 5 miles to the east, and Bullion Butte, to the north, although apparently not the same sandstone.

The lowest lignite bed observed, probably bed H, is 3 feet 4 inches thick at location 620–B, in the northeast corner of sec. 1. A second lignite bed, probably the Hansen bed of T. 136 N., R. 102 W., lies 16 feet above bed H and has an exceedingly ragged outcrop, owing to the fact that its cover is in places only a few feet thick and nowhere more than 200 feet thick. A good part of the outcrop of the Hansen bed is inferred, because exposures are few. The inference as to its occurrence around the base of the red hills is, however, fairly safe, because measurements of the bed were made at several places. The average thickness of the complete measurements on this bed is about 5 feet 6 inches at locations 614 to 620–A. These measurements are shown graphically on Plate 13. The Harmon bed is about 30 feet above the Hansen bed, and its outcrop is largely inferred. Only a few measurements were made on it in this and adjoining townships. At location 613, in the NW. ¼ sec. 8, it is more than 10 feet thick, its top being in contact with soil and its bottom being concealed by water. A small remnant of the Harmon bed underlies Round Top Butte and also a much larger area in the western part of the township. The red capped hills due to the burning of the Harmon lignite are shown on the map. In the field it was assumed that wherever the ground is sufficiently high and no red hills appear this bed of lignite has

not burned. The quality of the Hansen lignite is fairly good, although the bed is split by thin shale partings at locations 617 and 618 and by thick partings at location 321. The lignite is brown, and its woody structure is not so pronounced as that of the Harmon bed, which seems to be of better quality. A small amount of iron pyrites occurs in all the beds.

The township is classed as coal land partly on the basis of the lignite beds described and partly on the inferred presence of lignite beds in the underlying Ludlow lignitic member of the Lance formation.

T. 134 N., R. 102 W.

Clinker-capped hills are prominent in the valley of Deep Creek in T. 134 N., R. 102 W., and the eastern two-thirds of the township is mostly a treeless rolling upland, from which H T Butte rises about 500 feet to an altitude of 3,474 feet above sea level.

Good springs were noticed in secs. 35, 20, 8, and 14 and at the west end of H T Butte, and large water holes occur along Deep Creek, which usually contains running water.

The rock formations are essentially horizontal within this township, and the exposed strata belong to the Tongue River member of the Fort Union, the Sentinel Butte shale, and Oligocene (?) massive sandstone capping H T Butte. A small area of terrace gravel is also present in sec. 6.

This township contains an abundance of lignite, and all of it is classed as coal land. The lowest bed traced is in the Tongue River member and is probably bed H. This bed crops out slightly above the bottom of Deep Creek and was measured at locations 622–C, 625–B, 626, 632, 633, 635, and 636. Its observed thickness ranges from 2 feet to 5 feet 3 inches. (See pl. 13.) The thickest measurement was obtained at location 633, where lignite is mined for fuel by local inhabitants, although the total thickness was not ascertained because of water that had accumulated in the pit. At location 636 the bed is less than 30 inches thick. A thin bed 18 feet higher in the section is 2 feet 8 inches thick at location 622–B but was not mapped. The Hansen bed lies about 25 feet above this thin bed and underlies at shallow depth the eastern part of the township and some irregular tracts along Deep Creek. These isolated areas are generally covered by the Harmon porcellanite or clinker, and the position of the Hansen bed was not definitely determined around the base of the red hills. However, at locations 621, 622–A, 623, 625–A, 627, 628, 629, 630, and 631 the sections shown graphically on Plate 13 were measured. In these sections it ranges in thickness from 4 feet 10 inches to 8 feet. At location 624 there is a small opening on the bed, but the lignite is badly weathered. It is reported that Johnson Bros., who drilled a well in sec. 2, encountered 8 feet of lignite at the

Hansen horizon. The ground in secs. 3 and 10 is flat and cultivated. and the outcrop could not be traced definitely within these sections.

About 30 feet of sandstone and shale intervenes between the Hansen bed and the Harmon. The outcrop of the Harmon bed is commonly marked by clinker, and to a large degree it was mapped to accord with the apparent edge of its unburned area. The only measurement of this bed obtained in this township was at location 637, in sec. 14. The inhabitants for many miles around get a large part of their fuel supply from this country bank, in which at least 25 feet of high-grade lignite is exposed. A well in the NE. ¼ sec. 2 is reported to have penetrated a lignite bed about 30 feet thick, and a well in the SE. ¼ sec. 14 is also reported to have struck a thick lignite bed; both presumably encountered the Harmon bed.

A fourth lignite, the H T Butte bed, traced in the townships farther north, lies about 330 feet above the Harmon bed and crops out around the slopes of H T Butte, Squaw Butte, and a small high hill in the SE. ¼ sec. 14. At location 639 the bed is 8 feet 2 inches thick, and at location 638, 10 feet 2 inches. Thin shale partings occur in the bed, but otherwise the quality is fair. So far as known, this is the highest lignite in the township. It is quite probable that some lignite beds of Lance age also underlie the township, and for these reasons the entire township is considered coal land.

T. 133 N., R. 106 W.; TPS. 132 AND 131 N., RS. 106 AND 107 W.; TPS. 130 AND 129 N., RS. 105, 106, AND 107 W.

The 11 townships lying in the southwest corner of North Dakota are described together, because they contain no lignite of appreciable commercial value.

Little Missouri River and Little Beaver and Boxelder Creeks, which cross this area, are all perennial streams and furnish an abundant supply of fairly good water. Springs are somewhat rare, and water generally is obtained from shallow wells. It is probable that artesian water may be obtained at depths of less than 200 feet by wells along the river flats in this district. It probably could not be obtained south of T. 132 N. or on Little Beaver Creek in Bowman County. There is not enough lignite in these townships to supply local needs. At location 722, in sec. 2, T. 130 N., R. 105 W., there is 1 foot 6 inches of lignite at a small strip pit, and in sec. 35 there is a dirty bed 2 feet 6 inches thick. Near the De Clanahan ranch, in sec. 10, T. 129 N., R. 105 W., a strip pit of considerable length has been opened on 1 foot 4 inches of lignite, at location 735. At location 736, in the same township, 10 inches of lignite is exposed. It is probable that other small beds are present in this area, but none are large enough to be mined at a profit, except possibly within tracts a few acres in extent.

T. 133 N., R. 105 W.

T. 133 N., R. 105 W., lies almost wholly within the Little Missouri badlands and has a maximum relief of more than 400 feet; the highest points are in its extreme northeastern part. The surface rocks of the township belong to the Hell Creek and Ludlow lignitic members of the Lance formation, which have a northeastward dip of 1° or 2°, caused by the uplift of the Glendive anticline.

A very small amount of lignite is found in secs. 1, 2, 11, 12, 13, and 36, but most of the township is noncoal land. The T Cross lignite bed is the only one found to be over 2 feet 6 inches in thickness within this township, its thickness ranging from 8 feet at location 669 in sec. 36, to more than 3 feet 7 inches at location 666 in the NW. ¼ NE. ¼ sec. 12, where the bottom of the bed was not reached. It has a thickness of 7 feet 4 inches at location 671 and of more than 3 feet 10 inches in the NW. ¼ sec. 3, at location 667. These measurements and others at locations 673 and 670 are shown graphically on Plate 13. A lower bed 27 inches thick occurs at location 672, in the northeast corner of sec. 36. This may possibly be the same bed as that at location 668, in the SE. ¼ sec. 10, where 15 inches of lignite was measured, or the bed which crops out in secs. 3 and 4 at location 667, below the T Cross bed. The interval between these two beds is but a few feet in sec. 36, but it is somewhat more at the other places. No samples for analysis were taken from the T Cross bed within this township, as its exposures were too much weathered. The lignite is not of the best quality, for there are numerous dirty streaks of lignite and small shale partings in the bed.

T. 133 N., R. 104 W.

There is a fine spring within T. 133 N., R. 104 W., at the T Cross ranch, in sec. 20. The surface relief is about 350 feet and the topography of the township is of the broken upland type, the surface being deeply dissected only within the immediate valley of Bacon Creek. Considerable areas of terrace gravel occur in the neighborhood of the T Cross ranch.

The rock formations in this township dip somewhat to the northeast, and observations taken in the SE. ¼ sec. 26 show dips of 5° and 3°, with a strike of N. 45° W. However, the dip seems to be abnormally high and probably is local, for an observation taken in sec. 31 of the township to the east showed but a ½° dip.

An abundance of lignite occurs in this township, and except for a small area in secs. 17, 18, 19, 20, 29, 30, and 31 it is all classed as coal land. The T Cross lignite is the lowest workable bed exposed. It is 24 feet thick at the T Cross mine (location 665) in sec. 20, in the bank of Bacon Creek. (See pl. 4, *A*.) At this locality the T Cross bed contains numerous partings of shale and of an extremely white,

chalky, fine-grained, powdery substance. These white streaks measure from a fraction of an inch to an inch in thickness. The white substance may also occur as small pockets the size of walnuts or marbles. At location 663 the lignite is 12 feet 10 inches thick. The measurements are shown in detail on Plate 13. The outcrop of the bed in secs. 30 and 31 is entirely concealed by the large amount of red slaglike material formed by the burning of the lignite. This clinker bed is 20 to 40 feet thick and extends over a considerable area in these sections. The outcrop was also traced in secs. 17, 18, 20, and 29, at locations 664 and 665. (See pl. 13.) The Ives lignite lies about 50 feet above the T Cross bed and was traced around the head of Bacon Creek. It contains 4 feet of lignite at location 662 and 3 feet 6 inches at location 658. It was measured also at locations 660 and 661, as shown on Plate 13. As this bed is traced into sec. 16 from sec. 21 its thickness is found to diminish. No measurements were obtained to the north in this township.

About the base of the higher hills in the northeast corner of the township the inferred position of the Hansen bed is mapped. Extensive clinker beds cap these hills, particularly from the burning of the Harmon bed. It is presumed that two remnants of that bed underlie small hills in secs. 2 and 3.

No samples for analysis were taken from any of these beds in this township because all the exposures are too much weathered. All the lignite is brown and shows a great deal of woody material. The impurities noted in it are shale, iron pyrite, gypsum, and the white material found in the bed at the T Cross ranch.

T. 133 N., R. 103 W.

The surface of T. 133 N., R. 103 W., consists of a treeless rolling prairie broken only by scattered clinker-capped hills which give the township a maximum surface relief of about 300 feet. Deep Creek, which drains the township, is an intermittent stream, though water holes along its course persist throughout the year.

But three exposures of lignites were found in this township. One at location 655–A, in sec. 33, revealed 20 inches of lignite, probably representative of bed H, and the same bed is 24 inches thick at location 656, in sec. 35. The Hansen bed, the next bed above bed H, was measured at location 655 and showed a total thickness of 78 inches of lignite split by two 2-inch shale partings. No other exposure of this bed was found, and its outcrop as mapped is based on altitudes and on the clinker beds produced by the burning of the overlying Harmon bed.

The lignite beds exposed in this township are comparatively impure as well as thin. Workable beds of lignite below those measured are believed to underlie the township, however, and its entire area is therefore classed as coal land.

T. 133 N., R. 102 W.

Deep Creek, whose many upper tributaries spread throughout T. 133 N., R. 102 W., commonly contains running water and is fed by a number of springs scattered here and there along its course. This constitutes the water supply of the township except for water holes and shallow wells. Many square miles of red clinker hills are present in the western part, and similar hills are scattered over the broken rolling land to the east.

The surface rocks of the township belong to the Tongue River member of the Fort Union formation, are essentially horizontal, and consist of about 150 feet of fine-grained light-colored sandstone or light-colored sandy shale and beds of lignite.

The Harmon bed, which is less than 50 feet above the Hansen bed, underlies small areas in this township and probably underlies most of the township to the east. An isolated remnant of the bed may remain unburned in the high hill in the southeast cornor of sec. 36, and the high land in secs. 12 and 13 is probably underlain by it. In both places the cover is very thin, and its outcrop was drawn at the place where the evidence of burning ceased. The numerous conspicuous red hills throughout the township are capped by fused and baked rock, formed by the burning of this bed, which in near-by townships ranges from 16 to 34 feet in thickness and is the thickest known lignite bed in North Dakota. At location 640, in sec. 19, T. 133 N., R. 101 W., 5 feet 6 inches of lignite was measured, but the bottom was not reached because of the excessive amount of water. When visited lignite at this locality was being dug by farmers, who paid the owner $1.50 a wagon load. The Harmon bed contains slightly less impurities than the Hansen bed and consists of lignite of excellent quality.

It is probable that some of the lignite beds of Lance age, such as the T Cross bed, underlie this township, and the whole of the township is considered to be coal land.

The lowest lignite exposed in this township is correlated with the lower bench of the Hansen bed and was measured in the stream valley in sec. 21, at locations 650, 653, and 654. (See pl. 13.) The Hansen bed crops out in the valley that heads in the extreme southeast corner of the township, and the lignite bed is in two benches, separated by about 6 feet of sandstone. The lignite is worked in open pits at locations 643, 644, 646, and 648 by farmers who get a large supply of fuel from this bed. The best part of this bed underlies the eastern two tiers of sections. The position of the bed was largely inferred around the base of the numerous red slaglike hills. The sections of the bed at locations 642, 643, 644, 645, 646, 647, 648, 649, 651, and 652 are shown graphically on Plate 13.

T. 132 N., R. 105 W.

The northeast corner and east side of T. 132 N., R. 105 W., is hilly and somewhat grassy, but the area outside or west of the lignite outcrop is one of pronounced badlands.

About 600 feet of rocks belonging to the Lance formation are exposed in this township and dip northeastward 30 feet to the mile.

Three beds of lignite were found in this township. The lowest bed, probably the Cannonball bed, occurs at location 675, in the NW. ¼ sec. 16. The bed is only 2 feet thick and was traced for a short distance. The bed at location 674, 1 foot 8 inches thick, is probably the same lignite. In the bank of Coyote Creek in sec. 35, at location 681, the following section was measured:

Section on Coyote Creek, in sec. 35, T. 132 N., R. 105 W.

	Ft.	in.
Shale, carbonaceous		10
Lignite	1	1
Sandstone		1
Lignite	1	
Shale		1
Lignite	1	5
Clay.		
	4	6

Possibly this section and those at locations 674 and 675, in this township, and location 715, in T. 131 N., R. 105 W., represent the same lignite bed. They were not considered important enough to map.

The next higher bed and the most valuable one in the township is the T Cross bed, the outcrop of which was mapped in detail. The bed is 9 feet 7 inches thick at location 676, near the railroad track in sec. 11, but the upper 3 feet is impure, and there are in addition two shale bands, each 1 inch thick. At location 677, in the NE. ¼ SW. ¼ sec. 14, 6 feet 6 inches of weathered lignite was measured. Its outcrop was found to the south by the aid of little "burns" and was measured at location 678. At least 6 feet of lignite is exposed in an open pit at location 679, in the SE. ¼ NW. ¼ sec. 25, but the bottom was not ascertained because of water. At location 680, in the southern part of the same section, 4 feet 6 inches of lignite is exposed in another open pit. The pit is caved in, but the lignite is reported to be of good quality and is 6 feet or more thick. At location 682, in the SW. ¼ SE. ¼ sec. 36, the bed is 5 feet thick. Though generally of fair or good quality, the T Cross bed is very impure in the SW. ¼ sec. 26, the eastern part of sec. 22, and the eastern part of sec. 10. The best showings are those in the SE. ¼ sec. 25 and in sec. 36.

About 40 feet above the T Cross bed, near location 680, is a third bed of lignite on which the following section was obtained.

Section near location 680, T. 132 N., R. 105 W.

	Ft.	in.
Sandstone, yellow, fine grained, friable, with marcasite concretions.		
Lignite, impure	1	2
Shale, brown		10
Lignite	1	6
	3	6

At location 683 3 feet of impure lignite is exposed. Other local lenses of lignite occur in the township but were not mapped. The only coal land in this township is east of the outcrop of the T Cross bed and along Coyote Creek in sec. 35.

T. 132 N., R. 104 W.

T. 132 N., R. 104 W., consists of a treeless, rolling plain with very few rock exposures. The chief local features are big red clinker-capped hills (see pl. 6, *B*) and terrace deposits of gravel. The Rhame gravel pit, located partly in sec. 34, is in one of these terrace deposits.

The rock strata exposed in this township belong to the upper 200 feet of the Lance formation and the lower 200 feet of the Fort Union. They dip about 25 feet to the mile northeastward.

The following section is indicative of the normal character of the strata of the Tongue River member of the Fort Union:

Section at Postoffice Butte, in T. 132 N., R. 104 W.

	Ft.	in.
Clinker of the burned Harmon bed, which caps all the highland in this township and east for many miles	47	
Sandstone, very light yellow, almost white, fine grained, friable. This bed, probably not everywhere as thick, is present just below the clinker in this township and also in the township just east	68	
Clay, gray, sandy	11	
Shale, brown	1	6
Sandstone, yellow, fine grained, friable	5	
Shale or clay, gray	14	
Sandstone, yellowish to gray, fine grained, some layers clayey, with two very thin streaks of carbonaceous shale	38	
Bone	1	8
Sandstone (?), brownish, of tufaceous appearance, fairly hard, variable in thickness, porous with reed stems. Seems to be continuous beneath this township and also the one to the east	2	
	188	2

The most striking and peculiar stratum in the Fort Union is a siliceous rock that occurs about 75 feet above the top of the Lance formation.

The principal lignite bed of the township is the T Cross bed, which crops out in the bottom of the gullies in secs. 19, 30, and 31, where it was burned in several places. At location 684, sec. 30, at the Duckhorn prospect, 5 feet of impure lignite shows in outcrops, but the base is not exposed. The bed was reported to be over 10 feet thick, but when visited only a part of it could be seen. A little to the west of the northwest corner of sec. 30 a well 62 feet deep struck 2 or 3 feet of lignite, but the bottom of the bed was not reached. It was reported that the well at location 686, in the SE. ¼ sec. 27, struck 8 to 9 feet of lignite, which may be the same bed. A well at the south quarter corner of sec. 19, location 685, at a depth of 28 feet struck 8 feet of lignite. At the Old Clark or T Cross ranch, a few miles north of Ives, this bed is 24 feet thick.

The T Cross bed is overlain by 100 feet of sandstone and shale, which separate it from the Ives bed, exposed in the railroad cut east of Ives. The Ives bed can be traced for only a short distance to the southeast and underlies the eastern part of the township. This is probably the same bed as the one found across the divide, in secs. 9 and 4, and is also the one traced in the eastern part of T. 133 N., R. 104 W. There is 5 feet of impure lignite at location 687, in the SW. ¼ sec. 7; 6 feet in the prospect at location 688, in the SW. ¼ sec. 8; and 7 feet in a prospect at location 689, in sec. 4. Above the Fort Union-Lance contact occurs a thin bed of lignite which is 2 feet thick, as reported, in a spring at location 705, in the SE. ¼ sec. 35. A bed of lignite 1 foot 8 inches thick crops out about 120 feet below the base of the Harmon "burn" in secs. 1 and 12. About 80 feet above this thin bed and 40 feet below the base of the extensive "burn" is a bed 1 foot thick which may be the Hansen bed of the township to the north. At the prospect in the SE. ¼ NE. ¼ sec. 12 at location 690, the bed was reported to be 2½ feet thick by one person, 2 feet by another, and 4 to 5 feet by a third. The 3 feet of lignite in the well in the SE. ¼ sec. 14 is probably the same bed. The Harmon bed is burned out in this township, its presence being indicated only by the great thickness of fused rock on the red-capped hills, which may ultimately be used for road metal or ballast.

It is believed that the township is coal land, on the assumption that the underlying T Cross bed of lignite, which crops out in the lower gullies of Coyote Creek and to the west in T. 132 N., R. 105 W., is of workable thickness beneath this township.

T. 132 N., R. 103 W.

T. 132 N., R. 103 W., is crossed from east to west, near the middle, by the low, grassy, treeless divide between Little Missouri and Grand Rivers. Aside from shallow wells the only sources of permanent water supply are the numerous small springs that issue from beds of lignite and sandstone, which yield water containing little alkali.

The strata that crop out in the township are about 200 feet thick, are wholly of Tongue River age, and dip northeastward at about 23 feet to the mile. The township is so grassy that exposures are few; consequently little information was obtained regarding the character of the strata. However, they apparently consist of light-colored sandy shale and sandstone, with a few thin beds of lignite and carbonaceous shale. Where the Harmon lignite bed has burned in this township, there is an abundance of red baked rock which makes good road metal.

No lignite of economic importance crops out in this township, and probably no unburned area of the Harmon bed remains within the large areas of red rock formed by its burning. Lower beds of lignite crop out in adjacent townships, however, and it is probable that these lower lignites—the T Cross bed, for instance—underlie this township at depths of 150 to 250 feet. The township is considered to be coal land on this supposition.

T. 132 N., R. 102 W.

The surface of T. 132 N., R. 102 W., considered as a whole, is gently rolling and treeless. It is dotted with numerous low red clinker-capped hills rising from 25 to 75 feet above the surrounding country. The Twin Buttes, on the divide between Little Missouri and Grand Rivers near the southeast corner of the township, rise about 300 feet above the surrounding plain. These buttes are capped by a very hard quartzite, which protects the underlying strata from weathering and erosion.

Springs are scarce, and are found only in the northwest corner of the township, and water is obtained in wells at depths of 10 to 200 feet.

The rocks exposed in the township belong to the Tongue River member of the Fort Union formation and dip northeastward at about 27 feet to the mile. The character of these rocks is shown by the following section:

Section in Twin Buttes, T. 132 N., R. 102 W.

	Ft.	in.
Sandstone, yellow, fine, friable	7	6
Quartzite, whitish to dark gray, extremely hard, thin bedded, very fine grained; filled with large and small casts of reed stems parallel to the bedding; some of these holes are 3 or 4 inches in diameter but most of them are very small. The rock is very resistant but brittle, breaking up into plates and then smaller and smaller angular fragments. Pieces of this rock occur over all the township just northwest of the buttes and even west of Rhame; the rock seemed to be in place at the southwest end of the eastern butte	1	6
Sandstone, yellow, fine, friable	15	

	Ft.	in.
Mostly covered but all probably grayish sandy clay and gray sandstone	65	
Red "burn" of thin lignite bed, no section obtainable; no fusion. Sandstone, almost white, fine-grained, friable, with "log concretions"	25	
Covered	35	
Massive fused rock from burning of Harmon lignite bed.		
	149	

The lowest exposed bed of lignite is found in the northwest corner of the township, in the creek bottom. At the Lombard strip pit, at location 695, in the northwest corner of sec. 9, the bed is 4 feet 4 inches thick, but the upper 4 inches is rather impure. This bed has been prospected at location 694, in the northeast corner of sec. 8. Here at least 3 feet 6 inches of good lignite with 6 inches of dirty lignite at the top is exposed, but the bottom of the bed was not reached because of water.

Lignite is exposed farther up this creek valley, at locations 693 and 692, in secs. 7 and 18, but the bed is impure and only 20 inches thick. Probably these two outcrops are not on the same bed of lignite as the Lombard prospect. It is reported that a well in the northwest corner of sec. 10, at location 696, passed through 7 feet of lignite at a depth of 100 feet, and a well in the southwest corner of sec. 10, at location 695–A, struck 3 feet 6 inches of lignite at a depth of 28 feet. A well in the southeast corner of sec. 9 also struck lignite. The lignite bed discovered in these wells is probably the same as that in which the Lombard prospect is opened and is correlated with the Hansen bed of the township to the north.

About 100 feet above the lignite bed just described is the Harmon bed, whose outcrop was traced with a fair degree of certainty from the vicinity of the Harmon ranch, in T. 139 N., R. 102 W., southward to this township and thence eastward to Scranton, in T. 131 N., R. 100 W. No measurement of this bed was obtained in T. 132 N., R. 102 W., but 24 feet of lignite is reported to have been found in the well at location 697, in the southwest corner of sec. 12, and 30 feet of lignite was reached 133 feet below the surface in a well at location 697–A, in the southwest corner of sec. 14. (See pl. 13.) Reports concerning this lignite bed in other wells state that it is either extremely thick or else was not completely penetrated. Its inferred outcrop is shown on the map by a broken line. A small area probably remains unburned beneath Twin Buttes. Scattered over the township are numerous red baked and fused rock masses formed by the burning of this bed. Its quality is excellent, as shown by analysis 14485, page 54, of a sample from the Scranton mine.

The entire township is probably underlain by the T Cross bed, which crops out in the vicinity of Ives, on the west, and also along North Fork of Grand River.

T. 131 N., R. 105 W.

The western half of T. 131 N., R. 105 W., lies in the Little Missouri badlands, and the east half contains a dissected rolling prairie surface. Considerable terrace tracts border the river flood plain in the western part of the township, and the total surface relief is about 300 feet.

About 30 feet of the Fox Hills sandstone crops out in this township, including the light-colored Colgate sandstone member and part of the brown lower member. The whole of the somber-colored Hell Creek member of the Lance and the lower part of the Ludlow lignitic member are exposed in the township, and a lignite bed at the Hell Creek-Ludlow contact and one at the T Cross horizon of the Ludlow member were the only beds found in the township considered to be of sufficient value to merit mapping. The lower lignite bed, which is at about the Cannonball horizon, was measured at locations 716 to 719, in the southeast quarter of the township. The same bed underlies a small knoll near the northwest corner of sec. 3 and is 2 feet 1 inch thick at location 715.

The T Cross lignite was measured in the north-central part of sec. 12, at location 714 (see pl. 13), where the bed is parted by shale and is of poor quality.

T. 131 N., R. 104 W.

The Medicine Pole Hills, in the south side of sec. 35, T. 131 N., R. 104 W., are the highest points on the low, grassy divide between Little Missouri and Grand Rivers, ranging in altitude from 3,400 to 3,463 feet. The small buttes in sec. 21 have an altitude of 3,340 feet, and similar buttes in the center of sec. 16 stand at 3,264 feet. The gravel terrace in sec. 4 in which the Rhame gravel pit is opened has an altitude of 3,050 to 3,060 feet, and the stream valley in sec. 6 probably about 2,900 feet.

Considered as a whole, the township is hilly and mostly grass covered, but in some places there are small areas of badlands, and in others there are terraces, as in secs. 4 and 5.

The rock strata of this township dip about 40 feet to the mile northeastward, and the exposed strata include the upper 200 feet of the Ludlow member of the Lance and about 360 feet of the Tongue River member of the Fort Union. A conspicuous layer of quartzite about 100 feet above the base of the Tongue River and 100 feet below the Harmon lignite bed caps a number of small buttes.

The Rhame gravel pit, in sec. 4, is in an extensive bed of recent gravel, and a large quantity has been excavated for ballast for the Chicago, Milwaukee & St. Paul Railway. The area of the pit is about 60 acres, and the gravel shown in the vertical face of the pit is 10 or 12 feet deep. It is composed of pebbles of a great variety of

rocks, including quartzite, sandstone, shale, "clinker," porphyry, diabase, granite, and syenite, also a great number of waterworn fragments of bones. The gravel at the Rhame pit covers about two and a half sections of land. Possibly the gravel may not be so thick near the outer boundary of the area as it is in the pit.

The township is all considered to be coal land with the exception of a narrow strip along the west range line. The lowest valuable lignite is the T Cross bed which was mapped across the western part of the township. Three strip pits have been opened on it, one at the Funston ranch, at location 721, where the bed is at least 6 feet 7 inches thick; another in the SW. ¼ NW. ¼ sec. 7, at location 713, where it is at least 9 feet 8 inches thick with 15 inches of shale parting; and one in the SW. ¼ SW. ¼ sec. 6, at location 711, where the bed is 8 feet 8 inches thick, with shale partings amounting to 7 inches. Up the creek valley, at locations 709 and 710, in sec. 7, the bed is badly split up by shale partings. A well in the NE. ¼ SE. ¼ sec. 18, at location 720, at a depth of 8 feet struck 5 feet of lignite, then about 7 feet of shale, and at least 2 feet more of lignite. It is possible that the lower bed extends to the bottom of the well and is 6 or 8 feet thick. Sections at these locations are shown graphically on Plate 13. A second lignite bed occurs a short distance above the T Cross bed and was measured at locations 708 and 707.

Somewhat higher in the geologic section, at an altitude of 3,100 feet, in the NW. ¼ sec. 9, at location 706, a small prospect has been opened on a local lens of lignite 2 feet 10 inches thick. The lignite that is 4 feet 4 inches thick at location 703, in sec. 36, may be the same bed.

A fourth bed of lignite higher in the geologic column, which because of its position above the other beds and its thickness is supposed to be the Harmon bed, underlies small areas within this township at a prospect at location 723, near the south quarter corner of sec. 35, where 5 feet 6 inches of the bed is exposed at an altitude of 3,360 feet. Other outliers occur in secs. 24 and 25, where the bed has an altitude of 3,230 feet, indicating a northeasterly dip of about 40 feet to the mile. The bed in these outliers may be as much as 20 feet thick.

T. 131 N., R. 103 W.

The low grassy divide between Little Missouri and Grand Rivers lies near the west line of T. 131 N., R. 103 W. A few small springs are found along the course of Spring Creek and together with the contents of local reservoirs constitute the surface water supply of the township. The valley of Spring Creek is broad and grassy, but the country near the south township line is much dissected.

The rock strata exposed in this township include about 100 feet of the upper part of the Ludlow member of the Lance and about 300 feet of the lower part of the Tongue River member of the Fort Union,

all of which dip toward the northeast at about 25 to 30 feet to the mile.

A very persistent bed of quartzite in the lower part of the Tongue River member caps some of the low buttes in the southwest corner of the township. Numerous fragments of this rock are scattered over the ground and are particularly abundant in sec. 8. About 100 feet above the quartzite is the Harmon bed of lignite, which is very persistent. A great amount of fused and baked rock formed by the burning of this bed occurs in red hills and low ridges in different parts of the township.

Minor lignite beds occur in the Lance formation. On the west township line in sec. 31, at location 703, a bed at an altitude of about 3,100 feet is 4 feet 4 inches thick, but this is an exceptional thickness, as near-by exposures show the bed to be so thin as to be almost worthless. A lignite bed 11 inches thick crops out at an altitude of 3,000 feet at location 702, in the SE. ¼ SW. ¼ sec. 33, and 1 foot 4 inches was measured in the NE. ¼ SE. ¼ of the same section, at location 701. The bed was measured at the old Paoli prospect, at location 700, in the NW. ¼ sec. 35, where it consists of 1 foot 10 inches of lignite underlain by 13 feet of shale, 8 inches of impure lignite, and 2 feet 4 inches of good lignite. The lignite at the Paoli prospect is of poor quality. A strip pit has been opened at location 698, in the NW. ¼ sec. 1, on a bed of Fort Union lignite measuring 1 foot 11 inches. The same bed is opened at location 699, in sec. 3, where it measured 1 foot 3 inches of impure lignite. The altitude of the lignite is 3,017 feet. The thickest and best lignite bed outcropping in the township is the Harmon. Two outliers of this bed remain, one about 160 acres in extent in sec. 21 and another in and around sec. 19. A prospect on it has been opened near the Hawkes ranch, at location 704, in the NW. ¼ sec. 29, where the bed is at least 20 feet 6 inches thick. The altitude of the prospect is 3,203 feet. The quality of the lignite is good, and the estimated quantity in this bed in the township is 4,480,000 tons. The entire township is considered to be coal land, as without much doubt it is underlain by the T Cross bed, which crops out only a few miles to the south and west of this township.

T. 131 N., R. 102 W.

The Twin Buttes are conspicuous landmarks in T. 131 N., R. 102 W., which rise above a monotonous rolling grassy country.

About 500 feet of strata belonging to the Ludlow lignitic member of the Lance and the Tongue River member of the Fort Union crop out in this township, but owing to the generally low relief there are few exposures of bedrock to study. A stratum of hard siliceous rock, which crops out about 100 feet above the base of the Tongue River

member in the north side of sec. 28, in sec. 22, and at other places, is a good key bed.

The valuable Harmon lignite bed crops out about 200 feet above this quartzite, and fused red rock from the burning of this lignite was noted in secs. 2, 13, 15, and 16. The lignite bed is overlain by light-colored and weakly cemented sandstone. A section measured up the side of Twin Buttes is given on page 93. A hard fissile siliceous rock caps the buttes. Fragments of this layer are scattered over most of the township. It makes an excellent building stone, for it breaks into slabs from 2 inches to 1 foot thick, and the foundations of some of the buildings in Bowman are made of it. A small area of the Harmon lignite bed probably remains intact beneath the Twin Buttes, in secs. 1 and 2, and also beneath Talbot Butte, half a mile east of the east line of secs. 13 and 24. Its outcrops are inferred from the red fused rock formed by its burning. (See pl. 14.) No measurement of the bed was procured, but it is very thick, as shown by wells in the township to the north that struck from 20 to 30 feet of lignite, and by the mines at Scranton, about 12 miles to the east, where it is from 19 to 23 feet thick. The bed has been sampled at the Scranton mine, and analysis 14485, on page 54, was made from a sample taken at the Lydell mine during the summer of 1912. The lignite is of excellent quality and is woody, brown, and tough.

Conflicting reports were given concerning the possibility of a lignite at shallow depth beneath Bowman, some people reporting that in shallow wells 5 or 6 feet of lignite was encountered and others denying the presence of lignite in the wells. Some of the conflicting reports pertain to the same well, others to different wells. If the wells at Bowman are deep enough, they pass through the horizon of the T Cross lignite of the townships to the west and south. Largely because this bed is believed to underlie the township the whole of T. 131 N., R. 102 W., is considered to be coal land.

T. 130 N., R. 104 W.

A hilly divide separates the Little Missouri and Grand River drainage basins and culminates in the Medicine Pole Hills and Medicine Pole Butte, which rise to altitudes of about 3,400 to 3,430 feet. The total relief possibly does not exceed 500 feet. The upper valley of Skull Creek is broad and grassy and is surrounded by numerous red hills.

The rock strata have a northeastward dip, which is more pronounced in the extreme northeast corner than elsewhere. A quartzite bed in the lower part of the Fort Union formation caps several small buttes in this part of the township, and a bed of lignite overlies this main quartzite layer in Medicine Pole Butte.

Three and possibly four beds of lignite occur in this township. The lowest bed, which apparently is a local lens, is exposed in secs. 20 and 29 and was measured at location 731–A, where it is 2 feet 1 inch thick. It forms a line of "burns," with no fusion, 60 feet or more below the T Cross bed. A thin bed 20 feet below the main T Cross bed has been prospected in secs. 26 and 27. It is 2 feet thick and of fair quality at locations 733 and 731, but at location 730 it is only 1 foot 10 inches thick. This is probably higher stratigraphically than the one in sec. 29.

The T Cross lignite is the principal bed of this township, underlying the northeast corner and the high divide between Little Missouri and Grand Rivers, and its outcrop was mapped from sec. 6 to sec. 24 and has burned extensively in secs. 9 and 35. It is variable in thickness and quality, being 9 feet 2 inches thick at location 734, in sec. 33, whereas farther east it is poor and thin. (See sections at locations 725, 726, 727, 728, 729, 732, and 734, shown on pl. 13.) Location 728, in the NE. ¼ NW. ¼ sec. 25, may be on a different bed but is very probably at the same horizon. In view of the marked diminution in thickness of this bed from over 9 feet in sec. 33 to 3 feet 5 inches in sec. 27 (location 732), it seems probable that locations 728 and 729, in sec. 25, are on this bed. Measurements at prospects at locations 726 and 727, in sec. 24, show that the bed thickens again toward the north.

The analysis of a sample obtained at the Durkin mine, in the township to the east, is shown on page 54. As the Pierre shale, the Fox Hills sandstone, and the lower part of the Lance formation are believed to be barren of valuable lignite in this region, the portions of this township not underlain by the lignite beds just described are regarded as noncoal land.

T. 130 N., R. 103 W.

T. 130 N., R. 103 W., is treeless, rolling, and very grassy, and rock exposures are few. There are few if any springs within it, and the small creeks are dry when water is most needed. Consequently shallow wells are the principal source of supply. The relief of the surface is very slight, possibly not more than 150 feet, and the rocks have a northeasterly dip of about 20 feet to the mile, caused by the uplift to the west of the Glendive anticline.

The lowest and the only valuable lignite bed in this township is correlated with the T Cross bed and crops out in a southeasterly line across the southwestern part of the township. The only measurement of thickness positively known to be on this bed was that obtained at the Durkin mine, at location 746, in the SW. ¼ sec. 34, shown graphically on Plate 13. Analysis 14857 (p. 54) represents a sample

obtained from the lower part of this bed. The position of the T Cross bed west of the Durkin mine, at location 746 (pl. 14), is almost entirely inferred, as the surface is grassy and no rocks show in outcrop. Lignite 10 feet thick reported about 40 feet down in a 70-foot well, at location 747, at Amor, probably represents this bed. At a small prospect at location 748, in the northeast corner of sec. 19, 4 feet of good lignite was measured without reaching the bottom of the bed. This may possibly be an inlier of the main bed. Most of the deeper wells in the southeast corner of the township, in the valley of Alkali Creek, strike lignite. The one in the southwest corner of sec. 26 penetrated a considerable thickness of lignite, and the well near the east quarter corner of sec. 27 encountered a lignite bed at a depth of 15 feet; both these lignites probably represent the T Cross bed. The maximum cover above the T Cross bed within the township is probably about 200 feet.

At location 749, in the SE. ¼ sec. 17, is a small bed 1 foot 6 inches thick, which is somewhat higher stratigraphically than the T Cross bed. A bed of impure lignite about 2 feet thick at location 751, in the E. ½ sec. 6, has burned in several places. Other insignificant "burns" occur in the northern part of this township. The only land in the township not underlain by lignite is in the extreme southwest corner, which is outside the area of the T Cross bed.

T. 130 N., R. 102 W.

The surface of T. 130 N., R. 102 W., is rolling and grassy, and the total surface relief is about 150 feet. All the best land has been taken up and seems fairly well suited to dry farming, though drought and hail often destroy the crops. There is not enough water for irrigation. Potable water is generally obtained from shallow wells, though some yield water which is rather alkaline.

The surface formations are the Ludlow lignitic member of the Lance and the Fort Union. There are no good exposures, and the contact between the Lance and Fort Union was placed arbitrarily about midway between the T Cross lignite bed in the Lance and the quartzite bed in the Fort Union, which is in place along the township line north of sec. 5. The part of the Fort Union formation remaining in this township does not contain any beds of lignite.

Two beds of lignite in the Lance formation were mapped in this township, and its entire area is considered to be coal land. Part of the lower bed crops out at the McVicker prospect, at location 755, in sec. 25, where 5 feet 2 inches of lignite is exposed at an altitude of 2,836 feet. The second bed, correlated with the T Cross bed, is 62 feet above the McVicker prospect. The section measured in a prospect at location 756 shows 2 feet 8 inches of lignite above 3 feet 9 inches of shale and 1 foot 9 inches of lignite. The lignite at the

McVeigh prospect, at location 754, in sec. 26, at an altitude of 2,860 feet, is 3 feet 2 inches thick and is considered to be the T Cross bed. In the SW. ¼ NE. ¼ sec. 22, 3 feet of lignite is exposed, and at location 752, at an altitude of 2,877 feet, there is 1 foot of lignite which may be a different bed. At location 759, in sec. 31, a new prospect has been opened on a higher bed which is 3 feet 7 inches thick and is split by 6 inches of shale. The only other evidence of lignite is that encountered in wells, as in sec. 20, where lignite was found at a depth of 115 feet; in sec. 28, where an abundance of lignite was reported to have been found in a well; and in sec. 34, where 4 feet of lignite probably the T Cross bed, was struck at a depth of 16 feet.

T. 129 N., R. 104 W.

The surface of T. 129 N., R. 104 W., is somewhat rough, especially the west side, which approaches badlands in character. The strata within the township dip northeastward at about 30 feet to the mile.

A bed of impure lignite 19 inches thick is exposed at location 740, in sec. 23, with a brown fissile carbonaceous shale both above and below. On the quarter section line the bed has burned, forming clinker. The same bed forms clinker in the southeast corner of sec. 13 and in the valley in sec. 14. At location 741, in the SW. ¼ sec. 13, the following section of it was measured:

Section in SW. ¼ sec. 13, T. 129 N., R. 104 W.

	Ft.	in.
Shale, highly carbonaceous, approaching lignite	1	4
Shale, brown, fissile	1	3
Shale, black, carbonaceous, approaching lignite in character and weathering into flakes like shale and not like lignite. It does not have the woody fiber of lignite	3	10
	6	5

This material was not considered lignite, although it contains some charcoal and enough carbon to burn. Locally the burning has baked the shale.

A higher bed, also of no value, was measured at location 738, in the SE. ¼ sec. 17, as follows:

Section in SE. ¼ sec. 17, T. 129 N., R. 104 W.

	Ft.	in.
Shale, black, carbonaceous		4
Lignite		7
Shale, black, carbonaceous		5
Lignite		6
Shale, black, carbonaceous		8
Lignite, impure		5
Shale, black, carbonaceous	1	7
	4	6

At location 737, in the NW. ¼ sec. 17, the following measurement was obtained:

Section in NW. ¼ sec. 17, T. 129 N., R. 104 W.

	Ft.	in.
Bone and black carbonaceous shale	1	6
Shale, bony, carbonaceous	1	4
Shale, black, carbonaceous	1	2
Lignite, impure		7
Shale.		
	4	7

The same bed is exposed at location 736, 1 mile to the west, in sec. 13, T. 129 N., R. 105 W.

The highest bed of lignite and the only valuable bed in this township is tentatively correlated with the T Cross bed and is the one on which the Johnson prospect is located, in the SW. ¼ sec. 10, at location 742, at an altitude of 3,189 feet above sea level. Two outliers of this bed remain intact, one of them in secs. 9 and 10 and the other in sec. 20. At the Johnson prospect the bed is 7 feet 11 inches thick. (See pl. 13.)

The bed was sampled in this prospect, and a partial analysis shows that it contains 11 per cent of ash. Only the upper 71 inches of the 95-inch bed was included in the sample. This prospect is an open strip pit from which farmers and ranchmen obtain a supply of fuel. As the underlying Pierre shale and Fox Hills sandstone and most of the exposed Lance formation in this and adjacent areas do not contain lignite, it is probable that the portion of this township not underlain by the T Cross bed is barren of workable lignite.

T. 129 N., R. 103 W.

A lens of lignite split by shale partings is exposed at prospects at locations 743 and 744, in secs. 4 and 5. The T Cross lignite is the principal lignite bed of this township and lies somewhat above this lens. The T Cross bed underlies a considerable tract in secs. 15, 16, and 17, beneath a cover which does not exceed 50 feet. Considerable baked rock surrounds the outcrop, and possibly the area of unburned lignite is smaller than that indicated on the map. Two very small areas of the bed are possibly left intact in the SW. ¼ sec. 14, and a considerable area of the bed remains in secs. 1, 2, 3, 11, and 12. There is an abandoned and caved in prospect on this bed in the northeast corner of sec. 3. The only measurement on this bed was obtained at a strip pit at location 745 (see pl. 13), in the northeast corner of sec. 3.

The lignite is of fair quality, as shown by the analysis of the sample taken at the Durkin prospect, in sec. 34, T. 130 N., R. 103 W., which is given on page 54. It is highly probable that the greater portion of this township not underlain by the T Cross bed is noncoal land.

T. 129 N., R. 102 W.

Alkali Creek, which crosses the northeastern portion of T. 129 N., R. 102 W., is fed by some of the best springs in this region, which issue from the sandstone or lignite beds at the Hamilton Bros.' ranch, in sec. 5. These springs give rise to a strong, unfailing flow of water, which is free from alkali.

As a whole, the township is treeless, rather smooth, and rolling. The uplands are very much dissected, and the drainage lines are well established.

In this township the rock strata appear to dip northeastward at about 20 feet to the mile.

Apparently two beds of lignite, 130 feet apart vertically, underlie parts of this township. The upper one is correlated with the T Cross bed, and the lower is tentatively correlated with a bed traced from Haley, N. Dak., into the eastern part of T. 129 N., R. 101 W. The ower bed apparently underlies the entire valley of Alkali Creek, having been penetrated by wells or measured in surface outcrop at locations 762 to 767 and 769. The altitude of this bed at location 762 is 2,807 feet; 763, 2,820 feet; 764, 2,799 feet; 766, 2,800 feet. At location 769, near the center of sec. 33, a 2 or 3 foot bed of lignite at this horizon is reported to have been penetrated at a depth of 20 feet, and a small quantity of lignite was taken out for fuel. Similarly at location 767 a well penetrated several lignite beds a foot or less in thickness between depths of 45 and 115 feet, reaching a hard, water-bearing lignite bed. At location 768, in sec. 19, two benches of lignite 10 inches apart were measured, 1 foot 6 inches and 2 feet 1 inch thick. About 3 feet of lignite was also measured at a boggy place just south of the south quarter corner of sec. 31. At location 762, 5 feet of lignite was penetrated between depths of 40 and 45 feet, and more lignite was reached at 56 feet. At location 763, 4 feet of lignite was reached at a depth of 43 feet and a lower bench at 55 feet. In a prospect at location 764, 2 feet 8 inches of lignite was measured. A well at location 765 struck hard lignite at its bottom, and another at location 766 penetrated 4 feet of lignite between 45 and 49 feet.

The outcrop of the T Cross bed is shown on Plate 14. Where the outcrop could be traced with certainty, it is represented by a solid line; elsewhere by a broken line. The clinker masses at Hat Rock (altitude about 2,900 feet) were produced by the burning of this bed, which has also been mined in an open pit at location 760, in sec. 5. (See pl. 13.)

When examined the pit was full of water, and only about 5 feet of coal could be measured. The upper 18 inches or so was badly weathered. Its altitude is about 2,864 feet. The T Cross bed is also probably the one encountered in a well at location 770, in sec. 6, which is reported to have penetrated 6 feet of lignite. Lignite

encountered in a well in the SW. ¼ sec. 8 is possibly the same bed or may be a lower one. In that vicinity the bed has burned extensively, and the outcrop as shown on the map is placed back of the innermost "burn." The first evidence of the bed found east of the Hamilton Bros.' ranch, in sec. 5, was at a well at location 757, in sec. 34 of the township to the north, which penetrated a 4-foot lignite bed. Farther east, in sec. 2, are "burns" on this bed, and in the NE. ¼ sec. 2, at location 761, is the Hamilton coal mine. The bed at the Hamilton mine is 4 feet 6 inches thick (pl. 13) and of very good quality. Its altitude is 2,895 feet, which seems to be slightly higher than the prospect in sec. 5, although apparently on the T Cross bed. The quality of the T Cross bed is perhaps fairly well indicated by the analysis of a sample obtained from it at the Durkin mine, in T. 130 N., R. 103 W. (p. 54). The northern part of the township is coal land, and the southern part is noncoal land.

DEVELOPMENT

Throughout the area covered by this report the small quantity of lignite needed to supply the wants of the people is almost entirely obtained from open pits. The cover is removed by stripping, or in some places advantage is taken of the undercutting of the river and the lignite is dug from cut banks. The prospects are generally situated along small streams where the lignite is exposed by erosion. In some townships there are several such prospects, fresh ones being opened from season to season, for it is often only a short time after one is opened before mining reaches a point where the cover is too thick to be conveniently removed, or the overburden is allowed to accumulate in the pit until the remaining lignite can not be mined conveniently.

Part of the coal used in Bowman, Rhame, and Marmarth is shipped from the lignite mines at Scranton and Haynes, but a considerable quantity of higher-rank coal from Roundup, Mont., and other places is shipped into this area and distributed from the towns along the railroad. Sometimes the lignite is mixed with the higher-rank coal and is used advantageously in steam tractors. A few 40-acre tracts have been purchased as coal land, and the lignite has been mined and sold at the nominal cost of working the mines. One of these is the Hamilton Bros.' mine, in sec. 2, T. 129 N., R. 102 W.

No definite forecast as to the future development of the abundant resources of lignite in this field can be made at present. Undoubtedly the lignite is a great potential resource, but it may not be developed extensively until competition with the higher-rank coals of other fields is less keen or unless the advantage of superior heating and stocking qualities of other coals can be overcome by low-costing mining or by special treatment of the lignite. The geographic position

of the field with reference to the larger present markets is unfavorable to early development, as there are neither large centers of population nor large industrial concerns in or near the field.

The large quantity of water (35 to 45 per cent by weight) contained in raw lignite causes it to slack badly when exposed to the air and results in corresponding losses in freight paid on undried lignite. If, however, the lignite is dried and used as powdered fuel, or is partly carbonized and briquetted, its desirability as a fuel may be so increased as to enable it to invade markets now exclusively supplied from fields yielding coals of higher rank.

ESTIMATED RESERVES OF LIGNITE

The following table contains a brief statement of the estimated tonnage of individual beds in this field by townships. The estimate, of necessity only approximate, is based on the area underlain by each bed and its average thickness as indicated by all the measurements taken on it in a township. No account is taken of beds less than 2 feet thick. A square mile of lignite 1 foot thick is estimated to contain 1,152,000 short tons. The townships in which the Lance formation does not crop out or is exposed only in very small areas are assumed to be underlain by a bed of lignite 5⅓ feet thick. This assumption is based on the data collected in the townships where that formation and the lignite it contains are exposed and on the record of the well at Medora, which penetrated, below the assumed top of the Lance, a total of about 14 feet of lignite. The average thickness of the T Cross bed, which was traced from the Montana State line to the east side of R. 102 W., south of Bowman, is about 5⅓ feet. In addition to the main bed there are numerous others. Some of these, like the Yule bed, are thick and regular beds; others are of minor extent and irregular, yet if one thins out to less than 2 feet another is likely to be found higher or lower in the section. So it appears that the average figure of 5⅓ feet for the summation of all the Lance beds is a moderate assumption for this field. A 5⅓ foot bed beneath a full township would contain 220,000,000 tons, and that amount of Lance lignite is assigned to each one of the townships where that formation is chiefly or entirely covered by Fort Union rocks.

Estimated tonnage of lignite in the Marmarth field (N. Dak.) in beds over 2 feet thick

T. N.	R. W.	Lance formation		Fort Union formation		Total estimated tonnage in township
		Bed	Tons	Bed	Tons	
138	102	Lance	220,000,000	Harmon Garner Creek H T Butte	324,720,000 154,760,000 38,720,000	738,200,000
138	103	Lance	220,000,000	Garner Creek Harmon	121,246,000 235,704,000	576,950,000
138	104	Lance	220,000,000	Garner Creek Harmon	120,120,000 245,760,000	585,880,000
138	105	Lance	220,000,000	Harmon	228,720,000	448,720,000
138	106	Lance	71,200,000	Harmon	85,440,000	156,640,000
137	101	Lance	220,000,000	H T Butte Harmon	9,240,000 414,000,000	643,240,000
137	102	Lance		Bullion Butte H T Butte Meyer Harmon	18,488,000 22,880,000 23,240,000 334,642,000	399,250,000
137	103	Lance	220,000,000	Bullion Butte H T Butte Meyer Garner Creek Harmon	2,460,000 4,400,000 6,240,000 38,400,000 233,280,000	504,780,000
137	104	Lance	220,000,000	Harmon	153,920,000	373,920,000
137	105	Lance	220,000,000	Burkey	135,020,000	355,020,000
137	106	Lance	66,000,000	Burkey	72,600,000	138,600,000
136	102	Lance	220,000,000	Harmon Hansen Bed H	243,170,000 23,760,000 128,000,000	614,930,000
136	103	Lance	220,000,000	Harmon Hansen Bed H	210,970,000 93,760,000 164,000,000	688,730,000
136	104	Yule Other Lance beds	222,240,000 220,000,000	Harmon Hansen Bed H	136,000,000 81,600,000 144,200,000	804,040,000
136	105	Yule Other Lance beds	226,800,000 220,000,000	Bed H	16,280,000	463,080,000
136	106	Lance	180,000,000			180,000,000
135	102	Lance	220,000,000	Harmon Hansen Bed H	360,000,000 237,440,000 86,600,000	904,040,000
135	103	Lance	220,000,000	Harmon Bed H	285,600,000 180,000,000	685,600,000
135	104	Yule T Cross Other Lance	68,600,000 220,000,000 132,000,000	Harmon Hansen Bed H	62,720,000 101,450,000 136,320,000	721,090,000
135	105	Unnamed Do Do Do Cannonball	24,697,000 24,543,000 90,000,000 165,780,000 52,000,000			357,020,000
135	106	Unnamed Cannonball	91,200,000 58,000,000			149,200,000
134	102	Lance	220,000,000	H T Butte Hansen Harmon	13,680,000 57,600,000 110,660,000 369,840,000	771,780,000
134	103	Lance	220,000,000	Harmon Hansen	133,120,000 122,400,000	475,520,000

Estimated tonnage of lignite in the Marmarth field (N. Dak.) in beds over 2 feet thick—Continued

T. N.	R. W.	Lance formation		Fort Union formation		Total estimated tonnage in township
		Bed	Tons	Bed	Tons	
134	104	Lance	220,000,000	Harmon Hansen Bed H	7,680,000 10,800,000 42,000,000	280,480,000
134	105	Unnamed T Cross Unnamed Do	13,068,000 117,076,000 16,312,000 52,164,000			198,620,000
134	106	Cannonball	12,800,000			12,800,000
133	102	Lance	220,000,000	Harmon Hansen	1,790,000 90,400,000	312,190,000
133	103	Lance	220,000,000	Hansen	17,800,000	237,800,000
133	104	Ives T Cross	87,400,000 459,680,000	Hansen	5,200,000	552,280,000
133	105	T Cross	12,240,000			12,240,000
132	102	T Cross	220,000,000	Harmon Hansen	142,560,000 81,720,000	444,280,000
132	103	T Cross	176,000,000			176,000,000
132	104	T Cross Ives	171,600,000 117,200,000			288,800,000
132	105	T Cross	42,400,000			42,400,000
131	102	T Cross	220,000,000	Harmon	8,640,000	228,640,000
131	103	T Cross	220,000,000	Harmon	4,480,000	224,480,000
131	104	T Cross	184,540,000	Harmon	2,880,000	187,420,000
131	105	T Cross	1,200,000 1,400,000			2,600,000
130	102	T Cross Unnamed	170,800,000 198,000,000			368,800,000
130	103	T Cross	198,400,000			198,400,000
130	104	T Cross	90,000,000	Harmon	7,200,000	97,200,000
129	102	T Cross	18,000,000 118,800,000			136,800,000
129	103	T Cross	16,000,000			16,000,000
129	104	Unnamed	1,600,000			1,600,000

Total for Lance beds	8,809,740,000
Total for Fort Union beds	6,946,320,000
Grand total	15,756,060,000

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